Managing Hazardous Materials Incidents

Volume III
(revised)

Medical Management Guidelines for Acute Chemical Exposures

U.S. Department Of Health And Human Services
Public Health Service
Agency for Toxic Substances and Disease Registry

The state of knowledge regarding the treatment of patients potentially exposed to hazardous substances in the environment is constantly evolving and is often uncertain. In this document, the Agency for Toxic Substances and Disease Registry (ATSDR) has made diligent effort to ensure the accuracy and currency of the ‘information presented but makes no claim that the document comprehensively addresses all possible situations related to this topic. This document is intended as an additional resource for physicians and other health professionals in assessing the condition and managing the treatment of patients potentially exposed to hazardous substances. It is not, however, a substitute for the professional judgment of a health care provider and must be interpreted in light of specific information regarding the patient available to such a professional and in conjunction with other sources of authority.

Agency for Toxic Substances and Disease Registry
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Acronyms and Abbreviations

AAPCC	American Association of Poison Control Centers
ABG	arterial blood gases
ABS	acrylonitrile/butadiene/styrene
ACGIH	American Conference of Governmental Industrial Hygienists
AIHA	American Industrial Hygiene Association
ALS	advanced life support
AOEC	Association of Occupational and Environmental Clinics
ARDS	acute respiratory distress syndrome
ATSDR	Agency for Toxic Substances and Disease Registry
BAL	British anti-Lewisite (dimercaprol)
BUN	blood urea nitrogen
C	Celsius
CDC	Centers for Disease Control and Prevention
CAS	Chemical Abstract Service
CBC	complete blood count
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CNS	central nervous system
CPC	chemical protective clothing
CPK	creatine phosphokinase
DC	direct current
DHHS	Department of Health and Human Services
dL	deciliter
DMSA	2,3-demercaptosuccinic acid
DNA	deoxyribonucleic acid
DOT	Department of Transportation
ECG	electrocardiogram
ED	emergency department
EEG	electroencephalogram
EMS	emergency medical services
EMSA	Emergency Medical Services Authority
EPA	Environmental Protection Agency
ERPG	Emergency Response Planning Guideline
F	Fahrenheit
g	gram
GABA	gamma aminobutyric acid
GAO	General Accounting Office
GI	gastrointestinal
G6PD	glucose-6-phosphate dehydrogenase
HAZMAT	hazardous material
HCl	hydrochloric acid
HClO	hypochlorous acid
HSDB	Hazardous Substances Data Bank

IARC	International Agency for Research on Cancer
IDLH	immediately dangerous to life and health
IRIS	Integrated Risk Information System
i.v.	intravenous
kg	kilogram
L	liter
m	meter
mEq	milliequivalent
mg	milligram
mL	milliliter
mm Hg	millimeters of mercury
m^3	cubic meters
MSDS	Material Safety Data Sheet
MSHA	Mine Safety and Health Administration
MTBE	methyl-*t*-butyl ether
MW	molecular weight
NAC	N-acetylcysteine
NFPA	National Fire Protection Association
NIOSH	National Institute for Occupational Safety and Health
NO	nitric oxide
NPIRS	National Pesticides Information Retrieval System
NTP	National Toxicology Program
OSHA	Occupational Safety and Health Administration
PAM	pralidoxime chloride
PEG	polyethylene glycol
PEL	permissible exposure limit
PhAC	S-phenyl-N-acetyl cysteine
Po_2	partial pressure of oxygen
ppm	parts per million
PVC	polyvinyl chloride
RADS	reactive airways dysfunction syndrome
RBC	red blood cel1
SARA	Superfund Amendments and Reauthorization Act
SCBA	self-contained breathing apparatus
STEL	short-term exposure limit
TBA	*t*-butyl alcohol
TOCP	tri-*o*-cresyl phosphate
TSCA	Toxic Substances Control Act
TWA	time-weighted average
TERIS	Teratogen Information Service
UN	United Nations
UV	ultraviolet
WHO	World Health Organization

Preface

The Agency for Toxic Substances and Disease Registry (ATSDR) is an agency of the Public Health Service in the U.S. Department of Health and Human Services (DHHS). ATSDR was created by the U.S. Congress through the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA). The Agency's responsibilities were markedly increased through the Superfund Amendments and Reauthorization Act of 1986 (SARA). The mission of ATSDR is to prevent or mitigate adverse human health effects and diminished quality of life resulting form exposure to hazardous substances in the environment. In pursuit of this mission, ATSDR provides educational and referral resources to health care providers who are responsible for chemically exposed patients.

The *Medical Management Guidelines for Acute Chemical Exposures (Guidelines)* is designed to assist emergency department physicians. It is the third volume in a 3-volume series provided by ATSDR. The Guidelines contain 40 chemical-specific protocols that provide recommendations for the on-scene (prehospital) and hospital (ED) medical management of patients exposed during a hazardous materials (HAZMAT) incident. Other rescue personnel, such as first responders, emergency medical technicians, and public health officials, will also find the information useful, but because of the focus of the protocols, these professions are encouraged to rely on other sources and training in their primary field for more definitive and complete guidance.

Each chemical protocol is divided into five sections.

(1) **Description:** Contains synonyms, appearance, routes of exposure; potential for secondary contamination, sources/uses, physical properties, and exposure standards.

(2) **Health Effects:** Contains organ systems affected by acute exposure, potential sequelae, and effects of chronic exposure.

(3) **Prehospital Management:** Contains personal protection, decontamination, support, triage, and transportation. Organized by Hot Zone, Decontamination Zone, and Support Zone.

(4) **Emergency Department Management:** Contains specific medical procedures to treat the exposed patient, and patient disposition. Organized by Decontamination Area and Critical Care Area.

(5) **Patient Information Sheet:** Contains information on exposure, potential effects, and follow-up instructions for the victims of a HAZMAT incident.

The *Introduction* to this volume provides important background information and a brief overview of the activities at a HAZMAT incident. For more information on managing HAZMAT activities, consult Volumes I and II, *Emergency Medical Services: A Planning Guide for the Management of Contaminated Patients*, and *Hospital Emergency Department: A Planning Guide for the Management of Contaminated Patients*, respectively. The *Introduction* also describes the use, rationale, and limitations of the data contained in each section of a chemical protocol. It is written in the format of an individual protocol. The *Prehospital Management* and *Emergency Department Management* sections of the *Introduction* begin with the recommendations form the *Unidentified Chemical* protocol. The recommendations are followed by the rationale for the procedures suggested. The reader is urged to complete the *Introduction* before attempting to use the individual protocols.

Appendices I through IV contain resources for the emergency department physician seeking consultation in treating chemically exposed patients: AAPCC-Certified Regional Poison Control Centers; Association of Occupational and Environmental Health Clinics; State Health Officials; and private, university, and government consultants are listed. In addition, the *Guidelines* contains a glossary of chemical and medical terminology.

Acknowledgments

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This project was directed by Scott V. Wright, ATSDR. For the 2000 version, Lisa Ingerman, Ph.D., of Syracuse Research Corporation (SRC) was the project manager, and A. Rosa MacDonald, Ph.D., Fernando Llados, Ph.D., and Susan Little, Ph.D., of SRC were contributing scientists (under ATSDR contract No. 205-1999-00024).

The major contributors to the original (1992) *Medical Management Guidelines for Acute Chemical Exposures* were Jonathan Borak, MD, Kent R. Olson, MD, and Virginia Sublet, PhD.

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Introduction

This *Introduction*, which is in the same format as the individual protocols, describes the use and limitations of the information presented. The *Prehospital and Emergency Department* sections incorporate the *Unidentified Chemical* protocol as an example. The *Introduction* is key to the appropriate use of the protocols. Even trained and experienced responders are urged to read it before using the individual protocols in an emergency situation.

Use of trade names is for identification only and does not imply endorsement by the Public Health Service or the U.S. Department of Health and Human Services.

General Information Section
Chemical Name (Chemical Formula)
CAS Number; UN Number

Common synonyms

- **Potential for secondary contamination**
- **Common form and important characteristics such as odor and flammability**
- **Routes of exposure and potential for absorption**

Secondary Contamination

Primary contamination refers to direct contact of the victim with the hazardous material. Secondary contamination refers to the transfer of material from the victim to personnel or equipment. The potential for secondary contamination has implications for decontamination and triage of victims and for the protection of rescue and health care personnel. Immediate victim decontamination is recommended for materials that pose risks of secondary contamination; this eliminates both the potential for rescuer contamination and further exposure to the victim.

A substance poses a risk of secondary contamination if it is both toxic and likely to be carried on the clothing, skin, or hair of victims in sufficient quantities to threaten other personnel. Substances that present the most serious risks of secondary contamination include the following:

- highly toxic liquids and solids or finely divided solids (e.g., organophosphate pesticides)
- radioactive liquids and dusts
- certain biologic agents (e.g., harmful viruses or bacteria)

Every effort must be made to decontaminate contaminated victims before they are transported to a medical care facility.

Examples of substances with little or no risk of secondary contamination include the following:

- gases (e.g., carbon monoxide, amine)
- vapors (unless they condense to a liquid state on clothing or skin)
- substances with no serious toxicity or skin absorption (e.g., propylene glycol, motor oil)

Note that although several of the substances listed above are highly toxic (e.g., arsine, carbon monoxide), they do not pose

risks of secondary contamination because these chemicals will not contaminate the victim; therefore, they cannot secondarily contaminate rescuers.

Secondary contamination also may be a risk in cases of ingestion. Ingested materials may react with stomach acid to produce noxious gases, which can pose risks to both the victim and rescuers. Vomitus may off-gas the hazardous material or a reaction product. Toxic vomitus should be quickly isolated in closed containers.

Previously published documents on hazardous materials have recommended zipping patients into body bags to minimize the transfer of chemical from patient to rescuer. This technique is not completely effective for preventing rescuer exposure, and it may pose a significant risk of increased dermal absorption to victims. Body bags are not recommended as an alternative to thorough decontamination.

Description

This section summarizes the color, odor, and physical state (solid, liquid, or gas) of the chemical at room temperature. Methods of shipment or storage and the physical hazards associated with the chemical are also described.

Routes of Exposure

The most likely routes of exposure--inhalation, direct contact with the skin or eyes, and ingestion-are described. For each route of exposure, the risk of injury depends on the toxicity of the chemical involved, the concentration of the material, and the duration of con tact.

Inhalation

Inhalation is the most common route of exposure to gases and vapors. Liquids and solids may also be inhaled when they are finely divided mists, aerosols, fumes, or dusts. Highly water-soluble gases and vapors and larger mist or dust particles (greater than 10 microns in diameter) generally are deposited in the upper airways. Less soluble gases and vapors and smaller particles can be inhaled more deeply into the respiratory tract. Usually, highly water-soluble materials rapidly produce symptoms of upper-airway irritation, whereas less soluble materials may produce delayed symptoms in the lower airways. Inhaled substances may be absorbed into systemic circulation, causing toxicity to various organ systems. When available, information is provided on odor threshold, warning properties, and symptoms to be expected at specific exposure levels.

Skin/Eye Contact

Skin and eye contact can occur by exposure to solids, liquids, or gases. Corrosive agents cause direct damage to tissues by various

mechanisms including low or high pH, chemical reaction with surface tissue, removal of normal skin fats (defatting), or removal of moisture (desiccant effect). Some chemicals absorbed through the skin and eyes can produce systemic toxicity. Absorption, and therefore toxicity, is more likely to occur when the normal skin barrier is disrupted (e.g., chemical bum, cut, or abrasion) or when the chemical is highly fat-soluble (e.g., organophosphate and organochlorine pesticides).

Ingestion

Ingestion is not a common route of exposure in most hazardous materials (HAZMAT) incidents, although it is common in suicide attempts. Ingestion of corrosive agents can cause severe burns to the mouth, throat, esophagus, and stomach. Ingested chemicals may also be aspirated into the lungs, especially after vomiting, causing chemical pneumonitis. Ingested chemicals may react with stomach acid, creating products that are toxic to the patient, and potentially, the health care provider (e.g., hydrogen cyanide from ingested cyanide salts).

Sources/Uses

This section describes the chemical's most common uses and the methods of production.

Standards and Guidelines

Government agencies and professional organizations have established standards and guidelines for hazardous chemical exposures. The standards and guidelines address both acute and chronic exposures.

The Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) is a regulatory limit established to avoid adverse health effects from exposure. PELs are time-weighted-average (TWA) air concentrations. In most cases, a healthy, working adult can be exposed to a chemical at the PEL for an g-hour workday and a 40-hour workweek and suffer no adverse health effects. If the measured air concentration at a HAZMAT incident is less than the PEL and the exposure is short-term, persons at the scene are probably not at serious risk. The OSHA "skin" designation indicates the likelihood of dermal absorption.

The OSHA ceiling is an instantaneous concentration that must not be exceeded any time. If instantaneous monitoring is not feasible, the ceiling is normally assessed as a 15minute TWA concentration.

The OSHA short-term exposure limit (STEL) is a 15-minute (unless otherwise noted) TWA concentration that should not be

exceeded at any time, even if the 8-hour TWA concentration is below the PEL.

The National Institute for Occupational Safety and Health (NIOSH) recommends workplace exposure guidelines. The NIOSH immediately dangerous to life or health (IDLH) level represents the maximum chemical concentration from which one could escape within 30 minutes without a respirator and without experiencing any escape-impairing (e.g., severe eye irritation) or irreversible health effects.

The American Industrial Hygiene Association (AIHA) Emergency Response Planning Guidelines (ERPG) state concentrations at which one might reasonably anticipate observing adverse effects from exposure to specific substances. Unlike occupational expo sure standards, ERPG levels are applicable to the general public, including children and the elderly. The three ERPG levels vary with the health effects expected with exposure (transient symptoms, ability impairment, and life-threatening) and apply to practically all persons. The table in the Properties section includes only ERPG-2-the exposure level that could impair a person's ability to take protective action.

ERPG levels are defined as follows:

ERPG-1 is the maximum airborne concentration below which it is believed that nearly all persons could be exposed for up to 1 hour without experiencing symptoms other than mild transient adverse health effects or perceiving a clearly defined objectionable odor.

ERPG-2 is the maximum airborne concentration below which it is believed that nearly all persons could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action.

ERPG-3 is the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects.

Physical Properties

Description: Physical state and useful characteristics of the chemical at room temperature are presented.

Warning properties: Odor and irritation are the primary determinants of exposure awareness. When available, an objective description of odor (e.g., garlic-like) and the lowest air

concentration that can be detected (i.e., odor threshold) is provided. For chemicals with an odor threshold below the toxic air concentration, odor may provide an adequate warning of dangerous exposure conditions. However, a chemical is considered to have inadequate warning properties if it has no detectable odor at toxic air concentrations, has an odor that is not reliably detected because of olfactory fatigue, or does not cause irritation.

Molecular weight (MW) is the sum of the weights of the atoms in a molecule. Molecular weight is provided in daltons, a unit that is based on the mass of oxygen- 16. Molecular weight can be used to convert measurements of air concentrations of chemicals from parts per million (ppm) to milligrams per cubic meter (mg/m3) using the following equation:

mg/m^3 = (ppm x M W) / 22.4 L/mole

(1 mole of gas occupies 22.4 L at standard temperature and pressure).

Boiling point of a liquid is the temperature at which its vapor pressure is equal to the atmospheric pressure. A boiling point at or below room temperature means that the chemical is in the gaseous state at room temperature.

Freezing point is the temperature at which a chemical's solid phase is in equilibrium with the liquid phase. Freezing point and melting point are equal in numeric value. The term"freezing point" refers to the temperature at which a liquid forms a solid; "melting point" refers to the temperature at which a solid forms a liquid.

Specific gravity is the ratio of the density of a liquid to the density of a reference material (usually water). A specific gravity less than 1 indicates that the substance will float on water; a specific gravity greater than 1 indicates that the substance will sink in water.

Vapor pressure is the pressure (expressed in millimeters of mercury [mm Hg] of a vapor in equilibrium with its liquid or solid form at a given temperature. The higher the vapor pressure, the greater the amount of chemical existing in the vapor phase. A vapor pressure greater than 760 mm Hg at room temperature indicates that the chemical exists as a gas.

Gas density is the ratio of the density (weight per volume) of a substance (at a given temperature) to the density of air (at that temperature). A gas density greater than 1 indicates that the vapor or gas is heavier than air. A gas heavier than air may collect in

low-lying areas where it can displace air, creating an oxygen-deficient atmosphere.

Water solubility indicates the degree to which a substance dissolves in water at a specific temperature. Water solubility is measured in weight of substance per volume of water (e.g., g/100 ml or %). Water solubility may indicate the effectiveness of water in decontamination. A substance that is water soluble is likely to be removed from the skin and hair with a plain water wash. Substances that are poorly water soluble may require the use of soap.

Flammability is the ease with which a material will ignite. Flammable chemicals have flash points below l00 °F; combustible chemicals have flashpoints between 100 °F and 200°F; and nonflammable chemicals have flashpoints above 200 °F.

Flammable range (lower explosive limit to upper explosive limit) is expressed as the percentage of gas or vapor dispersed in air that will bum when an ignition source is present. The temperature, the flammable range, and the potential for a vapor or gas to travel to an ignition source and flash back may affect rescue activities. The flammable range may indicate the need for special protective clothing. Most chemical-resistant protective clothing is neither heat- nor flame-resistant and may melt if a fire occurs.

Incompatibilities

HAZMAT incidents commonly involve more than one chemical. Incompatibility and reactivity information, primarily from the NIOSH Pocket Guide to Chemical Hazards, is included in this section.

Health Effects Section

- **Common symptoms**
- **Systemic effects and mechanism of action**

Health risk depends on the intrinsic toxic potential of the chemical, its concentration, and the duration of exposure. Highly toxic chemicals may pose a risk of illness even if the exposure duration is brief or the concentration of the substance is low. Even mildly toxic substances, however, can be hazardous if the exposure is prolonged or the concentration is high.

Acute Exposure

When suspected or known, the mechanism of action is discussed.

Acute exposure is defined as chemical exposure of less than 14 days duration. Most HAZMAT incidents involve acute exposures that last only minutes, but the chemical concentration may be extremely high. Although HAZMAT incident exposures are likely to be short, risks of adverse health effects still exist. The onset of health effects caused by acute exposure can be immediate or delayed.

Organ systems or metabolic processes that are adversely affected by the chemical are discussed in the following sections. The organ system or metabolic process mentioned first in each chemical protocol is the most severely affected, those not affected by the chemical are not addressed.

Cardiovascular

Many chemicals have direct depressant or stimulatory effects on cardiac function. Hypotension and dysrhythmias may be aggravated by hypoxia from respiratory depression or pulmonary aspiration of gastric contents. Hypotension may also occur because of volume depletion from excessive vomiting, diarrhea, or severe chemical bums.

Certain solvents (e.g., chlorinated hydrocarbons, freons, aromatic hydrocarbons) may lower the myocardial threshold to the dysrhythmogenic effects of catecholamines. For several hours after solvent exposure, a victim may be susceptible to ventricular dysrhythmias (e.g., premature ventricular contractions, ventricular tachycardia, or ventricular fibrillation) especially from administered sympathomimetic drugs such as bronchodilators or dopamine or the increased quantity of endogenous epinephrine produced during intense physical activity.

CNS

Central nervous system (CNS) depressants (e.g., hydrocarbon solvents) cause a generalized decrease in brain activity. Headache, dizziness, confusion, lethargy, stupor, or coma may result. Severe depression of the brain stem can cause respiratory arrest and cardiovascular collapse. Some chemical depressants have early stimulatory effects, producing euphoria and giddiness similar to ethanol.

CNS stimulants (e.g., organophosphate insecticides) can cause agitation, anxiety, delirium, and seizures. Excessive muscular activity associated with seizures can cause hyperthermia.

Dermal

Dermal contact with chemicals can produce local injury; if absorbed, chemicals can also produce systemic effects. Local injuries (e.g., burns from mineral acids) usually are immediately obvious. However, a few chemicals (e.g., alkaline corrosives, hydrofluoric acid) cause a progressive penetrating injury that may not be apparent for hours.

The skin generally provides a relatively impermeable protective barrier. Many chemicals disrupt the skin's integrity by removing fats, producing chemical burns, or destroying cells. Physical injury such as thermal bums or traumatic events may also result in loss of the skin's barrier effect. Disruption of the normal protective barrier allows easier entry of chemicals into systemic circulation. Systemic illness can also occur without skin damage because many fat-soluble chemicals (e.g., some organophosphate insecticides) rapidly penetrate intact skin.

Electrolyte

Some chemicals can produce effects on serum electrolytes (e.g., potassium, calcium, sodium) and total anion gap. Electrolyte imbalance can cause muscle weakness and cardiac dysrhythmias.

Gastrointestinal

Nausea, vomiting, abdominal pain, and diarrhea are common symptoms after chemical exposure and may be due to direct gastrointestinal irritation or to systemic effects. Ingestion of some chemicals can also cause severe corrosive injury to the mouth, throat, esophagus, and stomach, with bleeding, perforation, scarring, or stricture formation as potential sequelae.

Hematologic

Components of the blood and blood-forming organs can be damaged by many chemicals (e.g., arsine, benzene). Most hematologic changes (e.g., hemolysis, methemoglobinemia, bone marrow suppression, and anemia) can be detected by blood tests or simply by the color or appearance of the blood

Hepatic Some chemical exposures result in acute injury to the liver, which typically does not manifest for 2 to 3 days after exposure. At that time, laboratory tests will show abnormal liver function (e.g., elevated bilirubin or aminotransferase levels or increased prothrombin time). Toxic hepatitis may progress to liver failure and death.

Immunologic Immunologic effects may include induced sensitivity and allergy.

Metabolic Metabolic acidosis is the most common adverse metabolic effect that occurs after chemical exposure. Acidosis results from an accumulation of acid anions such as formic, lactic, or oxalic acid.

Musculoskeletal Musculoskeletal damage due to chemical exposure is unusual. Some effects are arthritis and hardening, destruction, or cancer of the bone.

Ocular Most serious ocular injuries result from direct eye contact with corrosive liquids or solids. High concentrations of or prolonged exposures to gases or vapors may also injure the eye. Severe eye exposure carries a risk of blindness or other visual impairment and demands immediate evaluation by an ophthalmologist.

Most patients who have eye injuries involving the conjunctival or cornea1 surfaces experience pain and irritation, excessive lacrimation, and possibly crusting and swelling of the eyelids. Generally, corneal damage causes intense pain and the sensation of a foreign body in the eye.

Peripheral Neurologic Peripheral nervous system effects can include changes in sensation, reduced reflexes, and impaired motor function. Effects are pronounced in the largest muscle groups such as those in the lower limbs.

Renal Some chemicals injure the kidneys directly. In addition, any poisoning causing massive muscle destruction can lead to kidney injury from excessive myoglobin in the kidney tubules.

Respiratory Inhalation of a chemical irritant (e.g., ammonia, chlorine) usually causes rapid onset of burning and irritation of the nose, throat, and upper respiratory tract. Painful coughing, wheezing, and stridor may develop. If the exposure is massive, death may rapidly ensue from upper airway obstruction, massive alveolar destruction, or asphyxiation. Chest radiography may indicate pulmonary edema when damaged lung cells allow fluid to leak into the alveoli (referred to as noncardiogenic pulmonary edema because the fluid

accumulation is not caused by left ventricular failure, which occurs in cardiogenic pulmonary edema).

The onset and location of respiratory symptoms is partially related to the water solubility of the inhaled chemical. Highly water-soluble gases, such as ammonia, cause rapid onset of symptoms (burning nose and throat, painful cough, stridor, wheezing) as the gases dissolve in the mucous membranes of the upper respiratory tract. However, less soluble gases such as phosgene are breathed deeply into the lower airways and typically cause only mild or no early symptoms; noncardiogenic pulmonary edema may develop after 12 to 36 hours.

Injury to the respiratory tract also can occur after ingestion of a chemical substance. The unconscious or convulsing patient may vomit and then, because of depressed airway protective reflexes, may aspirate gastric contents into the lungs. Pulmonary aspiration of an ingested hydrocarbon can cause severe pneumonitis. Hydrocarbons irritate the lung tissue and interfere with surface tension in the alveoli, disrupting gas exchange. Pulmonary aspiration can sometimes be prevented by inserting a cuffed endotracheal tube into the patient's airway or by placing the patient in a head-down, left-side position and using suction immediately if vomiting occurs.

Potential Sequelae

Known or suspected sequelae and the prognosis for recovery after an acute exposure are described in this section. Signs and symptoms expected at various stages of recovery and the potential for permanent deficits are presented.

Chronic Exposure

Repeated, low-level exposures, typically over a long period of time, may produce health effects that differ in type or degree from effects of acute exposure. Most information about chronic toxicity is from epidemiologic studies and case reports of workplace exposures. Because HAZMAT incidents are unlikely to involve repeated or long-term exposures, chronic health effects are outlined only briefly.

Some major concerns of patients who have experienced an acute chemical exposure are the risks of cancer, reproductive effects, or impaired fetal development. No data exist on these outcomes from acute exposure to most chemicals. However, to guide the clinician who must address these patient concerns, we have included carcinogenic, reproductive, and developmental effects that have resulted from chronic exposure to the chemical. It is not known whether the data from chronic exposures are applicable to victims who are acutely exposed in a HAZMAT incident.

Carcinogenicity

The cancer information included in this section is derived from assessments made by the Department of Health and Human Services (DHHS), the International Association for Research on Cancer (IARC), or the Environmental Protection Agency (EPA). These organizations develop ratings of chemicals that indicate the cancer-producing ability of the chemicals. The information included was based on the following hierarchy: DHHS is offered if available, then IARC, then EPA. Failure of these organizations to evaluate a chemical does not necessarily mean that the chemical does not cause cancer.

Reproductive and Developmental Effects

Information about reproductive and developmental effects was obtained primarily from three data files that are included in TOMES Plus, a proprietary database of Micromedex, Inc., Denver, CO. These data files are Reprotext, edited by Betty J. Dabney, PhD; the Teratogen Information System (TERIS), developed by the University of Washington; and Shepard's Catalog of Teratogenic Agents, written by Thomas H. Shepard, MD. An additional source of information was Reproductive and Developmental Toxicants, a 1991 report published by the U.S. General Accounting Office (GAO Report no. GAOLPEMD-92-3) that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences. The 30 chemicals are alcohol, arsenic, cadmium, carbon disulfide, carbon monoxide, chlordecone, chloroprene, DDT, DBCP, DES, ethylene dibromide, EGEE, EGME, ethylene oxide, gossypol, hexachlorobenzene, lead, lithium, mercury, nicotine, PBBs, PCBs, 2,4,5-T, TCDD, tobacco smoke, toluene, vinyl chloride, vitamin A, and warfarin.

The topic of reproductive hazards is controversial and emotionally charged. Potentially high risk to the fetus may warrant considering termination of the pregnancy. Most clinicians are not adequately prepared to help the patient make this decision. Expert assistance may be available from regional poison control centers, regional reproductive risk/teratogen information centers, or the MotherRisk Program. For more information, see Appendices I and III.

Prehospital Management Section

The Prehospital Management section describes the activities that typically occur in the three concentric areas surrounding a HAZMAT incident (Figures 1 and 2), particularly those activities that relate to Emergency Medical Services (EMS) personnel. The Hot Zone (or Exclusion Area) is the area surrounding the chemical release; it is assumed to pose an immediate health risk. The Decontamination Zone (or Warm Zone) is the area surrounding the Hot Zone where primary contamination is not expected but where personnel must use protective clothing and equipment to avoid chemical exposure from contaminated victims. The Support Zone (or Cold Zone) is the outermost ring where no exposure or risk is expected. The incident commander, medical personnel, and other support persons and equipment operate in the Support Zone. The information provided in the chemical protocols is an attempt to offer an accurate and practical approach to the management of hazardous materials emergencies. 'The user of the protocols should be aware that large data gaps exist in the scientific literature.

Goals of the EMS HAZMAT Responder

- Protect yourself. Approach the Scene cautiously, arriving upwind. Maintain a safe distance and inspect the scene from a nearby elevated area such as a hill. Respect the established exclusion zones and resist the temptation to rush in to attempt a rescue. If a command post has been established, report to the incident commander.

- Identify the chemical. Be familiar with the Department of Transportation (DOT) placard system, the National Fire Protection Association (NFPA) hazard labeling system, Material Safety Data Sheets (MSDS), and shipping papers.

- Consult the appropriate protocol and local sources to obtain information about the chemical, its health effects, and medical treatment.

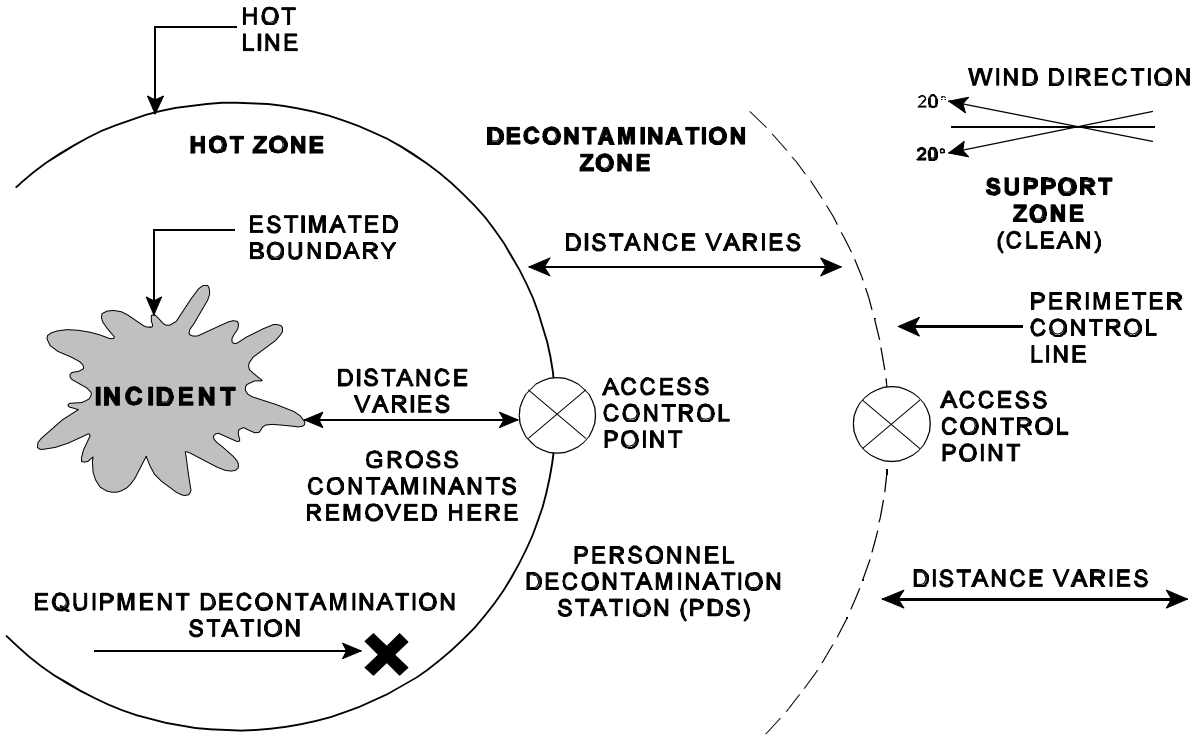
- Determine the potential for secondary contamination. Understand the risk to yourself and to others in the Support Zone, ambulance, or hospital if decontamination is not completed at the scene.

- Perform appropriate and thorough decontamination.

- Provide basic and advanced life support (ALS).

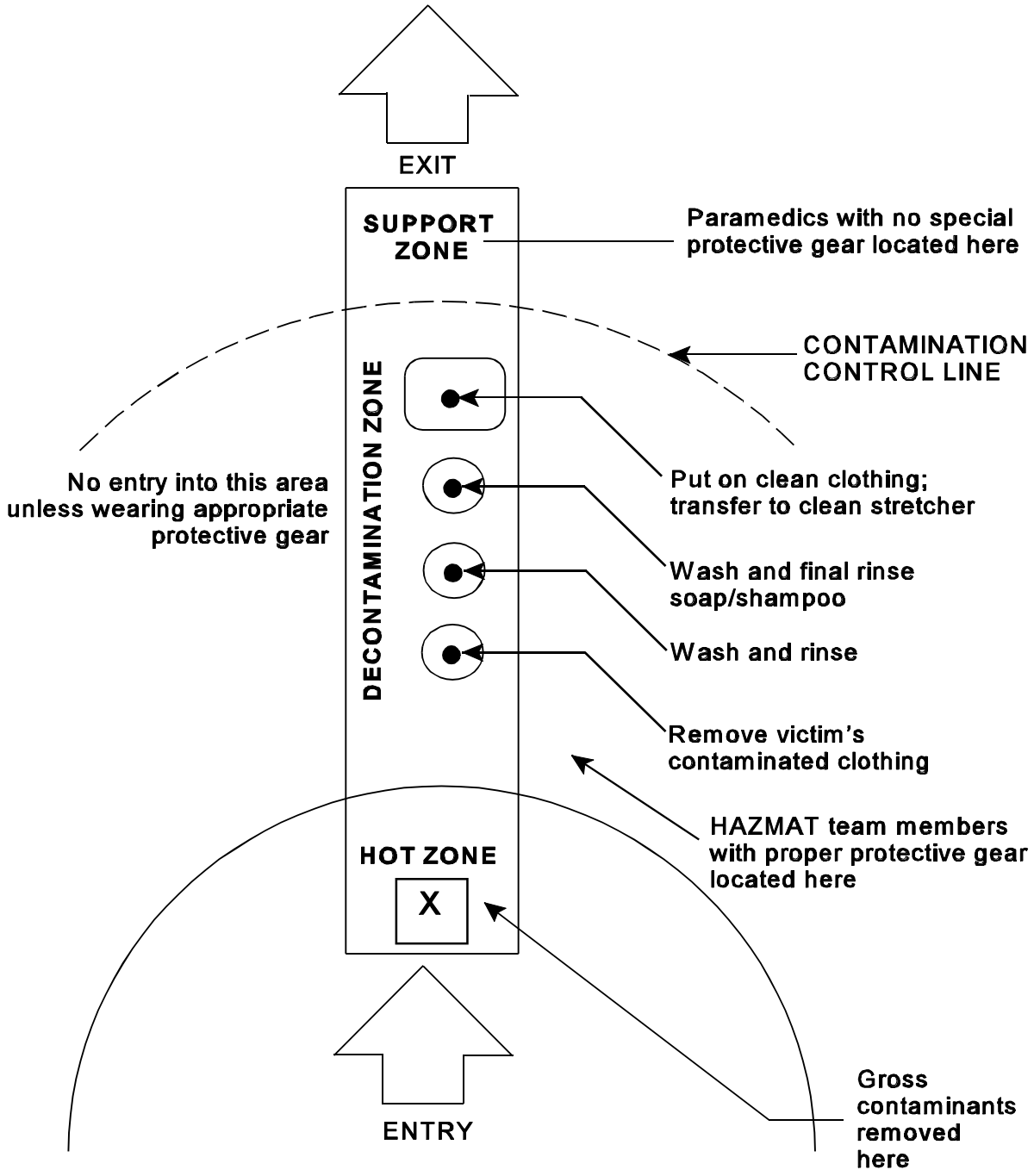
- Transport victims to an appropriate medical facility as quickly as possible.

Figure 1. Organization of a HAZMAT incident area



Adapted from Olson, KR, ed. Poisoning and drug overdose. Norwalk, CT: Appleton and Lange, 1990.

Figure 2. Detail of decontamination zone



Adapted from Hazardous material medical management protocols, 2nd edition. Sacramento, CA: Emergency Medical Services Authority, 1991.

Prehospital Management Section

- **Potential for secondary contamination**
- **Health effects expected from an acute exposure**
- **Patient care (supportive care, antidotes)**

Secondary contamination is discussed on page 3 of the *Introduction*.

In the prehospital setting, the key factors in determining the potential for secondary contamination are the route and extent of exposure. Victims exposed only to gas or vapor are not likely to carry significant amounts of chemical beyond the Hot Zone and are not likely to endanger personnel outside the Hot Zone. However, victims whose skin, hair, or clothing is grossly contaminated with solid or liquid chemical (including condensed vapor) may contaminate personnel by direct contact or by off-gassing vapor. Victims who have ingested a toxic chemical may expose others through toxic vomitus or by vapor off-gassing from toxic vomitus.

The bold text below is from the Unidentified Chemical protocol. It is presented as an example of the information presented in each section. The plain g&ace provides details or an explanation.

Hot Zone

Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment Is not available, or if rescuers have not been trained in its use, assistance should be obtained from a local or regional HAZMAT team or other properly equipped response organization.

The Hot Zone includes the area immediately around the chemical spill where persons may be in danger from chemical exposure or physical hazards (e.g., fire or explosion). Only persons who have specialized HAZMAT training should enter the Hot Zone. Although some of these persons may be trained as paramedics, only limited medical care can be provided in the Hot Zone. Advanced medical care is provided in the Decontamination Zone and Support Zone.

Rescuer Protection

When a chemical is unidentified, worst-case possibilities concerning toxicity must be assumed. The potential for severe local effects (e.g., irritation and burning) and severe systemic

effects (e.g., organ damage) should be assumed when specific rescuer-protection equipment is selected.

Respiratory Protection: Pressure-demand, self-contained breathing apparatus (SCBA) should be used in all response situations.

Skin Protection: Chemical-protective clothing should be worn when local and systemic effects are unknown.

Trained responders should select protective equipment and clothing based on the general regulations in 29 CFR 1910.120 (OSHA Hazardous waste operations and emergency response).

The protocols contain chemical-specific recommendations for rescuer protection. The Rescuer Protection section begins with a summary of the health hazards that are pertinent for one-time, short-term exposures such as those expected at a HAZMAT incident. The respiratory-tract and skin protection (e.g., respirators and chemical-protective clothing) recommendations are based on these health hazards.

Two basic types of respiratory protection are available: atmosphere-supplying and air-purifying respirators. Atmosphere-supplying respirators provide compressed air at greater than atmospheric pressure to a face mask that is worn by the rescuer and may be supplied-air or self-contained.

The self-contained breathing apparatus (SCBA) is often used in HAZMAT incident response to prevent inhalation of hazardous chemicals because it is self-contained, portable, and familiar. SCBA consists of a facepiece that seals, a tank of compressed air carried on the back, and a hose that runs from the air tank to the facepiece. The specific type of SCBA recommended in the Guidelines is “pressure demand”; that is, although air is always flowing into the facepiece (pressure), the flow increases in response to inhalation (demand).

Although commonly used at hazardous waste clean-up sites, the supplied-air respirator should not be used at a HAZMAT incident. The supplied-air respirator consists of a mask or facepiece connected to an air hose supplied by a compressor at a distant site. Because the air hose may be degraded by chemicals or heat and the hose may become tangled, the supplied-air respirator is not practical for operations during an emergency.

Air-purifying respirators do not supply air to the user; they simply filter the ambient air and are seldom used at HAZMAT incidents. Air-purifying respirators can use the same type of facepiece as an air-supplied respirator. Instead of an air-supply hose, they are connected to a charcoal or other filter-containing cartridge. The cartridge filters the air before it is inhaled. Conditions that preclude the use of an air-purifying respirator include

- oxygen-deficient atmosphere (19.5% O_2)
- unidentified contaminant
- unknown concentration of contaminant
- concentration of contaminant above NIOSH IDLH
- high relative humidity

Most HAZMAT incidents involve at least one of these conditions; therefore, air-purifying respirators are rarely appropriate for emergency response.

Dust or surgical masks are also air-purifying-they filter and prevent the inhalation of large particles. However, they offer no protection from the inhalation of chemical vapors or gases and are not recommended in the Guidelines.

Regardless of the type of respiratory protection used, all respirators should be approved by NIOSH and the Mine Safety and Health Administration(MSHA).NIOSH and MSHA designate performance characteristics of respirators.

Chemical-protective clothing (CPC) is not subject to performance standards set by a government agency. Chemical-specific resistance to degradation, penetration, and permeation are important factors to consider in selecting CPC. CPC that fails can subject the wearer to significant exposure and adverse health effects. Degradation involves the chemical breakdown of the suit material itself, causing exposure. Penetration is movement of a chemical through an opening in the material or article of clothing (e.g., through punctures or zippers). Permeation involves chemical movement through the suit material but not necessarily destruction of it.

The NFPA has established performance standards for two types of chemical-protective garments: a vapor-protective suit and a liquid-splash-protective suit. The standards provide methods for testing material and suits to assure chemical resistance, overall durability, and valve/closure construction suitability. The vapor protective suit is completely encapsulating; once the user is attired, even exhaled air is trapped inside until pressure activates

one-way release valves. Suits meeting the NFPA guidelines can be used to provide protection according to the EPA classifications described below. The certification accompanying protective clothing that meets NFPA guidelines specifies the chemicals and conditions under which the clothing was tested. The NFPA performance standards do not address respiratory protection; therefore, no assumptions can be made regarding respiratory protection based on the NFPA suit designation.

EPA has established a 4-stage classification system to address the levels of protection afforded by respiratory and chemical-protective clothing combinations commonly used by HAZMAT responders. The four classes, in descending order of protection, are called levels A through D. The EPA definitions do not address NFPA clothing; however, the equivalent NFPA suit is specified below.

> **Level A** includes a fully encapsulating chemical-resistant suit (equivalent to an NFPA vapor-protective suit) and a pressure-demand SCBA.
>
> **Level B** includes a nonencapsulating chemical-resistant suit (equivalent to an NFPA splash-protective suit) and an SCBA.
>
> **Level C** includes a nonencapsulating chemical-resistant suit (equivalent to an NFPA splash-protective suit) and an air-purifying respirator.
>
> **Level D** consists of work clothes that do not provide any specific respiratory or skin protection.

The EPA classification does not address use of the common fire-fighting ensemble - SCBA with “turnouts” or “bunker” gear. Turnouts are not designed to protect against chemical exposure and should not be worn when hazardous chemical exposure is possible.

Specialized personal protective gear should be used only by those with prior training and fitting. The choice of specific chemical-resistant materials (e.g., Tyvek, Saranex, or butyl rubber) is beyond the scope of this document and is generally the responsibility of an expert on the HAZMAT team. Additional protective equipment may be required when risks of fire or explosion exist.

Although CPC provides protection against adverse health effects due to chemical exposure, it contributes to heat stress. CPC prevents both the inward and. outward movement of moisture, decreasing the availability of evaporative cooling. During an incident, body heat builds quickly because of the heavy workload and CPC prevents heat dissipation. Several cooling systems are available for use under CPC; however, they serve only to reduce peripheral body temperature and not core body temperature. Because core body temperature does not decrease, cooling systems may actually be harmful. By cooling the skin and making the user feel more comfortable, cooling systems may encourage rescuers to work longer and build up a dangerously high core body temperature.

ABC Reminders

Quickly ensure a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible.

Only minimal patient care can be performed in the Hot Zone while wearing Level A or Level B protective gear. Rescuers can often perform only simple maneuvers such as ensuring a patent airway, applying a cervical collar, brushing off gross contaminants, and applying direct pressure to stop arterial bleeding. The goal in the Hot Zone is to quickly remove the victim from continued exposure and risk.

Victim Removal

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be removed on backboards or gurneys; if these are not available, carefully carry or drag victims to safety.

Victims should be removed from the Hot Zone to the Decontamination or Support Zone, as appropriate, in the safest and quickest way possible. Ambulatory victims may need to be guided to the Decontamination Zone. Nonambulatory victims can be removed on backboards, litters, or gurneys, or if necessary, carefully dragged or carried to safety.

Decontamination Zone

Victims exposed only to gas or vapor who have no skin or eye irritation may be transferred immediately to the Support Zone. All others require decontamination (see Basic Decontamination, page 25).

The Decontamination Zone is a corridor between the Hot Zone and the Support Zone. The Decontamination Zone may be set up in any convenient location that is safely beyond the Hot Zone, but

separate from the Support Zone. If possible, the Decontamination Zone should be established outdoors (preferably upwind and uphill from the Hot Zone) where natural ventilation will allow dispersion of vapor off-gassing from contaminated victims. Because personnel in the Decontamination Zone normally require protective gear, only trained HAZMAT-team members should be present.

Decontamination is not required for all victims. Victims exposed only to gases or vapor who do not have skin or eye irritation generally do not need decontamination. Victims who have been decontaminated or who do not require de contamination should be transferred immediately to the Support Zone.

Rescuer Protection

If the chemical or concentration is unidentified, personnel in the Decontamination Zone should wear the same protective equipment used in the Hot Zone (see Rescuer Protection, page 19).

Personnel in the Decontamination Zone normally require protective gear; only personnel with prior fitting and training should be permitted to don protective gear. Generally, the level of clothing is the same as that worn in the Hot Zone. A lower level of protective clothing can be used when the risk of secondary contamination is low. For example, a nonencapsulating suit (NFPA splash protective suit) can be used if an encapsulating suit (NFPA vapor-protective suit) is required in the Hot Zone. If the risk of inhaling off-gassing vapors is also low (i.e., the chemical is not highly volatile or the decontamination area is set up outside with good natural ventilation), it may be acceptable to use a lower level of respiratory protection. Air contaminants must be identified and measured to assure safety before a lesser level of respiratory protection is used.

ABC Reminders

Quickly ensure a patent airway. Stabilize the cervical spine with a collar and a backboard if trauma Is suspected. Administer supplemental oxygen as required. Assist ventilation with a bag valve-mask device If necessary.

To provide airway, breathing, and circulatory support for patients in the Decontamination Zone, the rescuer may have to establish an artificial airway, administer supplemental oxygen or nebulized bronchodilators, and assist ventilation. Direct pressure should be applied to control heavy bleeding. Depending on the concentration of the chemical and its potential for secondary contamination, victims with serious trauma or medical complications (e.g.,

seizures) may have to wait for advanced medical care until gross contamination is removed.

Rescuers wearing respirators and heavy gloves will find it difficult to provide advanced medical care such as inserting an intravenous line or performing endotracheal intubation; therefore, this care is not administered until the victim is transferred to the Support Zone. Electronic equipment, such as cardiac monitors, generally are not taken into the Decontamination Zone because the equipment may not be safe to operate and may be difficult to decontaminate.

Basic Decontamination

Victims who are able and cooperative may assist with their own decontamination. Remove and double-bag contaminated clothing and personal belongings.

Consider bagging the victim's jewelry and other valuables separately from clothing for easier retrieval later. Nonporous materials such as metal jewelry may be easy to decontaminate by washing, whereas clothing or shoes may require disposal. Leather items can be especially difficult to decontaminate and may need to be incinerated. Consult a HAZMAT specialist affiliated with the local fire department, the ATSDR/CDC Emergency Response 24-hour Hotline ([404] 639-0615) or the EPA Environmental Response Team, Edison, New Jersey ([732] 321-6740) for advice on the disposition of contaminated equipment and clothing.

Flush exposed or irritated skin and hair with water for 3 to 5 minutes. For oily or otherwise adherent chemicals, use mild soap on the skin and hair.

Flush exposed or irritated eyes with plain water or saline for at least 5 minutes. Remove contact lenses if present and easily removable without additional trauma to the eye. If a corrosive material is suspected or if pain or injury is evident, continue irrigation while transferring the victim to the Support Zone.

Many chemicals react violently with water, liberating toxic gases or creating explosions. Cautions about water reactivity (e.g., statement in the DOT Emergency Response Guidebook or in an MSDS) generally do not apply to flushing eyes, skin, and hair in the Decontamination Zone. There is little risk of creating a serious reaction hazard by adding large amounts of water to the small amount of residual chemical on the victim's body. In fact, the naturally occurring moisture on the skin is already reacting with

the chemical; hastening removal from the skin is preferable to leaving the chemical to further injure the victim.

Solids should be gently brushed from hair, skin, and clothing. During brushing, protect the victim's eyes, nose, and mouth. The length of time recommended for flushing exposed skin or eyes will vary with the chemical and the circumstances of exposure. Removal of oily or insoluble materials from the skin and hair requires washing with soap. Any liquid hand- or dish-washing soap will be satisfactory. Use only soft-bristled brushes; abrasive brushing may enhance skin injury and penetration. Most chemicals that cause only mild skin or eye irritation can be removed by flushing for 3 to 5 minutes. Ten to 15 minutes may be required for concentrated or strongly alkaline materials. Eye decontamination after exposure should be continued while the patient is transferred to the Support Zone and even during transport to a medical facility. An attempt should be made to remove contact lenses. Avoid forceful removal, which may inflict injury. Irrigation and transfer to the Support Zone should not be delayed because of difficulty in removing contact lenses.

Bleach, vinegar, or other solutions used for equipment decontamination should not be used for washing skin, hair, or eyes. Likewise, neutralizing agents should not be used for decontamination because the heat from neutralization may cause added injury. Dilution with large volumes of water is preferred for decontamination.

In cases of ingestion, do not induce emesis. Victims who are conscious and able to swallow should be given 4 to 8 ounces of water. Obtain medical care immediately.

Generally, vomiting should not be induced. Vomiting is relatively ineffective in emptying the stomach after a chemical ingestion and may be harmful to the victim. Vomiting may increase damage to the esophagus and stomach if irritating or corrosive chemicals have been ingested. The risk of pulmonary aspiration is also increased when vomiting occurs.

Activated charcoal adsorbs many chemicals and is relatively easy to administer. Unless a corrosive chemical has been ingested, a slurry of 50 to 60 grams of activated charcoal should be given to an adult patient who is awake and has a gag reflex. Charcoal may obscure the view when endoscopy is performed (at the hospital) to determine the extent of injury. See Ingestion Exposure, page

40, for further discussion of gastrointestinal-tract decontamination.

Transfer to Support Zone

As soon as basic decontamination is complete, move the victim to the Support Zone.

Victims should be moved from the Decontamination Zone to the Support Zone as soon as possible. Ambulatory patients can walk; others may require transport on a gurney.

Support Zone

Be certain that victims have been decontaminated properly. Victims who have undergone decontamination or have been exposed only to gas or vapor and who have no evidence of skin or eye irritation generally pose no serious risks of secondary contamination. In such cases, Support Zone personnel require no specialized protective gear.

Because the Support Zone is set up away from the dangers of physical hazards or chemical exposures, primary contamination is not a serious problem in this area. Personnel in the Support Zone do not require special protective clothing if victims have been decontaminated properly. An exception involves victims exposed to a potent and adherent chemical (e.g., an organophosphate pesticide), in which case the Support Zone team should wear disposable aprons or gowns and latex gloves.

ABC Reminders

Quickly ensure a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Ensure adequate respiration; administer supplemental oxygen as required. Ensure a palpable pulse. Establish intravenous access if necessary. Attach a cardiac monitor. More sophisticated medical management can begin in the Support Zone where rescuer movement is less encumbered and more equipment and personnel are available. Initially, this care is centered on airway, breathing, and circulatory support for the patient. Intravenous lines should be inserted as soon as possible. A cardiac monitor should be attached because of the potential for some chemicals (e.g., halogenated or aromatic hydrocarbons) to produce dysrhythmogenic effects.

Additional Decontamination

Continue irrigating exposed skin and eyes, as appropriate.

In cases of ingestion, do not induce emesis. If the patient is conscious and able to swallow, administer 4

to 8 ounces of water if it has not been given previously. Obtain medical care immediately.

Some victims may require continued irrigation of irritated skin and eyes. If a cardiac monitor is required, irrigation should be completed before the monitor is attached. The additional decontamination recommendations do not imply that the victim poses a risk of secondary contamination. Exposure to a concentrated or strongly alkaline material may require continued irrigation of eyes and skin during transport and in the hospital. Eye irrigation is easily and conveniently accomplished using saline or water and intravenous tubing attached to a nasal canula placed over the bridge of the nose with the prongs pointed down toward the eyes.

Ingestion exposure is an uncommon occurrence in a HAZMAT incident. If ingestion has occurred and initial gastrointestinal decontamination has not been carried out in the Decontamination Zone, appropriate treatment must be instituted in the Support Zone. Gastrointestinal decontamination procedures should be carried out only if the patient is alert and has a gag reflex.

For most chemicals, the protocols do not recommend emesis and in some cases (e.g., exposure to corrosives or hydrocarbons), emesis is contraindicated. Many chemicals are effectively adsorbed on the surface of charcoal. When indicated in the protocol, a slurry of activated charcoal should be administered as soon as possible to prevent gastrointestinal absorption. If the chemical is corrosive or has not been identified, rinse the mouth and throat by administering 6 to 8 ounces of water. The water will also dilute the hazardous material in the stomach.

Advanced Treatment

Intubate the trachea in cases of respiratory compromise. When the patient's condition precludes endotracheal intubation, perform cricothyroidotomy if equipped and trained to do so.

Treat patients who have bronchospasm with aerosolized bronchodilators. Use these and all catecholamines with caution because of the enhanced risk of cardiac dysrhythmias after exposure to certain chemicals.

Patients who are comatose, hypotensive, or have seizures or cardiac dysrhythmias should be treated according to ALS protocols.

In the Support Zone, more advanced medical care can be readily administered. Contact the regional poison control center (see Appendix 1) or the hospital base station for advice specific to the incident.

Bronchodilators, such as metaproterenol (Alupent or Metaprel) or albuterol (Proventil or Ventolin), can be administered by metered-dose inhaler, or preferably, by hand-held nebulizer. However, these medications increase heart rate and may provoke cardiac dysrhythmias in victims who have been exposed to certain chlorinated or aromatic hydrocarbons. When bronchodilators are needed, the lowest effective dose should be given and cardiac rhythm should be monitored.

Evaluate the patient for possible opioid overdose or hypoglycemia and administer naloxone (Narcan) and dextrose according to standard ALS protocols. Consider the possibility that coma or seizures may be the result of trauma (e.g., head injury) rather than of chemical poisoning.

Administer specific antidotes as described in the chemical-specific protocols if within the prehospital scope of practice.

Transport to Medical Facility

Report to the base station and the receiving medical facility the condition of the patient, treatment given, and estimated time of arrival at the medical facility.

If a chemical has been ingested, prepare the ambulance in case the victim vomits toxic material. Have ready several towels and open plastic bags to quickly clean up and isolate vomitus.

The base station and receiving medical facility should be apprised of the patients' status. Special procedures for patient care en route can be discussed, especially if transport time will be lengthy. Notifying the medical facility of your arrival time ensures appropriate emergency department preparation.

Before transporting patients who have ingested hazardous materials, prepare the ambulance by lining a basin or bucket with open plastic bags to catch and isolate toxic vomitus. Some chemicals are converted to poisonous gases by the action of stomach acids (e.g., cyanide salts create hydrogen cyanide gas; sodium azide can produce hydrazoic acid gas). Toxic vomitus can contaminate personnel and equipment by direct contact or by off-gassing volatile chemicals.

Ambulances that transport HAZMAT victims require only standard equipment. Most supplies recommended in the *Guidelines* are standard equipment or are easily obtained from grocery or drug stores. The specific equipment most likely to be used in HAZMAT response will vary with the training and policies of individual emergency medical services agencies, but at a minimum include the following:

- disposable gloves
- splash goggles
- waterproof disposable shoe covers
- disposable gowns to cover EMS personnel clothing and to be used by stripped and decontaminated patients
- large supply of oxygen
- plastic garbage bags
- large wash basin or bucket (lined with plastic to isolate toxic vomitus)
- liquid soap
- saline and intravenous tubing for eye irrigation
- disposable towels to soak up toxic vomitus

Only decontaminated patients or patients not requiring decontamination should be transported. Some earlier HAZMAT protocols called for zipping patients into "body bags" without proper decontamination. If patients have been decontaminated effectively, no danger of secondary contamination exists. Use of the body bag technique is not effective and puts the victim at risk of substantial skin injury and absorption.

Multi-Casualty Triage

All exposed patients should be transported to a medical facility for evaluation.

Asymptomatic patients who have not had direct chemical exposure can be discharged from the scene after their names, addresses, and telephone numbers are recorded. Those discharged should be advised to seek medical care promptly if symptoms develop.

Consult with the base station physician or regional poison control center for further advice regarding triage of multiple victims.

Triage is a complex process that identifies victims who have the most serious injuries and who can benefit most from rapid treatment and transport. The Multi-Casualty Triage section in each protocol makes general recommendations for transport

priorities based only on the chemical; however, the base station physician or regional poison control center (see Appendix I) should give advice for specific situations.

Emergency Department Management Section

The *Guidelines*, which represent a state-of-the-art, practical approach to the management and treatment of HAZMAT victims, are based on the consensus of a panel of experts. However, the user of the protocols should be aware that large data gaps exist in the scientific literature and knowledge regarding the treatment of patients exposed to hazardous substances is constantly evolving. The protocols are not a substitute for the professional judgment of a health care provider and must be interpreted in light of specific information regarding the patient and in conjunction with other sources of authority.

Goals of the Hospital Provider in HAZMAT Incidents:

- Determine the potential for secondary contamination.
- If necessary, decontaminate patients.
- Provide supportive and antidotal emergency care (resources for toxicity information include the *Guidelines* and a regional poison control center [*Appendix I*]).
- Obtain appropriate laboratory tests.
- Arrange for observation, hospital admission, and follow-up care as needed.

Emergency Department Management Section

- **Potential for secondary contamination**
- **Health effects expected from an acute exposure**
- **Patient care (supportive care, antidotes)**

Secondary contamination is discussed on page 3 of the introduction. Victims who were exposed only to gas or vapor or who were decontaminated at the scene are not likely to pose a risk of secondary contamination to hospital personnel. However, victims whose skin, hair, or clothing is grossly contaminated with solid or liquid chemical (including condensed vapor) may endanger health care personnel by direct contact or by off-gassing vapor. Toxic vomitus can also expose hospital personnel directly or through off-gassing vapor.

Decontamination Area

Previously decontaminated patients and patients exposed only to gas or vapor who have no evidence of skin or eye irritation may be transferred immediately to the Critical Care Area. Other patients will require decontamination as described below.

Basic decontamination should be carried out at the scene of the incident before the victim is transports, however, this does not always occur. For example, a contaminated victim might be brought directly to the emergency department by a coworker. Hospitals should plan for the arrival of contaminated victims.

Contaminated victims received in indoor facilities create potentially serious risks of secondary contamination to hospital personnel, especially if materials are volatile. Many hospital protocols suggest shutting off the ventilation system to protect the hospital from cross-contamination. However, lack of ventilation may compound the risk to emergency department personnel attending the victim. Very few hospitals have the financial resources to properly construct a separate decontamination room with appropriate ventilation.

Basic decontamination is safely and practically performed outside in a naturally ventilated area adjacent to the ambulance entrance. Suggested equipment and supplies for an outdoor hospital Decontamination Area include the following:

- Gurney with plastic tub or run-off collector. (Several companies make disposable or reusable decontamination

tables or foldable rubber tubs that can be placed on top of a gurney.)

- A warm-water source with a hose and soft-stream shower head
- Disposable chemical-resistant jumpsuits (e.g., of Tyvek or Saranex)
- Chemical-resistant gloves (e.g., of butyl rubber) in different sizes
- Rubber aprons
- Mild soap and shampoo
- Soft-bristled brushes
- Splash-protective goggles or other protective eye wear
- Wading pool for decontamination of ambulatory patients
- Plastic garbage bags
- Oxygen tanks with delivery supplies
- Disposable towels and gauze
- Surgical scrubs for decontaminated patients
- Extra blankets and sheets for patient privacy and warmth
- Portable privacy barriers (do not totally enclose decontamination area or natural ventilation will be lost)

ABC Reminders

Evaluate and support airway, breathing, and circulation. Intubate the trachea in cases of respiratory compromise. If the patient's condition precludes Intubation, surgically create an airway.

Treat patients who have bronchospasm with aerosolized bronchodilators; use these and all catecholamines wlth caution because of the potential enhanced risk of cardiac dysrhythmias.

Patients who are comatose, hypotensive, or have seizures or ventricular dysrhythmias should be treated in the conventional manner.

Generally, decontamination is performed before treatment is started. However, basic airway, breathing, and circulation must be addressed in victims who have life-threatening symptoms. Patients heavily contaminated with highly toxic organophosphate insecticides pose great risks of secondary contamination to health care personnel; patients should not be touched until staff is appropriately gloved and gowned. Persons soaked with flammable materials cannot be treated with DC countershock until decontamination has been carried out because of risk of fire and explosion. Simultaneous treatment and decontamination of patients should be carried out whenever possible.

Basic Decontamination

Patients who are able and cooperative may assist with their own decontamination. Remove and double-bag contaminated clothing and personal belongings.

For easier retrieval, consider bagging the victim's jewelry and other valuables separately from clothing. Nonporous materials such as metal jewelry may be easy to decontaminate by washing, whereas clothing or shoes may require disposal. Leather items can be especially difficult to decontaminate and may need to be incinerated.

Flush exposed or irritated skin and hair with plain water for 3 to 5 minutes. For oily or otherwise adherent chemicals, use mild soap on the skin and hair. Rinse thoroughly with water.

Flush exposed or irritated eyes with plain water or saline for at least 5 minutes. Remove contact lenses if present and easily removable without additional trauma to the eye. If a corrosive material is suspected or if pain or injury is evident, continue irrigation while transferring the patient to the Critical Care Area.

Some chemicals react violently with water, liberating toxic gases or creating explosions. Cautions about water reactivity (e.g., the statements in the DOT Emergency Response Guidebook or in an MSDS) generally do not apply when decontaminating victims with water. Adding large amounts of water to the small amount of residual chemical on the victim's body poses little risk of creating a serious reaction hazard. In fact, the naturally occurring moisture on the skin will react with the chemical; hastening removal of the chemical from the skin is preferable to leaving it to potentially cause further injury.

Solid contaminants should be gently brushed from hair, skin, and clothing. During brushing, protect the victim's eyes. The length of time for flushing exposed skin or eyes with water will vary with the chemical and the circumstances of exposure. Chemicals that cause only mild skin or eye irritation can be flushed for 3 to 5 minutes. Concentrated or strongly alkaline materials may require 10 to 15 minutes. Eye decontamination may be continued while the patient is transferred to the Critical Care Area. An attempt should be made to remove contact lenses. Avoid forceful removal that may inflict injury. Difficulty in removing contact lenses should not delay irrigation or transfer to the Critical Care Area.

Removal of oily or insoluble materials from the skin and hair requires washing with soap or shampoo. Any liquid hand- or dish-washing soap is satisfactory. Use only soft-bristled brushes; abrasive brushing may enhance skin injury and penetration.

Bleach, vinegar, or solutions used for decontaminating equipment should not be used for washing skin, hair, or eyes. Neutralizing agents should not be used because the heat of the neutralization may cause added injury. Flooding volumes of water are preferable.

In cases of ingestion, do not induce emesis. Administer 4 to 8 ounces of water to dilute stomach contents if the patient is conscious and able to swallow. Immediately transfer the patient to the Critical Care Area.

Emesis is not generally recommended in the protocols. Vomiting is relatively ineffective in emptying the stomach after a chemical ingestion and may be harmful to the victim. Vomiting may increase the risk of pulmonary aspiration or damage to the esophagus and stomach if irritating or corrosive chemicals have been ingested.

Activated charcoal adsorbs many chemicals and is relatively easy to administer. For most chemical ingestions, a slurry of 50 to 60 grams of activated charcoal should be administered to an adult patient who is awake and has a gag reflex. If a corrosive chemical has been ingested, do not administer activated charcoal because it may obscure the view when endoscopy is performed. See Critical Care Area below for further discussion of gastrointestinal decontamination.

Critical Care Area

If appropriate decontamination efforts have been completed before entry to the Critical Care Area, special precautions, such as covering floors and walls with plastic or shutting off the ventilation system, are not needed. However, if the patient has ingested a chemical, prepare to isolate toxic vomitus quickly (see Ingestion Exposure, page 40).

Be certain that appropriate decontamination has been carried out. (See Decontamination Area, page 33.)

ED personnel in the Critical Care Area generally do not need specialized protective gear. However, if risk of residual skin contamination exists (e.g., potent chemicals, such as some organophosphate pesticides, or radioactive dust), water-resistant gowns or aprons, latex gloves, and eye-splash protection ate

necessary. Emergency medical care providers usually carry these protective items for universal infection control or communicable disease control.

ABC Reminders

Evaluate and support airway, breathing, and circulation as in ABC Reminders, page 34. Establish intravenous access in seriously ill patients. Continuously monitor cardiac rhythm.

Patients who are comatose, hypotensive, or have seizures or ventricular dysrhythmias should be treated in the conventional manner.

Many chemicals can cause progressive airway injury or systemic illness with delayed onset. Watch for signs of laryngeal edema and respiratory system compromise, such as progressive hoarseness, strider, hypoventilation, or cyanosis.

Consider the possibility of exposure to multiple chemicals as well as multiple-system injuries. For example, smoke inhalation can cause airway injury because of heat and irritant chemicals and coma from asphyxiants such as carbon monoxide and cyanide.

Consider possible opioid overdose and evaluate for hypoglycemia; administer naloxone (Narcan) and dextrose according to usual protocols. Treat patients who have seizures with conventional anticonvulsants (e.g., diazepam, phenytoin, or phenobarbital). Consider the possibility that coma or seizures may be from a head injury or from alcohol or other drug intoxication, rather than from hazardous material exposure.

Place an intravenous line in all patients who are unconscious, obtunded, hypotensive, or may become so. Patients exposed to substances that may cause cardiac sensitization or intravascular hemolysis may also require intravenous access. An initial bolus of an appropriate intravenous solution should be given. The fluid should be titrated to maintain acceptable urine output and blood pressure. Care must be taken not to overhydrate the patient.

Treat patients who have hypotension using rapid infusions of normal saline (250 mL to 1 L in adults). Use dopamine or other inotropic drugs for persistent hypotension. Hypotension may be complicated by hypothermia or hyperthermia. Hypothermia should be considered if the victim was stripped and decontaminated with cold water or in a cold ambient setting. Hyperthermia may result from certain systemic poisons (e.g., dinitrophenol).

Inhalation Exposure

Administer supplemental oxygen by mask to patients who have respiratory complaints. Treat patients who have bronchospasm with aerosolized bronchodilators; use these and all catechola mines with caution because of the potential or possible enhanced risk of cardiac dysrhythmias.

Bronchodilators may provoke ventricular dysrhythmias in some patients who have been exposed to aromatic or halogenated hydrocarbons.

Although pulse oximetry is a convenient way to continuously monitor oxygenation in patients, it is unreliable or falsely normal in patients who have dyshemoglobinemias (e.g., methemoglobinemia or carboxyhemoglobinemia) because it measures only oxygen dissolved in the blood and not the status of tissue oxygenation. In patients who have altered hemoglobins, the pulse oximeter does not reflect the impaired oxygen carrying or delivery capacity of the red cells. In these situations, a Co-Oximeter should be used to measure specific levels of hemoglobins unable to transport oxygen.

Chemically induced pulmonary edema is due to leaky pulmonary alveoli, not left ventricular failure as is cardiogenic pulmonary edema. Patients who have chemically induced pulmonary edema do not benefit from digoxin, morphine, afterload reduction, or diuretics. Supplementary oxygen, delivered by mechanical ventilation and positive end-expiratory pressure, if needed, are standard treatments for chemically induced (noncardiogenic) pulmonary edema.

Corticosteroids and antibiotics have been commonly recommended for treatment of chemical pneumonitis, but their effectiveness has not been substantiated.

Soluble irritants (e.g., ammonia or hydrogen chloride) rapidly produce respiratory effects; poorly soluble irritants (e.g., phosgene and some nitrogen oxides) produce slow onset of airway irritation and respiratory distress. Poorly soluble agents are commonly associated with delayed (12 to 72 hours) onset pulmonary edema. The time period for developing pulmonary edema varies with the chemical and is noted in each individual protocol. Watch for signs of respiratory distress and intubate if necessary.

Skin Exposure

If chemical burns are present, treat as thermal burns.

The extent and depth of injury in a chemical burn is often not immediately apparent; hence the severity of the bum is frequently underestimated. Loss of circulating fluid may occur. In addition, dermal absorption of a corrosive chemical may contribute to systemic toxicity.

Patients who have been exposed to highly corrosive, penetrating, oily, or persistent chemicals may require additional or continuous decontamination. Residues may remain in the armpits, groin, buttocks, hair, ears, nostrils, and under the fingernails and toenails. If the material is highly contaminating (e.g., organophosphate pesticides or radioactive dust), care givers should wear gowns and gloves to protect themselves.

Use liquid soap for cleansing the skin and hair. Special decontaminating agents are recommended for only a few chemicals (see specific protocols).

Eye Exposure

Ensure that adequate eye irrigation has been completed. Test visual acuity. Examine the eyes for corneal damage using a magnifying device or a slit lamp and fluorescein stain. For small corneal defects, use ophthalmic antibiotic ointment or drops, analgesic medication, and an eye patch. Immediately consult an ophthalmologist for patients who have corneal injuries.

Ensure that contact lenses have been removed, that no visible residual material is in the conjunctival sac, and that the pH of the conjunctival fluid is normal.

Irrigation is easily continued in a hospital setting using intravenous tubing to provide a steady, low-pressure stream of water or saline. A Morgan Lenscan also be placed to provide continuous, thorough eye decontamination. Do not use neutralizing or other decontaminating solutions.

A corneal burn or abrasion can easily be seen with the aid of fluorescein stain, a UV light source, and a magnifier or slit lamp. The disrupted corneal surface allows accumulation of the fluorescein, which fluoresces under UV light. If serious injury is evident (e.g., extensive corneal fluorescein accumulation, cloudy or bloody material in the anterior chamber, or obvious perforation of the globe), an ophthalmologist should be consulted immediately.

Ingestion Exposure

Do not Induce emesis. If the patient is alert and charcoal has not been given previously, administer a slurry of activated charcoal. If a corrosive material is suspected, administer 4 to 8 ounces of water; do not give a slurry of activated charcoal. Consider endoscopy to evaluate the extent of gastrointestinal-tract injury. If a large dose has been ingested and the patient's condition is evaluated within 30 minutes after ingestion, consider gastric lavage.

Ingested chemicals and products formed by their reaction with stomach acid may be hazardous to ED personnel through direct contact with vomitus or by inhalation of the gases liberated from the vomitus. For example, ingested cyanide salts are converted to highly toxic hydrogen cyanide gas in the stomach. Staff must take measures, therefore, to isolate toxic vomitus or gastric washings. This can be done by attaching the lavage tube to isolated wall suction or other closed container.

Activated charcoal is capable of adsorbing most chemicals and should be given as early as possible. Even chemicals that have relatively poor adsorption to charcoal (e.g., cyanide and alcohols) are still bound to some extent. Charcoal may need to be removed by gastric washing before endoscopy can be performed. Corrosive liquids should be removed from the stomach as early as possible. However, care must be taken when placing the gastric tube because blind gastric-tube placement may further injure the chemically damaged esophagus or stomach.

Antidotes and Other Treatments

Treatment consists of supportive measures.

The individual guidelines provide information on the use of specific antidotes.

Laboratory Tests

Routine laboratory studies for all exposed patients include CBC, glucose, and electrolyte determinations. Additional studies for patients exposed to an unidentified chemical Include ECG monitoring, renal-function tests, and liver-function tests. Chest radiography and pulse oximetry (or ABG measurements) are recommended for severe inhalation exposure.

All patients should have CBC, glucose, and electrolyte determinations. Additional, specific recommendations are listed in the laboratory tests section to aid both diagnosis and treatment.

Laboratory test results are often within normal range immediately after an exposure but may become abnormal after a delay of several hours or even days, depending on the specific chemical exposure. For example, chest radiography may not show signs of pulmonary edema for 12 to 24 hours and signs of liver injury may not appear for 2 to 3 days following exposure. Pulse oximetry and routine arterial blood gas determination of Po_2 tests may provide falsely normal, unreliable, or misleading results in patients with abnormal hemoglobin states (e.g., methemoglobinemia or carboxyhemoglobinemia).

Tests to measure a specific chemical contaminant in biologic samples are rarely available on an emergency basis. The turn-around time may be several hours to days; hence, these tests rarely are clinically useful. However, the results of these tests may aid in confirming or documenting exposure. A regional poison control center (*Appendix I*) can assist with the selection and interpretation of specialized laboratory tests.

Disposition and Followup

Consider hospitalizing patients who have a suspected serious exposure and persistent or progressive symptoms.

Patient disposition should be determined based on the symptoms, the intrinsic toxicity of the chemical, and course of illness. Some patients may be safely discharged from the emergency department while others will require prolonged observation or intensive care.

Delayed Effects

When the chemical has not been identified, the patient should be observed for an extended period or admitted to the hospital.

The usual duration of observation in an emergency department is 6 to 8 hours. If the chemical agent is known to produce delayed-onset illness or is unidentified, the asymptomatic patient should be admitted for observation.

Patient Release

Asymptomatic patients who have minimal exposure, normal initial examinations, and no signs of toxicity after 6 to 8 hours of observation may be discharged with instructions to seek medical care promptly if symptoms develop.

Each protocol includes a detailed Patient Information Sheet with a list of possible delayed symptoms. This sheet should be reviewed with the patient before discharge. A signed copy should be

included in the medical chart, and a copy sent home with the patient.

Do not release clothing or personal items to the patient before a determination of residual contamination is made. Most items can be reused after washing. However, some contaminated articles cannot be rendered safe for reuse (e.g., leather goods, such as shoes, that are contaminated with methyl bromide or organophosphate pesticides). Some articles will require disposal at a hazardous waste site or by incineration. Consult a HAZMAT specialist affiliated with the local fire department or the ATSDR/CDC Emergency Response 24-hour Hotline ([404] 639-0615) for advice on the disposition of contaminated personal effects.

Followup

Provide the patient with follow-up instructions to return to the emergency department or a private physician to reevaluate initial findings. Patients who have corneal injuries should be reexamined within 24 hours.

Appendix II contains the telephone numbers and addresses of members of the Association of Occupational and Environmental Clinics (AOEC). These clinics employ specialists in the diagnosis and treatment of chemically exposed patients. They may provide consultation and follow-up advice.

Reporting

If a work-related incident has occurred, you may be legally required to file a report; contact your state or local health department.

Other persons may still be at risk in the setting where this incident occurred. If the incident occurred in the workplace, discussing it with company personnel may prevent future incidents. If a public health risk exists, notify your state or local health department or other responsible public agency. When appropriate, inform patients that they may request an evaluation of their workplace from OSHA or NIOSH. See *Appendices III* and IV for a list of agencies that may be of assistance.

Appendix III contains the telephone numbers of state health departments. In addition to filing a report, state health departments or the EPA's Environmental Response Team, Edison, New Jersey ([732] 321-6740) may be able to assist in determining procedures for the cleaning of hospital facilities and equipment.

You may also advise your patients to call the regional OSHA office to report a suspected violation of safe work practices. Appendix IV contains the numbers of the NIOSH office that may be of assistance.

Patient Information Sheet

The Patient Information Sheet provides information and follow-up instructions for persons who have been exposed to the chemical. It is written in an easy to understand question and answer format and addresses the questions most often asked. It is intended to be given to the patient.

The follow-up instructions on the back of the Patient Information Sheet are statements that the clinician can check off if they apply to the patient. The instructions include a list of signs and symptoms specific to each chemical (and directions to the patient to seek medical care if they occur); directions for obtaining follow-up appointments; and restrictions on activities, medications, alcohol and cigarette smoke. Space is provided for the clinician to write other instructions.

Acrolein (C_3H_4O)
CAS 107-02-8; UN 1092

Synonyms include 2-propenal, 2-propen-1-one, prop-2-en-1-al, acraldehyde, acrylaldehyde, acrylic aldehyde, allyl aldehyde, ethylene aldehyde, aqualine.

- **Persons exposed only to acrolein vapor do not pose secondary contamination risks. Persons whose clothing or skin is contaminated with liquid acrolein can secondarily contaminate others by direct contact or off-gassing vapor.**
- **At room temperature, acrolein is a clear, colorless to straw-colored liquid with a pungent, suffocating odor. It is highly flammable and burns to produce toxic gases (peroxides and oxides of carbon). It is volatile, producing toxic concentrations at room temperature. Vapors may travel to a source of ignition and flash back. The odor of acrolein may not provide adequate warning of hazardous concentrations.**
- **Acrolein is toxic by all exposure routes. Exposure causes inflammation and irritation of the skin, respiratory tract, and mucous membranes. Delayed pulmonary edema may occur after inhalation. Systemic effects may occur after exposure by any route.**

Description

Acrolein is a clear, colorless, or yellow liquid with a pungent, suffocating odor. It is very flammable and may polymerize violently. Acrolein should be stored in a cool, dry, well-ventilated area in tightly sealed containers separated from alkaline materials such as caustics, ammonia, organic amines, or mineral acids, strong oxidizers, and oxygen. Acrolein is soluble in water, alcohol, ether, and acetone.

Routes of Exposure

Inhalation

Inhaled acrolein is highly toxic. Acrolein is irritating to the upper respiratory tract even at low concentrations. Its odor threshold of 0.16 ppm is similar to the OSHA permissible exposure limit (0.1 ppm); thus odor may provide an adequate warning of potentially hazardous concentrations. Acrolein vapor is heavier than air, but asphyxiation in enclosed, poorly ventilated, or low-lying areas is unlikely due to its strong odor.

Children exposed to the same levels of acrolein vapor as adults may receive a larger dose because they have greater lung surface area:body weight ratios and higher minute volumes:weight ratios. In addition, they may be exposed to higher levels than adults in the

same location because of their short stature and the higher levels of acrolein vapor found nearer to the ground.

Skin/Eye Contact

Direct contact with liquid acrolein causes rapid and severe eye and skin irritation or burns. Exposure to vapor produces inflammation of mucous membranes and it is a potent lacrimator.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants affecting the skin.

Ingestion

Acrolein produces chemical burns of the lips, mouth, throat, esophagus, and stomach. Nausea, vomiting, and diarrhea also occur.

Sources/Uses

Acrolein is produced by oxidation of propylene.

Acrolein is principally used as a biocide to control plants, algae, molluscs, fungi, rodents, and microorganisms. Acrolein has also been used in the manufacture of other chemicals, as a warning agent in gases, as a test gas for gas masks, in military poison gases, in the manufacture of colloidal metals, in leather tanning, and as a fixative in histology.

Standards and Guidelines

OSHA PEL (permissible exposure limit) = 0.1 ppm as an 8-hr TWA concentration and 0.3 ppm as a 15-minute TWA short-term exposure limit (STEL).

NIOSH IDLH (immediately dangerous to life or health) = 2 ppm.

AIHA ERPG-2 (maximum airborne concentration below which it is believed that nearly all persons could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action) = 0.5 ppm.

Physical Properties

Description: Clear, colorless to yellow liquid.

Warning properties: Suffocating, pungent odor at 0.16 ppm.

Molecular weight: 56.06 daltons

Boiling point (760 mm Hg): 126.5 °F (52.5 °C)

Freezing point: -126 °F (-88.0 °C)

Vapor pressure: 210 mm Hg at 68 °F (20 °C)

Gas density: 1.94 (air = 1)

Specific gravity: 0.84 (water = 1)

Water solubility: 208 g/L at 20 °C

Flash point: -15 °F (-26.1 °C)

Flammable range: 2.8% to 31% (concentration in air)

Incompatibilities

Acrolein reacts with caustics, ammonia, organic amines, or mineral acids, strong oxidizers, and oxygen.

Health Effects

- **Acrolein is severely irritating to skin, eyes, and mucous membranes. Inhalation of acrolein may result in respiratory distress and delayed pulmonary edema. Contact with the skin or eyes produces irritation and lacrimation, and can result in chemical burns.**

- **The mechanism by which acrolein produces toxic symptoms is not known, but the compound is highly reactive. No information was found as to whether the health effects of acrolein in children are different than in adults. Exposure to acrolein produces severe respiratory problems and individuals with pre-existing breathing difficulties or skin disease may be more susceptible to its effects.**

Acute Exposure

The mechanism by which acrolein produces toxic symptoms is not known, but the compound is highly reactive, cross-links DNA, and inhibits the activities of some enzymes (including cytochrome P450 and glutathione-S-transferase) *in vitro* by reacting with sulfhydryl groups at the active sites. It has also been shown to suppress pulmonary antibacterial defenses, to release oxygen radicals, and to react with proteins. Onset of irritation is immediate, but pulmonary edema may be delayed and respiratory insufficiency may persist for up to 18 months after exposure.

Children do not always respond to chemicals in the same way that adults do. Different protocols for managing their care may be needed.

Respiratory

Acrolein produces irritation of the respiratory tract, increases airway resistance and tidal volume, and decreases respiratory frequency. It is also ciliastatic. Exposure to acrolein vapor concentrations as low as 10 ppm can lead to pulmonary edema and death. Inhalation may also cause an asthmatic reaction in sensitized individuals.

Acrolein is a weak sensitizer.

Children may be more vulnerable because of higher minute ventilation per kg and failure to evacuate an area promptly when exposed.

Dermal

Acrolein is a skin irritant. Contact with the liquid may cause skin burns, erythema, and edema.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants affecting the skin.

Ocular/Ophthalmic

Acrolein liquid or vapor can cause eye irritation and damage to the cornea.

Gastrointestinal

Acrolein causes burns of the lips, mouth, throat, esophagus, and stomach. Nausea, vomiting, and diarrhea have been reported. No data were located as to whether ingestion leads to systemic toxicity in humans.

Cardiovascular

Acrolein inhalation may cause hypertension and tachycardia.

CNS

Serious poisoning may cause CNS depression.

Immunologic

Acrolein may have the potential to be immunotoxic.

The immune system in children continues to develop after birth, and thus children may be more susceptible to certain chemicals.

Potential Sequelae

Respiratory insufficiency may persist for up to 18 months after exposure.

Chronic Exposure

Apart from rare cases of sensitization, no adverse effects in humans chronically exposed to low concentrations of acrolein have been reported.

Chronic exposure may be more serious for children because of their potential for a longer latency period.

Carcinogenicity

The Department of Health and Human Services has determined that acrolein may possibly be a human carcinogen. The International Agency for Research on Cancer has determined that acrolein is not classifiable as to its carcinogenicity to humans.

Reproductive and Developmental Effects

No studies were located that address reproductive or developmental effects of acrolein in humans. Acrolein caused developmental effects when injected into rats, but did not cause developmental effects when ingested by rabbits. No information was found as to whether acrolein crosses the placenta, but it has been measured in breast milk.

Acrolein is not included in *Reproductive and Developmental Toxicants,* a 1991 report published by the U.S. General Accounting Office (GAO) that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences.

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Prehospital Management

- **Victims exposed only to acrolein vapor do not pose contamination risks to rescuers. Victims whose clothing or skin is contaminated with liquid acrolein can secondarily contaminate response personnel by direct contact or by off-gassing vapor.**
- **Acrolein is a direct irritant to mucous membranes, skin, eyes, and the respiratory system. Acute inhalation exposure may lead to respiratory distress and noncardiogenic pulmonary edema.**
- **There is no antidote for acrolein. Treatment consists of respiratory and cardiovascular support.**

Hot Zone

Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if rescuers have not been trained in its use, assistance should be obtained from a local or regional HAZMAT team or other properly equipped response organization.

Rescuer Protection

Acrolein is highly toxic via all routes and is severely irritating to the eyes, mucous membranes, respiratory tract, and skin. Acrolein is highly flammable, can form explosive mixtures with air, and burns to produce irritating, corrosive and/or toxic gases. Acrolein vapor may travel to a source of ignition and flash back.

Respiratory Protection: Positive-pressure, self-contained breathing apparatus (SCBA) is recommended in response situations that involve exposure to potentially unsafe levels of acrolein.

Skin Protection: Chemical-protective clothing is recommended because acrolein can cause skin irritation, burns, and sensitization. Fully encapsulating, vapor protective clothing should be worn to deal with spills or leaks with no fire.

ABC Reminders

Quickly establish a patent airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible.

Victim Removal

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be removed on backboards or gurneys; if these are not available, carefully carry or drag victims to safety.

Consider appropriate management of anxiety in victims with chemically-induced acute disorders, especially children who may suffer separation anxiety if separated from a parent or other adult.

Decontamination Zone

Patients exposed only to acrolein vapor who have no skin or eye irritation may be transferred immediately to the Support Zone. Other patients will require decontamination as described below.

Rescuer Protection

If exposure levels are determined to be safe, decontamination may be conducted by personnel wearing a lower level of protection than that worn in the Hot Zone (described above).

ABC Reminders

Quickly establish a patent airway, ensure adequate respiration and pulse. Stabilize the cervical spine with a collar and a backboard if trauma is suspected. Administer supplemental oxygen as required. Assist ventilation with a bag-valve-mask device if necessary.

Basic Decontamination

Victims who are able may assist with their own decontamination. Quickly remove and double-bag contaminated clothing and personal belongings.

Flush exposed skin and hair with copious amounts of water. Wash with soap and rinse thoroughly with water. Use caution to avoid hypothermia when decontaminating victims, particularly children or the elderly. Use blankets or warmers after decontamination as needed.

Flush exposed or irritated eyes with tepid water for 15 minutes. Remove contact lenses if easily removable without additional trauma to the eye. Continue eye irrigation during other basic care and transport. If pain or injury is evident, continue irrigation while transferring the victim to the Support Zone.

In cases of ingestion, **do not induce emesis**. If the victim is alert, asymptomatic, and has a gag reflex, administer a slurry of activated charcoal at a dose of 1 g/kg (infant, child, and adult dose). A soda can and a straw may be of assistance when offering charcoal to a child.

Victims who are conscious and able to swallow should be given 4 to 8 ounces of milk or water (not to exceed 15 mL/kg in a child). If the victim is symptomatic, delay decontamination until other emergency measures have been instituted.

Consider appropriate management of chemically contaminated children at the exposure site. Provide reassurance to the child during decontamination, especially if separation from a parent occurs.

Transfer to Support Zone

As soon as basic decontamination is complete, move the victim to the Support Zone.

Support Zone

Be certain that victims have been decontaminated properly (see *Decontamination Zone*, above). Victims who have undergone decontamination or have been exposed only to vapor pose no serious risks of secondary contamination to rescuers. In such cases, Support Zone personnel require no specialized protective gear.

ABC Reminders

Quickly establish a patent airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Administer supplemental oxygen as required and establish intravenous access if necessary. Place on a cardiac monitor.

Additional Decontamination

Continue irrigating exposed skin and eyes, as appropriate.

In cases of ingestion, **do not induce emesis**. If the victim is alert, asymptomatic, and has a gag reflex, administer a slurry of activated charcoal at a dose of 1 g/kg (infant, child, and adult dose) if it has not already been administered. A soda can and a straw may be of assistance when offering charcoal to a child.

Victims who are conscious and able to swallow should be given 4 to 8 ounces of milk or water (not to exceed 15 mL/kg in a child) if it has not been given previously. If the victim is symptomatic, delay decontamination until other emergency measures have been instituted.

Advanced Treatment

In cases of respiratory compromise, secure airway and respiration via endotracheal intubation. If not possible, perform cricothyrotomy if equipped and trained to do so.

Treat patients who have bronchospasm with an aerosolized bronchodilator such as albuterol. Consider that acrolein inhalation may cause hypertension and tachycardia, in which case the use of bronchodilators that are known cardiac sensitizing agents may pose enhanced risk. Administer corticosteroids as indicated to patients who have persistent wheezing or hypersensitivity pneumonitis.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution; repeat every 20 minutes as needed, cautioning for myocardial variability.

Patients who are comatose, hypotensive, or having seizures or cardiac arrhythmias should be treated according to advanced life support (ALS) protocols.

If evidence of shock or hypotension is observed, begin fluid administration. For adults with systolic pressure less than 80 mmHg, bolus perfusion of 1,000 mL/hour intravenous saline or lactated Ringer's solution may be appropriate. Higher adult systolic pressures may necessitate lower perfusion rates. For children with compromised perfusion, administer a 20 mL/kg bolus of normal saline over 10 to 20 minutes, then infuse at 2 to 3 mL/kg/hour.

Transport to Medical Facility

Only decontaminated patients or patients not requiring decontamination should be transported to a medical facility. "Body bags" are not recommended.

Report to the base station and the receiving medical facility the condition of the patient, treatment given, and estimated time of arrival at the medical facility.

If acrolein has been ingested, prepare the ambulance in case the victim vomits toxic material. Have ready several towels and open plastic bags to quickly clean up and isolate vomitus.

Multi-Casualty Triage

Consult with the base station physician or the regional poison control center for advice regarding triage of multiple victims.

Patients who are seriously symptomatic (as in cases of chest tightness or wheezing), patients who have histories or evidence of significant exposure, and all patients who have ingested acrolein should be transported to a medical facility for evaluation. Others may be discharged at the scene after their names, addresses, and telephone numbers are recorded. Those discharged should be advised to seek medical care promptly if symptoms develop (see *Patient Information Sheet* below).

Emergency Department Management

- **Hospital personnel in an enclosed area can be secondarily contaminated by direct contact or by off-gassing vapor from soaked skin or clothing. Patients do not pose contamination risks after contaminated clothing is removed and the skin is washed.**
- **Acrolein is irritating to mucous membranes, skin, eyes, and the respiratory tract. Acute inhalation exposure may lead to respiratory distress and noncardiogenic pulmonary edema.**
- **There is no antidote for acrolein. Treatment consists of respiratory and cardiovascular support.**

Decontamination Area

Unless previously decontaminated, all patients suspected of contact with acrolein liquid and all victims with skin or eye irritation require decontamination as described below. Because acrolein reacts with the skin, don butyl rubber gloves and an apron before treating patients. Acrolein readily penetrates most rubbers and barrier fabrics or creams, but butyl rubber provides good skin protection. All other patients may be transferred immediately to the Critical Care Area.

Be aware that use of protective equipment by the provider may cause anxiety, particularly in children, resulting in decreased compliance with further management efforts.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants that react with the skin. Also emergency room personnel should examine children's mouths because of the frequency of hand-to-mouth activity among children.

ABC Reminders

Evaluate and support airway, breathing, and circulation. In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, surgically create an airway.

Treat patients who have bronchospasm with an aerosolized bronchodilator such as albuterol. Consider that acrolein inhalation may cause hypertension and tachycardia, in which case the use of bronchodilators that are known cardiac sensitizing agents may pose enhanced risk. Administer corticosteroids as indicated to patients who have persistent wheezing or hypersensitivity pneumonitis.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution; repeat every 20 minutes as needed, cautioning for myocardial variability.

Patients who are comatose, hypotensive, or have seizures or ventricular arrhythmias should be treated in the conventional manner.

Basic Decontamination

Patients who are able may assist with their own decontamination. Remove and double-bag contaminated clothing and all personal belongings.

Flush exposed skin and hair with water for 2 to 3 minutes (preferably under a shower), then wash thoroughly with mild soap. Rinse thoroughly with water. Use caution to avoid hypothermia when decontaminating victims, particularly children or the elderly. Use blankets or warmers after decontamination as needed.

Flush exposed eyes with plain tepid water for at least 15 minutes. Remove contact lenses if easily removable without additional trauma to the eye. If pain or injury is evident, continue irrigation while transporting the patient to the Critical Care Area.

In cases of ingestion, **do not induce emesis**. If the victim is alert, asymptomatic, and has a gag reflex, administer a slurry of activated charcoal at a dose of 1 g/kg (infant, child, and adult dose) if it has not already been administered. A soda can and a straw may be of assistance when offering charcoal to a child.

Victims who are conscious and able to swallow should be given 4 to 8 ounces of milk or water (not to exceed 15 mL/kg in a child) if it has not been given previously (see *Critical Care Area* below for more information on ingestion exposure).

Critical Care Area

Be certain that appropriate decontamination has been carried out (see *Decontamination Area* above).

ABC Reminders

Evaluate and support airway, breathing, and circulation as in ABC Reminders above under *Decontamination Zone*. Establish intravenous access in seriously ill patients if this has not been done previously. Continuously monitor cardiac rhythm.

Patients who are comatose, hypotensive, or have seizures or cardiac arrhythmias should be treated in the conventional manner.

Inhalation Exposure

Administer supplemental oxygen by mask to patients who have respiratory symptoms. Treat patients who have bronchospasm with an aerosolized bronchodilator such as albuterol. Consider that acrolein inhalation may cause hypertension and tachycardia, in which case the use of bronchodilators that are known cardiac sensitizing agents may pose enhanced risk. Administer corticosteroids as indicated to patients who have persistent wheezing or hypersensitivity pneumonitis.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution; repeat every 20 minutes as needed, cautioning for myocardial variability.

Skin Exposure

If the skin was in contact with liquid acrolein, chemical burns may occur; treat as thermal burns.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants affecting the skin.

Eye Exposure

Continue irrigation for at least 15 minutes. Test visual acuity. Examine the eyes for corneal damage and treat appropriately. Immediately consult an ophthalmologist for patients who have corneal injuries.

Ingestion Exposure

Do not induce emesis. If the victim is alert, asymptomatic, and has a gag reflex, administer a slurry of activated charcoal at a dose of 1 g/kg (infant, child, and adult dose) if it has not already been administered. A soda can and a straw may be of assistance when offering charcoal to a child.

Victims who are conscious and able to swallow should be given 4 to 8 ounces of milk or water (not to exceed 15 mL/kg in a child) if it has not been given previously.

Consider endoscopy to evaluate the extent of gastrointestinal-tract injury. Extreme throat swelling may require endotracheal intubation or cricothyrotomy. Gastric lavage is useful in certain circumstances to remove caustic material and prepare for endoscopic examination. Consider gastric lavage with a small nasogastric (NG) tube if: (1) a large dose has been ingested; (2) the patient's condition is evaluated

within 30 minutes; (3) the patient has oral lesions or persistent esophageal discomfort; and (4) the lavage can be administered within one hour of ingestion. Care must be taken when placing the gastric tube because blind gastric-tube placement may further injure the chemically damaged esophagus or stomach.

Because children do not ingest large amounts of corrosive materials, and because of the risk of perforation from NG intubation, lavage is discouraged in children unless performed under endoscopic guidance.

Toxic vomitus or gastric washings should be isolated, e.g., by attaching the lavage tube to isolated wall suction or another closed container.

Antidotes and Other Treatments

There is no antidote for acrolein. Treatment is supportive of respiratory and cardiovascular functions.

Laboratory Tests

Routine laboratory studies for all exposed patients include CBC, glucose, and electrolyte determinations. Patients who have respiratory complaints may require pulse oximetry (or ABG measurements), chest radiography, and peak-flow spirometry.

Disposition and Follow-up

Consider hospitalizing patients who have histories of significant inhalation exposure and are symptomatic (e.g., chest tightness or wheezing) or who have ingested acrolein.

Delayed Effects

Pulmonary edema may be delayed for 24 hours after inhalation exposure and respiratory dysfunction may remain for as long as 18 months after exposure.

Patient Release

Patients who remain asymptomatic for 24 hours after exposure may be discharged with instructions to seek medical care promptly if symptoms develop (see the *Acrolein—Patient Information Sheet* below).

Follow-up

Obtain the name of the patient's primary care physician so that the hospital can send a copy of the emergency department (ED) visit to the patient's doctor.

If significant inhalation or skin contact has occurred, monitor pulmonary function. In rare cases individuals may be permanently sensitized and may need to be removed from future work with acrolein; patients should consult an occupational medicine or

pulmonary specialist before returning to work that entails exposure to acrolein.

Patients who have corneal injuries should be reexamined within 24 hours.

Reporting

If a work-related incident has occurred, you may be legally required to file a report; contact your state or local health department.

Other persons may still be at risk in the setting where this incident occurred. If the incident occurred in the workplace, discussing it with company personnel may prevent future incidents. If a public health risk exists, notify your state or local health department or other responsible public agency. When appropriate, inform patients that they may request an evaluation of their workplace from OSHA or NIOSH. See Appendix III for a list of agencies that may be of assistance.

Acrolein
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to acrolein.

What is acrolein?
Acrolein is a colorless to pale-yellow liquid with a strong, pungent odor. Acrolein is principally used as a biocide to control plants, algae, molluscs, fungi, rodents, and microorganisms. Acrolein has also been used in the manufacture of other chemicals, as a warning agent in gases, as a test gas for gas masks, in military poison gases, in the manufacture of colloidal metals, in leather tanning, and as a fixative in histology.

What immediate health effects can be caused by exposure to acrolein?
Low levels of acrolein in the air can irritate the eyes, nose, throat, and lungs and cause cough, chest tightness, and shortness of breath. Higher levels can cause a build-up of fluid in the lungs, which may cause death. If liquid acrolein comes in contact with the skin or eyes, it can cause severe burns. Generally, the more serious the exposure, the more severe the symptoms.

Can acrolein poisoning be treated?
There is no antidote for acrolein, but its effects can be treated and most exposed persons get well. Seriously exposed persons may need to be hospitalized.

Are any future health effects likely to occur?
Respiratory dysfunction may persist for over a year. In rare cases, after exposure to acrolein, certain persons can be sensitized so that even small exposures to acrolein or other irritants can trigger allergic reaction. Therefore, it is important to tell your doctor that you have been exposed to acrolein. The Department of Health and Human Services has determined that acrolein may possibly be a human carcinogen, based in part on limited evidence of cancer in rats that were exposed to acrolein in the drinking water for a lifetime.

What tests can be done if a person has been exposed to acrolein?
Specific tests for the presence of acrolein in blood are not available. If a severe exposure has occurred, respiratory function tests and a chest x-ray may show whether lung damage has occurred. In some cases, lung damage may not be noticed immediately following exposure. Specialized tests exist for reacted hemoglobin in blood and for modified DNA in white blood cells.

Where can more information about acrolein be found?
More information about acrolein can be obtained from your regional poison control center; your state, county, or local health department; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor, or a clinic in your area that specializes in occupational and environmental health. If the exposure happened at work, you may wish to discuss it with your employer, the Occupational Safety and Health Administration (OSHA), or the National Institute for Occupational Safety and Health (NIOSH). Ask the person who gave you this form for help in locating these telephone numbers.

Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow *only* the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:

- coughing, wheezing, difficulty breathing, shortness of breath, or chest pain
- increased pain or a discharge from your eyes
- increased redness or pain or a pus-like discharge in the area of a skin burn

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.
[ ] Call for an appointment with Dr. _____ in the practice of _____. When you call for your appointment, please say that you were treated in the Emergency Department at _____ Hospital by _____ and were advised to be seen again in _____ days.
[ ] Return to the Emergency Department/ _____ Clinic on (date) _____at _____ AM/PM for a follow-up examination.
[ ] Do not perform vigorous physical activities for 1 to 2 days.
[ ] You may resume everyday activities including driving and operating machinery.
[ ] Do not return to work for _____ days.
[ ] You may return to work on a limited basis. See instructions below.
[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.
[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.
[ ] Avoid taking the following medications: _____
[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: ___
_____
_____
[ ] Other instructions: _____
_____
_____

- Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.

- You or your physician can get more information on the chemical by contacting: _____ _____ or _____, or by checking out the following Internet Web sites: _____; _____.

Signature of patient _____ Date _____

Signature of physician _____ Date _____

Acrylonitrile (CH_2=CHCN)
CAS 107-13-l; UN l093

Synonyms include AN, cyanoethylene, propenenitrile, VCN, vinyl cyanide, carbacryl, fumigain, and ventox.

- **Persons whose clothing or skin are contaminated with liquid acrylonitrile can secondarily contaminate response personnel by direct contact or through off-gassing vapor.**
- **Acrylonitrile is a clear, colorless or slightly yellow liquid that is highly volatile and toxic. Acrylonitrile vapor is heavier than air. It has a pungent odor of onion or garlic that does not provide adequate warning of hazardous levels.**
- **Acrylonitrile is poisonous by inhalation, ingestion or skin contact. Within the body acrylonitrile releases cyanide.**

Description

At room temperature, acrylonitrile is a clear, colorless, or slightly yellow liquid. It is very volatile, producing flammable and toxic air concentrations at room temperature and may explode. It is moderately soluble in water and soluble in most organic solvents.

Routes of Exposure

Inhalation

Acrylonitrile vapor is absorbed readily through the lungs, and inhalation is an important route of. **Acrylonitrile's odor does not provide adequate warning of hazardous concentrations.**

The odor threshold is about 10-fold greater than the OSHA permissible exposure limit, so workers can be overexposed to acrylonitrile without being aware of its presence. In addition, olfactory fatigue develops rapidly. CNS symptoms have been caused by exposure to airborne concentrations as low as 16 ppm for 30 minutes. Acrylonitrile is heavier than air and exposure can result in asphyxiation in poorly ventilated, enclosed, or low-lying areas.

Children exposed to the same levels of acrylonitrile vapor as adults may receive larger dose because they have greater lung surface area:body weight ratios and increased minute volumes:weight ratios. In addition, they may be exposed to higher levels than adults in the same location because of their short stature and the higher levels of acrylonitrile vapor found nearer to the ground.

Skin/Eye Contact

Exposure to acrylonitrile vapor can cause skin and eye irritation. Splashes in the eye may result in corneal injury. Acrylonitrile is absorbed through intact skin, and this can lead to systemic toxicity. Prolonged skin contact with the liquid may cause formation of vesicles and burns, resembling a second degree thermal burn.

Children are more vulnerable to toxicants absorbed through the skin because of their larger surface area:weight ratio.

Ingestion

Acute toxic effects, including fatal systemic poisoning, can result from ingestion.

Sources/Uses

Acrylonitrile, one of the world's most important industrial chemicals, is produced by catalytic reaction of propylene with ammonia. In 1990, U.S. production exceeded 3 billion pounds. It is a raw material in the manufacture of acrylic fibers, styrene plastics, and adhesives. Such fibers and plastics are components of clothing, furniture, appliances, construction materials, motor vehicles, and food packaging. In the past, acrylonitrile was also used as a room fumigant and pediculicide (an agent used to destroy lice).

Standards and Guidelines

OSHA PEL (permissible exposure limit) = 2 ppm (skin) (averaged over an 8-hour workshift).

OSHA STEL (short-term exposure limit) = 10 ppm (over a 15-minute time period).

NIOSH IDLH (immediately dangerous to life or health) = 85 ppm.

AIHA ERPG-2 (maximum airborne concentration below which it is believed that nearly all persons could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action) = 35 ppm.

Physical Properties

Description: Clear, colorless, or slightly yellow liquid

Warning properties: Inadequate; unpleasant onion or garlic odor at 20 ppm

Molecular weight: 53.0 daltons

Boiling point (760 mm Hg): 171 °F (77 °C)

Freezing point: -116 °F (-82 °C)

Specific gravity: 0.80 (water = 1)

Vapor pressure: 83 mm Hg at 68 °F (20 °C)

Gas density: 1.8 (air = 1)

Water solubility: Water soluble (7% at 68 °F) (20 °C)

Flammability: Flammable and explosive at temperatures >30 °F (-1 °C)

Flammable range: 3% to 17% (concentration in air)

Incompatibilities

Acrylonitrile reacts with strong oxidizers, acids, alkalies, bromine, amines, and copper. Unless inhibited (usually with methylhydroquinone), acrylonitrile may polymerize spontaneously. It may also polymerize when heated or in the presence of strong alkalies.

Health Effects

- **Acrylonitrile is irritating to the skin, eyes, and respiratory tract.**
- **Toxic effects range from headache, fatigue, dyspnea, nausea and vomiting to asphyxiation, lactic acidosis and cardiovascular collapse.**
- **Toxic effects are due primarily to the bioreactivity of acrylonitrile with cellular proteins and to its epoxide intermediate that is mutagenic and genotoxic.**
- **Toxicity is also due to the release of cyanide during the metabolism of acrylonitrile.**

Acute Exposure

Some, but not all, of the toxicity of acrylonitrile may be due to the metabolic release of cyanide, which inhibits numerous enzymes, including cytochrome oxidase, resulting in cellular asphyxiation. Toxicity not related to cyanide formation is due to the formation of reactive vinyl groups and epoxide intermediates which can deplete glutathione stores and cause liver damage. The onset of symptoms due to cyanide release may be delayed 4 to 12 hours.

Children do not always respond to chemicals in the same way that adults do. In addition, children of different ages (e.g., *in utero*, infants, toddlers, older children) may have different responses to certain chemical exposures, and thus, different protocols for managing their care may be needed.

CNS

CNS signs and symptoms can evolve rapidly or be delayed. Initial symptoms are usually nonspecific and include irritability, dizziness, nausea, vomiting, headache, and weakness in the arms and legs. As poisoning progresses, CNS signs include drowsiness, tetanic spasm, lockjaw, convulsions, hallucinations, loss of consciousness, and coma. Brain damage from lack of oxygen may develop.

Cardiovascular

Depression of the cardiovascular system can occur as a result of cyanide liberated from acrylonitrile. Initial tachycardia is followed by bradycardia (the ECG may show ischemic changes); dysrhythmias, hypotension and peripheral vascular collapse may follow.

Respiratory

Acute inhalation exposure can irritate the mucous membranes of the respiratory tract. Sneezing, tearing, chest discomfort, and cough can result. Victims may complain of shortness of breath and chest tightness. Pulmonary symptoms may include rapid

breathing and increased depth of respirations. As poisoning progresses, respiration becomes slow, shallow, and gasping. Cyanosis may occur, and pulmonary edema develops in fatal cases.

Children may be vulnerable because of relatively increased minute ventilation as well as failure to evacuate an area promptly when exposed.

Metabolic

An anion-gap, acid-base imbalance occurs in severe poisoning, caused by disruption of cellular metabolism and production of lactic acid.

Hepatic

Acrylonitrile may cause liver dysfunction characterized by jaundice, malaise, anorexia, and leukocytosis. Liver dysfunction is compounded by depletion of glutathione stores.

Dermal

Acrylonitrile causes skin irritation and blisters. Prolonged skin contact with the liquid may cause formation of vesicles and burns, resembling a second degree thermal burn. Intolerable itching of the skin with no demonstrable dermatitis has been reported in workers.

Because of their larger surface area:body weight ratio, children are more vulnerable to toxicants absorbed through the skin.

Ocular

High concentrations of gaseous acrylonitrile can cause eye irritation and lacrimation. Splash contact causes only transient disturbances usually without long-term corneal damage.

Potential Sequelae

No information is available for acrylonitrile, but survivors of severe acute cyanide poisoning may develop delayed neurologic sequelae.

Chronic Exposure

Chronic exposures to acrylonitrile have been associated with liver damage. Chronic exposure may be more serious for children because of their potential longer latency period.

Carcinogenicity

The Department of Health and Human Services has determined that acrylonitrile may reasonably be anticipated to be a carcinogen. IARC has determined that acrylonitrile is possibly carcinogenic to humans (Group 2B) based on sufficient evidence of carcinogenicity in experimental animals and inadequate evidence for carcinogenicity in humans. ACGIH classifies it as an A_2 suspected human carcinogen. In animals, chronic exposure can cause tumors of the mammary gland, gastrointestinal tract, and CNS. Increased rates of lung and prostate cancer have been

documented in some groups of chronically exposed workers, but not in others.

Reproductive and Developmental Effects

According to Shepard's Catalog of Teratogenic Agents, when large doses of acrylonitrile were administered to experimental animals by oral, inhalation, or intraperitoneal routes, teratogenic effects were produced. In humans, there is no documented evidence that acrylonitrile is a reproductive or developmental toxicant. Acrylonitrile is not currently reviewed in the TERIS or Reprotext databases. Acrylonitrile is not included in *Reproductive and Developmental Toxicants*, a 1991 report published by the U.S. General Accounting Office (GAO) that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences.

There is no information regarding whether acrylonitrile can cross the placenta or whether it can accumulate in breast milk and be transferred to nursing infants.

Prehospital Management

- **Victims exposed only to acrylonitrile vapor do not pose secondary contamination risks to rescuers. Victims whose clothing or skin is contaminated with liquid acrylonitrile can secondarily contaminate response personnel by direct contact or through off-gassing vapor.**
- **Acrylonitrile is irritating to the skin, eyes, and respiratory tract. Systemic effects can occur from all routes of exposure and may include dyspnea, CNS and cardiovascular disturbances, and lactic acidosis.**
- **Treatment consists of supportive care. The first priority is to establish adequate ventilation, oxygen and circulation. Cyanide antidotes such as sodium nitrite and sodium thiosulfate as contained in the cyanide antidote kit, have been recommended although their efficacy in human toxicity has not been fully established.**

Hot Zone

Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if rescuers have not been trained in its use, assistance should be obtained from a local or regional HAZMAT team or other properly equipped response organization.

Rescuer Protection

Acrylonitrile is a highly toxic systemic poison that is absorbed well by inhalation, through the stomach, and through the skin. It is also irritating to the skin and eyes on direct contact.

Respiratory Protection: Positive-pressure, self-contained breathing apparatus (SCBA) is recommended in response situations that involve exposure to potentially unsafe levels of acrylonitrile vapor.

Skin Protection: Chemical-protective clothing is recommended because acrylonitrile liquid and vapor can be dermally absorbed and may contribute to systemic toxicity. Direct contact with liquid acrylonitrile can cause skin burns. Cutaneous absorption occurs through contaminated leather and rubber because of excellent penetration properties. Butyl gloves should be worn rather than cotton or latex.

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible.

Victim Removal

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be removed on backboards or gurneys; if these are not available, carefully carry or drag victims to safety.

Consider proper management of chemically contaminated children, such as measures to reduce separation anxiety if a child is separated from a parent or other adult.

Decontamination Zone

All victims suspected of ingestion or significant exposure to liquid acrylonitrile require decontamination. Others may be transferred immediately to the Support Zone.

Rescuer Protection

If exposure levels are determined to be safe, decontamination may be conducted by personnel wearing a lower level of protection than that worn in the Hot Zone (described above).

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and palpable pulse. Stabilize the cervical spine with a collar and a backboard if trauma is suspected. Administer supplemental oxygen as required. Assist ventilation with a bag-valve-mask device if necessary.

Basic Decontamination

Victims who are able, may assist with their own decontamination. Quickly remove and double-bag contaminated clothing and personal belongings. Leather absorbs acrylonitrile; items such as leather shoes, gloves, and belts may require disposal by incineration. Acrylonitrile may also penetrate rubber. Butyl rubber gloves should be worn.

Flush exposed skin and hair with plain water for 2 to 3 minutes. Wash twice with mild soap. Rinse thoroughly with water.

Irrigate exposed or irritated eyes with plain water or saline for at least 15 minutes. Eye irrigation should be carried out simultaneously with other basic care and transport. Remove contact lenses if easily removable without additional trauma to the eye.

In cases of ingestion, **do not induce emesis**. If the victim is symptomatic, delay decontamination until other emergency measures have been instituted, including the use of a cyanide antidote kit. (See *Advanced Treatment* below.) If the victim is not symptomatic, administer activated charcoal at 1 gm/kg, usual adult dose 60–90 g, child dose 25–50 g. A soda can and straw may be of assistance when offering charcoal to a child.

Consider appropriate management of chemically contaminated children at the exposure site. Also, provide reassurance to the child during decontamination, especially if separation from a parent occurs. If possible, seek assistance from a child separation expert.

Transfer to Support Zone

As soon as basic decontamination is complete, move the victim to the Support Zone.

Support Zone

Be certain that victims have been decontaminated properly (see *Decontamination Zone* above). Victims who have undergone decontamination or have been exposed only to vapor pose no serious risks of secondary contamination. In such cases, Support Zone personnel require no specialized protective gear.

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and palpable pulse. If trauma is suspected, maintain cervical immobilization and apply a cervical collar and a backboard. (administer supplemental oxygen as required). Establish intravenous access if necessary. Place on a cardiac monitor.

Additional Decontamination

Continue irrigating exposed skin and eyes, as appropriate.

In cases of ingestion, **do not induce emesis**. If the patient is symptomatic, delay decontamination and institute other emergency measures if they have not previously been given, including the use of a cyanide antidote kit (see Advanced Treatment below). If the patient is not symptomatic, administer a slurry of activated charcoal (dose 1 mg/kg) if not already done in the *Decontamination Zone*.

Advanced Treatment

In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, perform cricothyroidotomy if equipped and trained to do so. Administer 100% oxygen.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Also consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Acrylonitrile poisoning is not known to pose additional risk during the use of bronchial or cardiac sensitizing agents.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in water, repeat every 20 minutes as needed cautioning for myocardial variability.

Patients who are comatose, hypotensive, or have seizures or cardiac dysrhythmias should be treated according to advanced life support (ALS) protocols. These patients may be seriously acidotic; under medical control, consider giving them 1 ampule of sodium bicarbonate (pediatric dose: 1 mEq/kg may be appropriate).

If massive exposure is suspected or if the patient is severely symptomatic with hypotension, infuse intravenous saline or lactated Ringer's solution. For adults, bolus 1,000 mL/hour if blood pressure is under 80 mm Hg; if systolic pressure is over 90 mm Hg, an infusion rate of 150 to 200 mL/hour is sufficient. For children with compromised perfusion administer 20 mL/kg of normal saline or Ringer's lactate delivered over 10 to 20 minutes, then at a 2 to 3 mL/kg/hour infusion rate.

Antidotes

When possible, treatment with cyanide antidotes should be given under medical-base control to unconscious victims with known or strongly suspected acrylonitrile poisoning. Cyanide antidotes amyl nitrite perles and intravenous infusions of sodium nitrite and sodium thiosulfate are packaged in the cyanide antidote kit.

Amyl nitrite perles (0.2 mL) should be broken onto a gauze pad and held under the nose, over the Ambu valve intake, or placed under the lip of the face mask. A new perle is crushed and inhaled for 30 seconds every minute until intravenous sodium nitrite is given.

Infuse sodium nitrite intravenously as soon as possible. The usual adult dose is 10 to 20 mL of a 3% solution infused over no less than 5 minutes to produce a 20% methemoglobin level in adults. Children should receive 0.33 mL/kg of the 3% solution at an infusion rate of 2.5 mL/minute, up to a maximum of 10 mL. Administer sodium nitrite doses to children on the basis of body weight, since fatal methemoglobinemia has occurred in children dosed at adult rates. Monitor blood pressure during administration, and slow the rate of infusion if hypotension develops.

Immediately after sodium nitrite infusion, administer sodium thiosulfate intravenously. The usual adult dose is 50 mL (12.5 g) of a 25% solution infused at a rate of 3 to 5 mL/minute; the

average pediatric dose is 1.65 mL/kg (412.5 mg/kg) up to 50 mL. If symptoms reappear or persist within 1 hour, readminister sodium nitrite and sodium thiosulfate at 50% of the initial dose.

Transport to Medical Facility

Only decontaminated patients or patients not requiring decontamination should be transported to a medical facility. "Body bags" are not recommended.

Report to the base station and the receiving medical facility the condition of the patient, treatment given, and estimated time of arrival at the medical facility.

If acrylonitrile has been ingested, prepare the ambulance in case the victim vomits toxic material. Have ready several towels and open plastic bags to quickly soak up and isolate vomitus.

Multi-Casualty Triage

Consult with the base station physician or the regional poison control center for advice regarding triage of multiple victims.

Patients who have evidence of substantial exposure and all persons with acrylonitrile ingestion ,should be transported to a medical facility for evaluation. Others may be discharged at the scene after their names, addresses, and telephone numbers are recorded. Those discharged should be advised to seek medical care promptly if symptoms develop or recur (see *Patient Information Sheet* below).

Emergency Department Management

- **Hospital personnel in an enclosed area can be secondarily contaminated by vapor off-gassing from heavily soaked clothing or from the vomitus of victims who have ingested acrylonitrile. Patients do not pose serious contamination risks after contaminated clothing is removed and the skin is thoroughly washed.**
- **Acrylonitrile is irritating to the skin, eyes, and respiratory tract. Systemic effects can (occur from all routes of exposure and may include dyspnea, CNS and cardiovascular disturbances, and lactic acidosis.**
- **Treatment consists of supportive measures. Cyanide antidotes such as sodium nitrite and sodium thiosulfate have been recommended although their efficacy in human acrylonitrile toxicity has not been fully established.**

Decontamination Area

Unless previously decontaminated, all patients suspected of contact with liquid acrylonitrile and all victims with skin or eye irritation require decontamination as described below.

Acrylonitrile is absorbed through the skin. Don butyl rubber gloves and apron before treating patients who are wet with liquid acrylonitrile. Acrylonitrile readily penetrates most rubbers and barrier fabrics or creams, but butyl rubber provides good skin protection.

Be aware that use of protective equipment by the provider may cause fear in children, resulting in decreased compliance with further management efforts.

Because of their relatively larger surface area: weight ratio, children are more vulnerable to toxicants absorbed through the skin. Also, emergency room personnel should examine children's mouths for ulceration or irritation because of the frequency of hand-to-mouth activity among children.

ABC Reminders

Evaluate and support airway, breathing, and circulation. In cases of respiratory compromise, secure airway and respiration via endotracheal intubation. If not possible, surgically secure an airway. Symptomatic patients should be placed on supplemental oxygen.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Also consider the health of the myocardium before

choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Acrylonitrile poisoning is not known to pose additional risk during the use of bronchial or cardiac sensitizing agents.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in water, repeat every 20 minutes as needed cautioning for myocardial variability.

Patients who are comatose, hypotensive, or have seizures or cardiac dysrhythmias should be treated in the conventional manner. Consider dopamine or norepinephrine.

Correct acidosis in the patient who has coma, seizures, or cardiac arrhythmias by administering intravenously an ampule of sodium bicarbonate (Dose 1 mEq/kg, maximum 100 mEq, usual adult dose is 1 ampule).

Basic Decontamination

Patients who are able, may assist with their own decontamination. If the patient's clothing is wet with acrylonitrile, quickly remove and double-bag contaminated clothing and personal belongings.

Flush exposed skin and hair with plain water (preferably under a shower) for 2 to 3 minutes, then wash twice with mild soap. Rinse thoroughly with water. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Begin irrigation of exposed eyes. Remove contact lenses if easily removable without additional trauma to the eye. Exposed eyes should be irrigated with copious amounts of tepid water for at least 15 minutes. Continue irrigation while transporting the patient to the Critical Care Area.

If the patient has ingested acrylonitrile, **do not induce emesis**. If the patient is alert and able to swallow, administer activated charcoal at 1 gm/kg, usual adult dose 60–90 g, child dose 25–50 g. A soda can and straw may be of assistance when offering charcoal to a child.

Critical Care Area

Be certain that appropriate decontamination has been carried out (see *Decontamination Area* above).

ABC Reminders

Evaluate and support airway, breathing, and circulation as in ABC Reminders above. Children may be more vulnerable to corrosive agents than adults because of the smaller diameter of their airways. Establish intravenous access in seriously symptomatic patients if it has not been done previously. Place on supplemental oxygen and continuous cardiac monitor.

Patients who are comatose, hypotensive, or have seizures or cardiac arrhythmias should be treated in the conventional manner.

If not previously administered, give one ampule of sodium bicarbonate intravenously to the patient with acidosis (initial dose is 1 mEq/kg); further bicarbonate therapy should be guided by ABG measurements.

Inhalation Exposure

Administer supplemental oxygen by mask to patients who have respiratory symptoms. Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Also consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Acrylonitrile poisoning is not known to pose additional risk during the use of bronchial or cardiac sensitizing agents.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in water, repeat every 20 minutes as needed cautioning for myocardial variability.

Skin Exposure

If the skin was in contact with liquid acrylonitrile, chemical burns may occur; treat as thermal burns.

Because of their relatively larger surface area:weight ratio, children are more vulnerable to toxicants absorbed through the skin.

Eye Exposure

Ensure that adequate eye irrigation has been completed. Continue irrigation for at least 15 minutes. Test visual acuity. Examine the eyes for corneal damage and treat appropriately. Immediately consult an ophthalmologist for patients who have severe corneal injuries.

Ingestion Exposure

Do not induce emesis. If the patient is alert administer a slurry of activated charcoal if not done previously (1 gm/kg, usual adult dose 60–90 g). Administer a slurry of activated charcoal. A soda can and straw may be of assistance when offering charcoal to a child.

Consider endoscopy to evaluate the extent of gastrointestinal tract injury. Extreme throat swelling may require endotracheal intubation or cricothyroidotomy. Gastric lavage is useful under certain circumstances to remove caustic material and prepare for endoscopic examination. Consider gastric lavage with a small nasogastric tube if: (1) a large dose has been ingested; (2) the patient's condition is evaluated within 30 minutes; (3) the patient has oral lesions or persistent esophageal discomfort; and (4) the lavage can be administered within 1 hour of ingestion. Care must be taken when placing the gastric tube because blind gastric-tube placement may further injure the chemically damaged esophagus or stomach.

Because children do not ingest large amounts of corrosive materials, and because of the risk of perforation from NG intubation, lavage is discouraged in children unless intubation is performed under endoscopic guidance.

Carefully isolate toxic vomitus; it can cause secondary contamination through off-gassing vapor or direct contact.

Antidotes and Other Treatments

Patients who have signs or symptoms of significant systemic toxicity should be evaluated for treatment. The antidotes include amyl nitrite perles and intravenous infusions of sodium nitrite and sodium thiosulfate, which are packaged in the cyanide antidote kit.

If one dose of the antidotes in the cyanide antidote kit has been administered previously by prehospital personnel and inadequate clinical response has occurred, a second dose of one-half the initial amounts may be given 30 minutes after the initial dose. Further doses should be guided by the patient's clinical condition and not by the percentage of methemoglobin induced.

While infusions are being prepared, break amyl nitrite perles on to a gauze pad and hold under the patient's nose or over the Ambu valve intake or place under the lip of the face mask. Use a new perle every 3 minutes if sodium nitrite infusions will be delayed. Infuse sodium nitrite intravenously as soon as possible. The usual adult dose is 10 to 20 mL of a 3% solution infused over no less than 5 minutes; the average pediatric dose is 0.15 to

0.20 mL/kg body weight. Monitor blood pressure during administration, and slow the rate of infusion if hypotension develops. Administer sodium nitrite doses to children on the basis of body weight, since fatal methemoglobinemia has occurred in children dosed at adult rates. Monitor blood pressure during administration, and slow the rate of infusion if hypotension develops.

Next, infuse sodium thiosulfate intravenously. The usual adult dose is 50 mL of a 25% solution infused over 10 to 20 minutes; the average pediatric dose is 1.65 mL/kg.

Amyl nitrite and sodium nitrite oxidize the ferrous (Fe^{+2}) iron of hemoglobin to methemoglobin (Fe^{+3}). Methemoglobin levels should not exceed 20%. Repeat treatment with nitrite and thiosulfate as required.

It has been suggested that the hepatotoxic effects of acrylonitrile poisoning may be prevented or diminished by administration of N-acetylcysteine (NAC, Mucomyst). Recommended oral doses of NAC are those usually given for the treatment of acetaminophen overdose (140 mg/kg loading dose, followed by 70 mg/kg every 4 hours for 72 hours). Liver function, serum bilirubin, and prothrombin time should be monitored.

Laboratory Tests

The diagnosis of acute acrylonitrile toxicity is primarily clinical, based on dyspnea and cyanosis. However, laboratory testing is useful for monitoring the patient and evaluating complications. Routine laboratory studies for all exposed patients include CBC, glucose, and electrolyte determinations. Additional studies for patients exposed to acrylonitrile include ECG monitoring, lactate levels, and liver-function tests. Chest radiography and pulse oximetry (or ABG measurements) may be useful for patients exposed through inhalation.

In severe cases, the venous PO_2 may be elevated so that the normal gap between arterial and central venous PO_2 narrows.

After treatment with nitrites, serum methemoglobin levels should be monitored. Increased cyanide and thiocyanate levels have been found in the blood of persons exposed to acrylonitrile; however, they do not correlate with exposure levels. Cyanide and thiocyanate levels may be useful to document exposure.

Disposition and Follow-up

Consider hospitalizing patients who have histories of significant exposure and are symptomatic. Whenever intravenous cyanide antidotes are used, admit the patient to the intensive care unit. Blood methemoglobin levels should be monitored.

Delayed Effects

Acrylonitrile follows first order kinetics, its half life is approximately 8 hours and it is excreted in the urine. Because of continued metabolic release of cyanide, symptoms of severe poisoning may recur and the patient may relapse.

Jaundice may develop 24 hours after exposure and persist for several days.

Patient Release

Patients who remain asymptomatic 12 to 18 hours after exposure may be discharged and urged to seek medical care promptly if symptoms develop (see *Acrylonitrile—Patient Information Sheet* below).

Follow-up

Patients who have serious systemic cyanide poisoning may be at risk for CNS sequelae including Parkinson-like syndromes; they should be monitored for several weeks to months.

Patients who have corneal injuries should be reexamined within 24 hours.

Reporting

If a work-related incident has occurred, you may be legally required to file a report; note incident details and contact your state or local health department.

Other persons may still be at risk in the setting where this incident occurred. If the incident occurred in the workplace, discussing it with company personnel may prevent future incidents. If a public health risk exists, notify your state or local health department or other responsible public agency. When appropriate, inform patients that they may request an evaluation of their workplace from OSHA or NIOSH. See Appendices III and IV for a list of agencies that may be of assistance.

Acrylonitrile
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to acrylonitrile.

What is acrylonitrile?
Acrylonitrile is a clear, colorless, or slightly yellow liquid. At room temperature, it readily becomes a vapor. The vapor is flammable and can explode. Acrylonitrile is used to make a variety of fibers and plastics.

What immediate health effects can be caused by exposure to acrylonitrile?
Breathing acrylonitrile can result in a variety of symptoms, including sneezing, tightness in the chest, cough, weakness of the arms and legs, nausea and vomiting, sleepiness, irregular heartbeat, seizures, and fainting. Generally, the more serious the exposure, the more severe the symptoms. In the body, acrylonitrile breaks down to release cyanide. Symptoms can occur from any type of exposure to acrylonitrile including through the skin or by ingestion.

Can acrylonitrile poisoning be treated?
The treatment for acrylonitrile poisoning includes breathing pure oxygen and, in the case of severe exposure, specific antidotes, including those used to treat cyanide poisoning. Persons with serious symptoms may need to be hospitalized.

Are any future health effects likely to occur?
A single small exposure from which a person recovers quickly is not likely to cause delayed or long-term effects. After a large exposure, a patient may have brain, heart, or liver damage. Acrylonitrile has caused cancer in laboratory animals, cancer in humans has not been completely established.

What tests can be done if a person has been exposed to acrylonitrile?
Specific tests for the presence of acrylonitrile (or cyanide) in blood and urine generally are not useful to the doctor. If a severe exposure has occurred, blood and urine analysis and other tests may show whether the liver, heart, or nervous system has been injured. Testing is not needed in every case.

Where can more information about acrylonitrile be found?
More information about acrylonitrile can be obtained from your regional poison control center; your state, county, or local health department; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in occupational and environmental health. If the exposure happened at work, you may wish to discuss it with your employer, the Occupational Safety and Health Administration (OSHA), or the National Institute for Occupational Safety and Health (NIOSH). Ask the person who gave you this form for help in locating these telephone numbers.

Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow *only* the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:

- weakness in the limbs, dyspnea, irritability
- headache, apprehension
- chest discomfort, nausea, vomiting, diarrhea
- burning sensation in the throat

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.
[ ] Call for an appointment with Dr. _____ in the practice of _____.
When you call for your appointment, please say that you were treated in the Emergency Department at _ _____ Hospital by _____ and were advised to be seen again in _____ days.
[ ] Return to the Emergency Department/ _____ Clinic on (date) _____ at _____ AM/PM for a follow-up examination.
[ ] Do not perform vigorous physical activities for 1 to 2 days.
[ ] You may resume everyday activities including driving and operating machinery.
[ ] Do not return to work for _____ days.
[ ] You may return to work on a limited basis. See instructions below.
[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.
[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.
[ ] Avoid taking the following medications: _____
[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: _____
_____
_____
[ ] Other instructions: _____
_____
_____

- Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.

- You or your physician can get more information on the chemical by contacting: _____ _____ or _____, or by checking out the following Internet Web sites: _____; _____.

Signature of patient _____ Date _____

Signature of physician _____ Date _____

Ammonia (NH_3)
CAS 7664-41-7; UN 2672 (between 12% and 44% solution), UN 2073 (>44% solution), UN 1005 (anhydrous gas or >50% solution)

Synonyms include ammonia gas, anhydrous ammonia, and liquid ammonia. Aqueous solutions are referred to as aqueous ammonia, ammonia solution, and ammonium hydroxide.

Persons exposed only to ammonia gas do not pose significant risks of secondary contamination to personnel outside the Hot Zone. Persons whose clothing or skin is contaminated with liquid ammonium hydroxide can secondarily contaminate response personnel by direct contact or through off-gassing ammonia vapor.

Ammonia dissolves readily in water to form ammonium hydroxide a corrosive, alkaline solution at high concentrations.

Ammonia's pungent odor and irritating properties usually provide adequate warning of its presence; however, olfactory fatigue can occur. Inhalation can result in fatalities.

Description

At room temperature, anhydrous ammonia is a colorless, highly irritating gas with a pungent, suffocating odor. It is lighter than air and flammable, with difficulty, at high concentrations and temperatures. It is easily compressed and forms a clear, colorless liquid under pressure. Anhydrous ammonia is hygroscopic. Ammonia dissolves readily in water to form ammonium hydroxide-an alkaline solution. The concentration of aqueous ammonia solutions for household use is typically 5% to 10% (weight:volume), but solutions for commercial use may be 25% (weight:volume) or more and are corrosive. Aqueous ammonia is commonly stored in steel drums. Anhydrous ammonia is stored and shipped in pressurized containers, fitted with pressure-relief safety devices, and bears the label "Nonflammable Compressed Gas". Despite not meeting the Department of Transport definition of flammable it should be treated as such.

Routes of Exposure

Inhalation

Inhalation of ammonia may cause nasopharyngeal and tracheal burns, bronchiolar and alveolar edema, and airway destruction resulting in respiratory distress or failure. Ammonia's odor threshold is sufficiently low to acutely provide adequate warning of its presence (odor threshold = 5 ppm; OSHA PEL = 50 ppm). However, ammonia causes olfactory fatigue or adaptation, making its presence difficult to detect when exposure is prolonged. Anhydrous ammonia is lighter than air and will

therefore rise (will not settle in low-lying areas); however, vapors from liquefied gas are initially heavier than air and may spread along the ground. Asphyxiation may occur in poorly ventilated or enclosed.

Children exposed to the same levels of ammonia vapor as adults may receive larger dose because they have greater lung surface area:body weight ratios and increased minute volumes:weight ratios. In addition, they may be exposed to higher levels than adults in the same location because of their short stature and the higher levels of ammonia vapor found nearer to the ground.

Skin/Eye Contact

The extent of injury produced by exposure to ammonia depends on the duration of the exposure and the concentration of the gas or liquid. Even low airborne concentrations (100 ppm) of ammonia may produce rapid eye and nose irritation. Higher concentrations may cause severe eye injury. Contact with concentrated ammonia solutions, such as some industrial cleaners (25%), may cause serious corrosive injury, including skin burns, permanent eye damage, or blindness. The full extent of damage to the eyes may not be clear until up to 1 week after the injury is sustained. Contact with liquefied ammonia can cause frostbite injury.

Children are more vulnerable to toxicants that affect the skin because of their relatively larger surface area:body weight ratio.

Ingestion

Ingestion of ammonium hydroxide, while uncommon, results in corrosive damage to the mouth, throat, and stomach. Ingestion of ammonia does not normally result in systemic poisoning.

Sources/Uses

Ammonia is manufactured by reacting hydrogen with nitrogen. About 80% of the ammonia produced is used in fertilizers. It is also used as a refrigerant gas, and in the manufacture of plastics, explosives, pesticides, and other chemicals, as a corrosion inhibitor, in the purification of water supplies, as a component of household cleaners, in the pulp and paper, metallurgy, rubber, food and beverage, textile and leather industries, and in the manufacture of pharmaceuticals. Ammonia is also produced naturally from decomposition of organic matter and under unusual conditions, can reach dangerous concentrations.

Standards and Guidelines

OSHA PEL (permissible exposure limit) = 50 ppm (8-hour TWA).

NIOSH IDLH (immediately dangerous to life or health) = 300 ppm.

AIHA ERPG-2 (the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms which could impair an individual's ability to take protective action) = 200 ppm.

Physical Properties

Description: Clear, colorless gas at room temperature; easily liquefied; readily dissolves in water to form caustic solutions.

Warning properties: Pungent odor at ~5 ppm; eye irritation at 20 ppm

Molecular weight: 17.0 daltons

Boiling point (760 mm Hg): -28 °F (-33.4°C)

Vapor pressure: >6,000 mm Hg at 68 °F (20 °C)

Gas density: 0.59 (air = 1)

Water solubility: 33.1% at 68 °F (20 °C)

Autoignition temperature: 1,204 °F (650 °C)

Flammable range: 16–25% (concentration in air) Combustible gas, but difficult to burn

Incompatibilities

Ammonia reacts with strong oxidizers, acids, halogens (including chlorine bleach), and salts of silver, zinc, copper, and other heavy metals. It is corrosive to copper and galvanized surfaces.

Health Effects

Ammonia is highly irritating to the eyes and respiratory tract. Swelling and narrowing of the throat and bronchi, coughing, and an accumulation of fluid in the lungs can occur.

Ammonia causes rapid onset of a burning sensation in the eyes, nose, and throat, accompanied by lacrimation, rhinorrhea, and coughing. Upper airway swelling and pulmonary edema may lead to airway obstruction.

Prolonged skin contact is prolonged (more than a few minutes) can cause pain and corrosive injury.

Acute Exposure

Anhydrous ammonia reacts with moisture in the mucous membranes to produce an alkaline solution (ammonium hydroxide). Exposure to ammonia gas or ammonium hydroxide can result in corrosive injury to the mucous membranes of the eyes, lungs, and gastrointestinal tract and to the skin due to the alkaline pH and the hygroscopic nature of ammonia.

Respiratory

The extent of injury produced by exposure to ammonia depends on the duration of the exposure, the concentration of the gas, and the depth of inhalation. Even fairly low airborne concentrations (50 ppm) of ammonia produce rapid onset of eye, nose, and throat irritation; coughing; and narrowing of the bronchi. More severe clinical signs include immediate narrowing of the throat and swelling, causing upper airway obstruction and accumulation of fluid in the lungs. This may result in low blood oxygen levels and an altered mental status. Mucosal burns to the tracheobronchial tree can also occur.

Children may be more vulnerable to corrosive agents than adults because of the smaller diameter of their airways. Children may also be more vulnerable because of failure to evacuate an area promptly when exposed.

Dermal

Dilute aqueous solutions (less than 5%) rarely cause serious burns but can be moderately irritating. Exposure to concentrated vapor or solution can cause pain, inflammation, blisters, necrosis and deep penetrating burns, especially on moist skin areas. Skin contact with compressed, liquid ammonia (which is stored at -28 °F) causes frostbite injury, and may also result in severe burns with deep ulcerations.

Ocular

Ammonia has a greater tendency to penetrate and damage the eyes than does any other alkali. Even low concentrations of ammonia vapor (100 ppm) produce rapid onset of eye irritation. Contact with high concentrations of the gas or with concentrated ammonium hydroxide may cause swelling and sloughing of the surface cells of the eye, which may result in temporary or permanent blindness.

Gastrointestinal

Nausea, vomiting, and abdominal pain are common symptoms following ingestion of ammonia. On rare occasions, deliberate ingestion of household ammonia (5–10%) has resulted in severe esophageal burns. Ingestion of more concentrated ammonia can cause severe corrosive injury to the mouth, throat, esophagus and stomach.

Potential Sequelae

Survivors of severe inhalation injury may suffer residual chronic lung disease. In cases of eye contact, ulceration and perforation of the cornea can occur after weeks or months, and blindness may ensue. Cataracts and glaucoma have been reported in persons acutely exposed. Ingestion of ammonia may cause permanent damage to the mucous membranes of the alimentary canal, with bleeding, perforation, scarring, or stricture formation as potential sequelae.

Chronic Exposure

Repeated exposure to ammonia may cause chronic irritation of the respiratory tract. Chronic cough, asthma and lung fibrosis have been reported. Chronic irritation of the eye membranes and dermatitis have also been reported.

Carcinogenicity

Ammonia has not been classified for carcinogenic effects.

Reproductive and Developmental Effects

No data exist to evaluate the reproductive and developmental effects of ammonia in humans. Ammonia is not included in *Reproductive and Developmental Toxicants*, a 1991 report published by the U.S. General Accounting Office (GAO) that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences. Decreased egg production and conception rates have been observed in animals, and ammonia has been shown to cross the ovine placental barrier.

Prehospital Management

Victims exposed only to ammonia gas do not pose substantial risks of secondary contamination to personnel outside the Hot Zone. Victims whose clothing or skin is contaminated with liquid ammonium hydroxide can secondarily contaminate response personnel by direct contact or through off-gassing ammonia vapor.

Ammonia causes rapid onset of a burning sensation in the eyes, nose, and throat, accompanied by lacrimation, rhinorrhea, and coughing. Upper airway swelling and pulmonary edema may lead to airway obstruction.

Ammonia gas or solution can cause serious corrosive burns on contact.

There is no antidote for ammonia poisoning. Treatment consists of supportive measures. These include administration of humidified oxygen and bronchodilators and airway management; treatment of skin and eyes with copious irrigation; and dilution of ingested ammonia with milk or water.

Hot Zone

Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if rescuers have not been trained in its use, assistance should be obtained from a local or regional HAZMAT team or other properly equipped response organization.

Rescuer Protection

Ammonia is a caustic and corrosive chemical that causes irritation and chemical burns upon contact of the gas or liquid with the eyes, skin, respiratory tract, or alimentary canal.

Respiratory Protection: Positive-pressure, self-contained breathing apparatus (SCBA) is recommended in response situations that involve exposure to potentially unsafe levels of ammonia.

Skin Protection: Chemical-protective clothing is recommended because ammonia can cause skin irritation and burns.

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible.

Victim Removal

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be removed on backboards or gurneys; if these are not available, carefully carry or drag victims to safety.

Consider appropriate management of chemically contaminated children, such as measures to reduce separation anxiety if a child is separated from a parent or other adult.

Decontamination Zone

Victims exposed only to ammonia gas who have no skin or eye irritation do not need decontamination. They may be transferred immediately to the Support Zone. All others require decontamination as described below.

Rescuer Protection

If exposure levels are determined to be safe (<20 ppm), decontamination may be conducted by personnel wearing a lower level of protection than that worn in the Hot Zone (described above).

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. Stabilize the cervical spine with a collar and a backboard if trauma is suspected. Administer supplemental oxygen as required. Assist ventilation with a bag-valve-mask device if necessary.

Basic Decontamination

Rapid skin and eye decontamination is critical. Victims who are able, may assist with their own decontamination. Remove contaminated clothing while flushing exposed areas. Double-bag contaminated clothing and personal belongings.

Flush liquid-exposed skin and hair with water for at least 5 minutes. If feasible, wash exposed skin extremely thoroughly with soap and water. Use caution to avoid hypothermia when decontaminating of children or the elderly. Use blankets when appropriate.

Irrigate exposed or irritated eyes with plain water or saline for at least 15 minutes. Remove contact lenses, if easily removable without additional trauma to the eye. Continue irrigation while transferring the victim to the Support Zone.

In cases of ingestion **do not induce emesis**, perform gastric lavage, or attempt neutralization. **Do not administer activated charcoal.** Victims who are conscious and able to swallow should be given 4 to 8 ounces of water or milk.

Consider appropriate management of chemically contaminated children at the exposure site. Also, provide reassurance to the child during decontamination, especially if separation from a parent occurs. If possible, seek assistance from a child separation expert.

Transport to Support Zone

As soon as basic decontamination is complete, move the victim to the Support Zone.

Support Zone

Be certain that victims have been decontaminated properly (see *Decontamination Zone* above). Victims who have undergone decontamination or have been exposed only to vapor pose no serious risks of secondary contamination. Support Zone personnel require no specialized protective gear in such cases.

ABC Reminders

Quickly access a patent airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Ensure adequate respiration and pulse; administer supplemental oxygen as required. Establish intravenous access if necessary. Place on a cardiac monitor.

Additional Decontamination

Continue irrigating exposed skin and eyes, as appropriate. In cases of ingestion, **do not induce emesis, do not administer activated charcoal, and do not attempt to neutralize with weak acids**. If the patient is conscious and able to swallow, administer 4 to 8 ounces of water or milk if it has not been given previously.

Advanced Treatment

In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, perform cricothyroidotomy if equipped and trained to do so. Patients who are hypotensive or have seizures should be treated according to advanced life support (ALS) protocols.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Also consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Ammonia poisoning is not known to pose additional risk during the use of bronchial or cardiac sensitizing agents.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in water, repeat every 20 minutes as needed cautioning for myocardial variability.

Patients who are comatose, hypotensive, or are having seizures or have cardiac arrhythmias should be treated according to ALS protocols.

Monitor fluid and electrolyte balance and restore if abnormal. Fluids should be administered cautiously to patients with pulmonary edema.

Transport to Medical Facility

Only decontaminated patients or patients not requiring decontamination should be transported to a medical facility. "Body bags" are not recommended.

Report to the base station and the receiving medical facility the condition of the patient, treatment given, and estimated time of arrival at the medical facility.

If ammonia has been ingested, prepare the ambulance in case the victim vomits toxic material. Have ready several towels and open plastic bags to quickly clean up and isolate vomitus.

Multi-Casualty Triage

Consult with the base station physician or the regional poison control center for advice regarding triage of multiple victims.

The following exposed persons should be evaluated at a medical facility: those who have ingested ammonia, those who have persistent upper respiratory irritation or other acute symptoms of severe inhalation exposure, and those who have eye or skin burns that cover a large surface area.

Persons who have been exposed only to ammonia gas and are currently asymptomatic are not likely to develop complications. After their names, addresses, and telephone numbers are recorded, these patients may be released from the scene with follow-up instructions to seek medical care promptly if symptoms develop (see *Patient Information Sheet* below).

Emergency Department Management

Hospital personnel in an enclosed area can be secondarily contaminated by vapor off-gassing from heavily soaked clothing or from the vomitus of victims who have ingested ammonia. Patients do not pose a contamination risk after contaminated clothing is removed and the skin and hair are washed.

Inhaling ammonia causes rapid onset of a burning sensation in the eyes, nose, and throat, accompanied by lacrimation, rhinorrhea, and coughing. Upper airway swelling may lead to airway obstruction.

Ammonia gas or solution can cause serious corrosive burns on contact.

There is no antidote for ammonia poisoning. Treatment consists of support of respiratory and cardiovascular functions.

Decontamination Area

Previously decontaminated patients and patients exposed only to ammonia gas who have no skin or eye irritation may be transferred immediately to the Critical Care Area. Other patients will require rapid decontamination as described in Basic Decontamination below.

Be aware that use of protective equipment by the provider may cause fear in children, resulting in decreased compliance with further management efforts.

Because of their larger surface area:weight ratio, children are more vulnerable to toxicants absorbed through the skin. Also, emergency room personnel should examine children's mouths because of the frequency of hand-to-mouth activity among children.

ABC Reminders

Evaluate and support airway, breathing, and circulation. Watch for signs of laryngeal edema and airway compromise. Children may be more vulnerable to corrosive agents than adults because of the smaller diameter of their airways. In cases of respiratory compromise, secure airway and respiration via endotracheal intubation. If not possible, surgically secure an airway.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Also consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use

of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Ammonia poisoning is not known to pose additional risk during the use of bronchial or cardiac sensitizing agents.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in water, repeat every 20 minutes as needed cautioning for myocardial variability.

Patients who are comatose, hypotensive or have seizures should be treated in the conventional manner. Manage hypotension and shock with intravenous fluids (use caution when pulmonary edema is present); pressor agents may be required.

Basic Decontamination

Patients who are able, may assist with their own decontamination. Remove and double bag contaminated clothing and personal belongings.

Because ammonia in solution can cause burns, ED staff should don chemical-resistant jumpsuits (e.g., of Tyvek or Saranex) or butyl rubber aprons, rubber gloves, and eye protection if the patient's clothing or skin is wet. After the patient has been decontaminated, no special protective clothing or equipment is required for ED personnel.

Flush liquid-exposed skin and hair with water for at least 5 minutes. If feasible, wash exposed skin extremely thoroughly with soap and water.

Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Irrigate exposed or irritated eyes with plain water or saline for at least 15 minutes. Remove contact lenses, if easily removable without additional trauma to the eye. Continue irrigation while transferring the victim to the Critical Care Area. An ophthalmic anesthetic, such as 0.5% tetracaine, may be necessary to alleviate blepharospasm, and lid retractors may be required to allow adequate irrigation under the eyelid.

In cases of ingestion, **do not induce emesis; do not administer activated charcoal**. If the patient is conscious and able to swallow, administer 4 to 8 ounces of water or milk if it has not been given previously (see *Critical Care Area* below for more information on ingestion exposure).

Critical Care Area

Be certain that appropriate decontamination has been carried out. (See *Decontamination Area* above.)

ABC Reminders

Evaluate and support airway, breathing, and circulation as in ABC Reminders above. Children may be more vulnerable to corrosive agents than adults because of the smaller diameter of their airways. Establish intravenous access in seriously ill patients if this has not been done previously. Continuously monitor cardiac rhythm.

Patients who are comatose, hypotensive, having seizures or have cardiac arrhythmias should be treated in the conventional manner.

Inhalation Exposure

Administer supplemental oxygen by mask to patients who have respiratory symptoms. Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Also consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Ammonia poisoning is not known to pose additional risk during the use of bronchial or cardiac sensitizing agents.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in water, repeat every 20 minutes as needed cautioning for myocardial variability.

Observe patients carefully for 6 to 12 hours for signs of upper-airway obstruction. Patients who have had a severe exposure may develop noncardiogenic pulmonary edema.

Skin Exposure

If ammonia gas or solution was in contact with the skin, chemical burns may result; treat as thermal burns.

Eye Exposure

Continue irrigation for at least 15 minutes or until the pH of the conjunctival fluid has returned to normal. Test visual acuity. Examine the eyes for corneal damage and treat appropriately. Immediately consult an ophthalmologist for patients who have severe corneal injuries.

Ingestion Exposure

Do not induce emesis because this may re-expose the esophagus and mouth to the caustic substance. Do not administer activated charcoal. Do not perform gastric lavage or attempt neutralization after ingestion. If not given during decontamination, give 4 to 8 ounces of water by mouth to dilute stomach contents.

Consider endoscopy to evaluate the extent of gastrointestinal-tract injury. Extreme throat swelling may require endotracheal intubation or cricothyroidotomy.

Antidotes and Other Treatments

There is no specific antidote for ammonia poisoning. Although administration of corticosteroids to limit esophageal scarring is recommended by some toxicologists, this treatment is unproven and may be harmful in patients who have perforation or serious infection. Hemodialysis is not effective.

Laboratory Tests

Routine laboratory studies for all exposed patients include CBC, glucose, and electrolyte determinations. Chest radiography and pulse oximetry (or arterial blood gases measurements) are recommended for severe inhalation exposure or if pulmonary aspiration is suspected. No specific biologic test for ammonia exposure exists.

Disposition and Follow-up

Consider hospitalizing patients who have evidence of respiratory distress or significant skin burns or who have ingested an ammonia solution.

Delayed Effects

Pulmonary injury may continue to evolve over 18 to 24 hours. Residual bronchoconstriction, bronchiectasis and small airway disease may occur, and chronic obstructive pulmonary disease can develop. Patients exposed by inhalation who are initially symptomatic should be observed carefully and reexamined periodically. Pulmonary function tests should be repeated on an annual basis. Patients who develop pulmonary edema should be admitted to an intensive care unit.

Acute ocular exposure to ammonia may result in persistent intraocular pressure, cataract formation, and glaucoma with significant reduction in visual acuity.

Patient Release

Patients who are asymptomatic following exposure or who experienced mild symptoms that have been treated may be released and advised to seek medical care promptly if symptoms recur or develop (see *Ammonia—Patient Information Sheet* below). Cigarette smoking may exacerbate pulmonary injury and should be discouraged for 72 hours after exposure.

Follow-up

Obtain the name of the patient's primary care physician so that the hospital can send a copy of the ED visit to the patient's doctor.

Patients with mild to moderate skin burns should be reexamined within 24 hours.

Patients who have eye injuries should be reexamined by an ophthalmologist in 24 hours.

Reporting

If a work-related incident has occurred, you may be legally required to file a report; note incident details and contact your state or local health department.

Other persons may still be at risk in the setting where this incident occurred. If the incident occurred in the workplace, discussing it with company personnel may prevent future incidents. If a public health risk exists, notify your state or local health department or other responsible public agency. When appropriate, inform patients that they may request an evaluation of their workplace from OSHA or NIOSH. See Appendices III and IV for a list of agencies that may be of assistance.

Ammonia
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to ammonia gas or ammonium hydroxide solution.

What is ammonia?
Ammonia is a colorless, highly irritating gas with a sharp, suffocating odor. It easily dissolves in water to form a caustic solution called ammonium hydroxide. It is not highly flammable, but containers of ammonia may explode when exposed to high heat. About 80% of the ammonia produced is used in fertilizers. It is also used as a refrigerant and in the manufacture of plastics, explosives, pesticides, and other chemicals. It is found in many household and industrial-strength cleaning solutions.

What immediate health effects can result from ammonia exposure?
Most people are exposed to ammonia from breathing the gas. They will notice the pungent odor and experience burning of the eyes, nose, and throat after breathing even small amounts. With higher doses, coughing or choking may occur. Exposure to high levels of ammonia can cause death from a swollen throat or from chemical burns to the lungs. Skin contact with ammonia-containing liquids may cause burns. Eye exposure to concentrated gas or liquid can cause serious corneal burns or blindness. Drinking a concentrated ammonia solution can cause burns to the mouth, throat, and stomach. Generally, the severity of symptoms depends on the degree of exposure.

Can ammonia poisoning be treated?
There is no antidote for ammonia poisoning, but ammonia's effects can be treated, and most people recover. Persons who have experienced serious signs and symptoms (such as severe or persistent coughing or burns in the throat) may need to be hospitalized.

Are any future health effects likely to occur?
A single small exposure from which a person recovers quickly is not likely to cause delayed or long-term effects. After a severe exposure, injury to the eyes, lungs, skin, or digestive system may continue to develop for 18 to 24 hours, and serious delayed effects, such as gastric perforation, chronic pulmonary obstructive disease, or glaucoma, are possible.

What tests can be done if a person has been exposed to ammonia?
Specific tests for the presence of ammonia in blood or urine generally are not useful to the doctor. If a severe exposure has occurred, blood and urine analyses, chest x-rays, and other tests may show whether the lungs have been injured. Testing is not needed in every case. If ammonia contacts the eyes, the doctor may put a special dye in the eyes and examine them with a magnifying lamp.

Where can more information about ammonia be found?
More information about ammonia can be obtained from your regional poison control center; your state, county, or local health department; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in occupational or environmental health. If the exposure happened at work, you may wish to discuss it with your employer, the Occupational Safety and Health Administration (OSHA), or the National Institute for Occupational Safety and Health (NIOSH). Ask the person who gave you this form for help in locating these telephone numbers.

Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow *only* the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:
- coughing
- difficulty breathing or shortness of breath
- wheezing or high-pitched voice
- chest pain or tightness
- increased pain or a discharge from exposed eyes
- increased redness or pain or a pus-like discharge in the area of a skin burn
- stomach pain or vomiting

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.
[ ] Call for an appointment with Dr. _____ in the practice of _____. When you call for your appointment, please say that you were treated in the Emergency Department at _ _____ Hospital by _____ and were advised to be seen again in _____ days.
[ ] Return to the Emergency Department/ _____ Clinic on (date) _____ at _____ AM/PM for a follow-up examination.
[ ] Do not perform vigorous physical activities for 1 to 2 days.
[ ] You may resume everyday activities including driving and operating machinery.
[ ] Do not return to work for _____ days.
[ ] You may return to work on a limited basis. See instructions below.
[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.
[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.
[ ] Avoid taking the following medications: _____
[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: _____
_____
_____
[ ] Other instructions: _____
_____
_____

- Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.
- You or your physician can get more information on the chemical by contacting: _____ _____ or _____, or by checking out the following Internet Web sites: _____; _____.

Signature of patient _____ Date _____

Signature of physician _____ Date _____

Aniline ($C_6H_5NH_2$)
CAS 62-53-3; UN 1547

Synonyms include aminobenzene, aminophen, arylamine, benzenamine, aniline oil, and phenylamine.

- **Persons exposed only to aniline vapor do not pose risks of secondary contamination to others. Persons whose clothing or skin is contaminated with liquid aniline can cause secondary contamination by direct contact or through off-gassing vapor.**
- **Aniline vapor is heavier than air and may accumulate in low-lying areas. The vapor is combustible. Aniline has a characteristic aromatic or fishy odor which provides adequate warning of acute exposure.**
- **Aniline is rapidly absorbed after inhalation and ingestion. Aniline liquid and vapor are also absorbed well through skin, and this can contribute to systemic toxicity.**

Description

At room temperature, aniline, the simplest aromatic amine, is a clear to slightly yellow, oily liquid that darkens to a brown color on exposure to air. It has a low vapor pressure at room temperature. Aniline is slightly soluble in water and is miscible with most organic solvents.

Routes of Exposure

Inhalation

Inhaled aniline is rapidly and almost completely absorbed from the lungs, leading to systemic toxicity. Its aromatic or fishy odor can generally be perceived at 1 ppm which is below established occupational safety limits (OSHA PEL-TWA is 5 ppm), and thus, odor usually provides an adequate indication of hazardous concentrations. Aniline vapor is heavier than air and may cause asphyxiation in enclosed, poorly ventilated, or low-lying areas.

Children exposed to the same levels of aniline vapor as adults may receive larger dose because they have greater lung surface area:body weight ratios and increased minute volumes:weight ratios. In addition, they may be exposed to higher levels than adults in the same location because of their short stature and the higher levels of aniline vapor found nearer to the ground.

Skin/Eye Contact

Contact with liquid aniline may cause mild irritation to skin or eyes. Aniline is absorbed well through the skin, and this can contribute to systemic toxicity. The effects of skin absorption can be delayed for several hours.

Children are more vulnerable to toxicants absorbed through the skin because of their relatively larger surface area:body weight ratio.

Ingestion

Aniline is rapidly absorbed from the gastrointestinal tract. Ingestion can lead rapidly to severe systemic toxicity, nausea and vomiting usually occur.

Sources/Uses

Aniline is synthesized by catalytic hydrogenation of nitrobenzene or by ammonolysis of phenol. In industry, aniline is an initiator or intermediary in the synthesis of a wide variety of products, most notably polyurethane foam, agricultural chemicals, analgesics, synthetic dyes, antioxidants, stabilizers for the rubber industry, and hydroquinone for photographic developing. Aniline has been used as an octane booster in gasoline.

Standards and Guidelines

OSHA PEL (permissible exposure limit) = 5 ppm (skin) (averaged over an 8-hour workshift)

NIOSH IDLH (immediately dangerous to life or health) = 100 ppm

Physical Properties

Description: Slightly yellow-to-brown, clear oily liquid

Warning properties: Aromatic or fishy odor at about 1 ppm; adequate warning for acute exposure

Molecular weight: 93.1 daltons

Boiling point (760 mm Hg): 363 °F (184.4 °C)

Freezing point: 21 °F (-6.2 °C)

Specific gravity: 1.02 (water = 1)

Vapor pressure: 0.6 mm Hg at 68 °F (20 °C)

Gas density: 3.2 (air = 1)

Water solubility: Water soluble (4% at 68 °F) (20 °C)

Flammability: Flammable at temperatures >158 °F (70 °C)

Flammable range: 1.3% to 25% (concentration in air)

Incompatibilities

Aniline reacts with strong oxidizers, strong acids, alkalis and toluene diisocyanate. It reacts violently with benzenediazonium-2-carboxylate, boron trichloride, dibenzoyl peroxide 90% performic acid, N-bromosuccinimide, trichloronitromethane, and

perchromate, and it spontaneously ignites in the presence of red fuming nitric acid.

Health Effects

- **Aniline is irritating to the skin, eyes, and respiratory tract. Effects can result from all routes of exposure. Aniline induces methemoglobinemia, which impairs the delivery of oxygen to tissues.**
- **Aniline may also cause the destruction of red blood cells, which manifests as acute or delayed hemolytic anemia. Heart, liver, and kidney effects may be secondary to hemolysis.**
- **Insufficient delivery of oxygen and destruction of red blood cells may cause cardiopulmonary complaints with the development of ischemia, arrhythmia and shock.**

Acute Exposure

Many of the adverse health effects of aniline are due in part to the formation of methemoglobinemia. Aniline converts the Fe^{+2} in hemoglobin to Fe^{+3} which impairs its oxygen transport capacity. The mechanism by which aniline produces methemoglobin in the blood appears to be related to an active metabolite. Methemoglobin formation from aniline exposure may develop insidiously, and onset of symptoms may be delayed for hours. Production of methemoglobin may continue for up to 20 hours after exposure. Exposure to 7–53 ppm aniline vapor causes slight symptoms after several hours, and concentrations greater than 100–160 ppm cause serious disturbances. As little as 1 g of ingested aniline can be fatal to humans, the mean lethal dose is 5–30 g (HSDB 2000).

Children do not always respond to chemicals in the same way that adults do. Different protocols for managing their care may be needed. The very young and the very old can be more adversely affected by aniline in an acute exposure.

Hematologic

Aniline causes metheglobinemia and hemolysis; these changes can be detected by blood tests or by the color and appearance of the blood. Methemoglobinemia is a concern in infants up to 1 year old. Children may be more vulnerable to loss of effectiveness of hemoglobin because of their relative anemia, higher metabolic rate and greater sensitivity to hypoxia compared to adults. The elderly are more vulnerable due to limited cardiovascular reserves. Signs and symptoms expected at various percentages of methemoglobin formation are outlined below. Patients who have underlying diseases may develop signs and symptoms at even lower methemoglobin percentages.

Methemoglobin Level:	Signs and Symptoms:
30–50%	Headache, fatigue, dizziness, rapid heart rate, mild shortness of breath
50–70%	Stupor, slow heart rate, respiratory depression, irregular heart rhythm, acid-base imbalance
60–70%	Cardiac arrest, loss of consciousness, coma, death

When methemoglobin levels are 15% to 30%, the patient's skin may become bluish in color, which is due to the dark color of methemoglobin and not to inadequate oxygen in the blood. The blood itself has a chocolate-brown appearance. Methemoglobin levels exceeding 70% are potentially lethal if untreated.

Acute or delayed (2 to 7 days) hemolytic anemia (caused by destruction of red blood cells) also results from aniline exposure. Aniline induces the formation of Heinz bodies. Persons with glucose-6-phosphate dehydrogenase (G6PD) deficiency or alcoholism are at increased risk of aniline-induced hemolysis.

Cardiovascular Cardiac effects of acute aniline exposure, such as irregular heart rhythm, heart block, and acute congestive heart failure, may be caused by decreased oxygen delivery to the tissues. Death can result from progressive acidosis, ischemia and cardiovascular collapse.

CNS Acute aniline exposure can cause confusion, ringing in the ears, weakness, disorientation, dizziness, impaired gait, lethargy drowsiness, convulsions, loss of consciousness, and coma. These effects are usually transitory and probably secondary to lack of oxygen.

Renal Acute aniline exposure can cause painful urination; blood, hemoglobin or methemoglobin in the urine; decreased urinary output; and acute kidney failure. Bladder-wall irritation, kidney ulceration, and tissue death can also occur.

Dermal Moderate skin irritation and sensitization and dermatitis have been reported. Systemic effects can result from skin contact with aniline vapor or liquid. Patients who have methemoglobinemia can appear gray, bronze, or blue.

Because of their larger surface area:body weight ratio, children are more vulnerable to toxicants absorbed through the skin.

Ocular

Aniline can cause mild to severe eye irritation, corneal damage, and discoloration.

Hepatic

Liver damage and jaundice may occur.

Gastrointestinal

Nausea and vomiting can occur.

Respiratory

Inhalation of aniline can cause respiratory tract irritation with cough, or difficulty in breathing. Methemoglobin causes absorption interference with pulse oximetry reading, rendering falsely high values as with the calculated value from the arterial blood gas (ABG) analyzer. Accurate oxygen saturation determinations require co-oximeter measurements.

Children may be more vulnerable because of increased minute ventilation per kg and failure to evacuate an area promptly when exposed.

Potential Sequelae

Persons exposed to aniline may have chronic effects due to the persistence of acutely produced damage to the brain, heart, and kidneys.

Chronic Exposure

Chronic exposure to aniline may cause anemia, headaches, tremor, parathesis, pain, narcosis or coma, and cardiac arrhythmia. Heart, kidney, and liver damage may also occur, possibly as secondary effects of hemolysis.

Chronic exposure may be more serious for children because of their potential longer latency period.

Carcinogenicity

The International Agency for Research on Cancer (IARC) has determined that aniline is not classifiable as to its carcinogenicity to humans. Bladder cancers reported in aniline-exposed workers, but have been attributed to concurrent exposure to chemicals other than aniline.

Reproductive and Developmental Effects

Aniline is not listed in the TERIS or Reprotext databases. One gavage study in pregnant rats is noted in Shepard's Catalog of Teratogenic Agents, and this study resulted in no teratogenic effects. Aniline is not included in *Reproductive and Developmental Toxicants*, a 1991 report published by the U.S. General Accounting Office (GAO) that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences. A high incidence of gynecological disorders and excess frequency of spontaneous abortions have been reported in chemically exposed women.

Aniline can cross the placental barrier. Aniline induces the production of methemoglobin in both adults and children. The fetal liver can also N-oxygenate aniline to form phenylhydroxylamine which has a high potency for methemoglobin production. Because fetal hemoglobin is more easily oxidized to methemoglobin than is adult hemoglobin and is less easily reduced back to normal hemoglobin, methemoglobin is likely to be at higher levels in fetuses than in exposed mothers. No data were located to assess potential transfer of aniline to nursing infants via breast milk.

Prehospital Management

- **Persons exposed only to aniline vapor do not pose secondary contamination risks to rescuers. Those whose clothing or skin is contaminated with liquid aniline can secondarily contaminate response personnel by direct contact or through off-gassing vapor.**
- **Aniline is irritating to the eyes and skin. Systemic effects occur from all routes of exposure and can include methemoglobinemia and hemolysis. CNS depression and cardiovascular collapse may also result, primarily secondary to hypoxia.**
- **Immediate treatment for aniline overexposure consists of decontamination and cardiopulmonary support. Symptomatic individuals should be administered supplemental oxygen and the methemoglobin antidote, methylene blue, as soon as possible.**

Hot Zone

Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if rescuers have not been trained in its use, assistance should be obtained from a local or regional HAZMAT team or other properly equipped response organization.

Rescuer Protection

Aniline is a highly toxic systemic poison that is absorbed well by inhalation and through the skin.

Respiratory Protection: Positive-pressure, self-contained breathing apparatus (SCBA) is recommended in response situations that involve exposure to potentially unsafe levels of aniline vapor.

Skin Protection: Chemical-protective clothing is recommended because aniline vapor and liquid can be dermally absorbed and may contribute to systemic toxicity. Direct contact with liquid aniline can cause skin burns.

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible.

Victim Removal

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be removed on backboards or gurneys; if these are not available, carefully carry or drag victims to safety. Victims should not be allowed to overexert themselves, as exposure to aniline can

produce hypoxia (due to methemoglobinemia) which can be exacerbated by physical effort.

Consider appropriate management of chemically-contaminated children, such as measures to reduce separation anxiety if a child is separated from a parent or other adult.

Decontamination Zone

Patients exposed only to aniline vapor who have no skin or eye irritation may be transferred immediately to the support zone. Other patients will require decontamination as described below.

Rescuer Protection

If exposure levels are determined to be safe, decontamination may be conducted by personnel wearing a lower level of protection than that worn in the Hot Zone (described above).

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. Stabilize the cervical spine with a collar and a backboard if trauma is suspected. Administer supplemental oxygen. Assist ventilation with a bag-valve-mask device if necessary.

Basic Decontamination

Victims who are able may assist with their own decontamination, but minimize patient exertion since this could exacerbate symptoms of hypoxemia. Because aniline is absorbed through the skin, it is important to remove wet clothing quickly. Remove and double-bag contaminated clothing and personal belongings.

Flush exposed skin and hair with plain water for 2 to 3 minutes, then wash thoroughly with mild soap. Rinse thoroughly with water. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Irrigate exposed or irritated eyes with tepid water for 15 minutes. Remove contact lenses if easily removable without additional trauma to the eye. If pain or injury is evident, continue irrigation while transferring the victim to the support zone.

In cases of ingestion, **do not induce emesis**. If the victim is alert and asymptomatic, administer a slurry of activated charcoal at 1 gm/kg, usual adult dose 60–90 g, child dose 25–50 g. A soda can and straw may be of assistance when offering charcoal to a child.

Consider appropriate management of chemically contaminated children at the exposure site. Provide reassurance to the child

during decontamination, especially if separation from a parent occurs.

Transfer to Support Zone

As soon as basic decontamination is complete, move the victim to the Support Zone.

Support Zone

Be certain that victims have been decontaminated properly (see Decontamination Zone above). Victims who have undergone decontamination or who have been exposed only to vapor pose no serious risks of secondary contamination to rescuers. Support Zone personnel require no specialized protective gear in such cases.

ABC Reminders

Quickly access for a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard. Ensure adequate respiration and pulse; administer supplemental oxygen. Establish intravenous access if necessary. At low levels of methemoglobin, skin color is not a reliable sign for judging hypoxemia or poor perfusion because the apparent cyanosis is not caused by true hypoxemia but by methemoglobin pigmentation. Place on a cardiac monitor.

Additional Decontamination

Continue irrigating exposed skin and eyes, as appropriate.

In cases of ingestion, **do not induce emesis**. If the victim is alert and asymptomatic, administer a slurry of activated charcoal if it has not been given previously (at 1 gm/kg, usual adult dose 60–90 g, child dose 25–50 g). A soda can and straw may be of assistance when offering charcoal to a child.

Advanced Treatment

In cases of respiratory compromise secure airway and respiration by endotracheal intubation. If not possible, perform cricothyroidotomy if equipped and trained to do so.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Also consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Aniline poisoning is not known to pose additional risk during the use of bronchial or cardiac sensitizing agents.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine

solution in water, repeat every 20 minutes as needed cautioning for myocardial variability.

Patients who are comatose, hypotensive, or have seizures or cardiac dysrhythmias should be treated according to advanced life support (ALS) protocols.

Antidotes

Administer methylene blue antidote to patients who have cardiopulmonary symptoms. The standard intravenous dose is 1 to 2 mg of methylene blue per kg of body weight (0.1 to 0.2 mL/kg of a 1% solution) over 5 to 10 minutes, repeated in one hour if needed. Clinical response is usually observed within 30 to 60 minutes. The total dose over a 24 hour period should not exceed 7 mg/kg, methylene blue itself can cause hemolysis at greater doses.

Consider hyperbaric oxygen therapy in patients who are refractory to methylene blue therapy.

Transport to Medical Facility

Only decontaminated patients or patients not requiring decontamination should be transported to a medical facility. “Body bags” are not recommended.

Report to the base station and the receiving medical facility the condition of the patient, treatment given, and estimated time of arrival at the medical facility.

If aniline has been ingested, prepare the ambulance in case the patient vomits toxic material. Have ready several towels and open plastic bags to quickly clean up and isolate toxic material.

Multi-Casualty Triage

Consult with the base station physician or the regional poison control center for advice regarding triage of multiple victims.

Patients with evidence of significant exposure (e.g., cyanosis, dizziness, headache or severe skin irritation) should be transported to a medical facility for evaluation. Others may be discharged from the scene after their names, addresses, and telephone numbers are recorded. They should be advised to seek medical care promptly if symptoms develop (see *Patient Information Sheet* below).

Emergency Department Management

- **Hospital personnel in an enclosed area can be secondarily exposed by vapor off-gassing from heavily contaminated clothing or from the vomitus of victims who have ingested aniline. Patients exposed only to aniline vapor or who have been decontaminated do not pose secondary contamination risks to hospital personnel.**
- **Aniline exposure can cause methemoglobinemia and hemolysis. CNS depression and cardiovascular collapse may result, primarily secondary to hypoxia.**
- **Immediate treatment for aniline overexposure consists of cardiopulmonary support and administration of the methemoglobinemia antidote, methylene blue.**

Decontamination Area

Patients who have been decontaminated should be taken immediately to the Critical Care area. Patients who have ingested aniline or have skin contact with liquid aniline require decontamination as described below.

Be aware that use of protective equipment by the provider may cause fear in children, resulting in decreased compliance with further management efforts.

Because of their larger surface area:body weight ratio, children are more vulnerable to toxicants absorbed through the skin. Also, emergency room personnel should examine children's mouths because of the frequency of hand-to-mouth activity among children.

ABC Reminders

Evaluate and support airway, breathing, and circulation. Children may be more vulnerable to corrosive agents than adults because of the smaller diameter of their airways. Secure the airway and respiration via endotracheal intubation in cases of respiratory compromise. If the patient's condition precludes intubation, surgically create an airway.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Also consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Aniline poisoning is not known to pose additional risk during the use of bronchial or cardiac sensitizing agents.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in water, repeat every 20 minutes as needed cautioning for myocardial variability.

Patients who are comatose, hypotensive, or have seizures or ventricular arrhythmias should be treated in the conventional manner.

Basic Decontamination

Patients who are able may assist with their own decontamination. Because aniline is absorbed through the skin, hospital personnel should don 2 layers of latex gloves when decontaminating patients. If the patient's clothing is wet with aniline, quickly remove the contaminated clothing while flushing exposed skin and hair with plain water for 2 to 3 minutes (preferably under a shower). Then wash twice with mild soap. Rinse thoroughly with water. Double-bag the contaminated clothing and all personal belongings.

Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Irrigate exposed eyes with tepid water for at least 15 minutes. Remove contact lenses if easily removable without additional trauma. If pain or injury is evident, continue irrigation while transferring the patient to the Critical Care Area.

In cases of ingestion, **do not induce emesis**. If the victim is alert and asymptomatic, administer a slurry of activated charcoal if it has not been given previously (at 1 gm/kg, usual adult dose 60–90 g, child dose 25–50 g). A soda can and straw may be of assistance when offering charcoal to a child.

Critical Care Area

Be certain that appropriate decontamination has been carried out (see *Decontamination Area* above).

ABC Reminders

Evaluate and support airway, breathing, and circulation as in ABC Reminders above. Children may be more vulnerable to corrosive agents than adults because of the smaller diameter of their airways. Establish intravenous access in ill patients if this has not been done previously. Continuously monitor cardiac rhythm. Place symptomatic patients on oxygen.

Patients who are comatose, hypotensive, or have seizures or cardiac arrhythmias should be treated in the conventional manner.

Inhalation Exposure

Administer supplemental oxygen and treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Also consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Aniline poisoning is not known to pose additional risk during the use of bronchial or cardiac sensitizing agents.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in water, repeat every 20 minutes as needed cautioning for myocardial variability.

Skin Exposure

Treat dermal irritation or burns with standard topical therapy. Patients developing hypersensitivity reactions may require treatment with systemic or topical corticosteroids or antihistamines.

Eye Exposure

Ensure that adequate eye irrigation has been completed. If eye irritation or injury is evident, test visual acuity. Examine the eyes for corneal damage and treat appropriately. Immediately consult an ophthalmologist for patients who have severe corneal injuries.

Ingestion Exposure

Do not induce emesis.

Gastric lavage is useful in certain circumstances to remove caustic material and prepare for endoscopic examination. Consider gastric lavage with a small nasogastric tube if: (1) a large dose has been ingested; (2) the patient has oral lesions or persistant esophageal discomfort; and (3) the lavage can be performed within 1 hour of ingestion. Care must be taken when placing the gastric tube because blind gastric-tube placement may further injure the chemically damaged esophagus or stomach.

If the patient is alert and charcoal has not been given previously, administer a slurry of activated charcoal (at 1 gm/kg, usual adult dose 60–90 g, child dose 25–50 g). A soda can and straw may be of assistance when offering charcoal to a child.

Consider endoscopy to evaluate the extent of gastrointestinal tract injury. Extreme throat swelling may require endotracheal intubation or cricothyriodotomy.

Because children do not ingest large amounts or corrosive materials, and because of the risk of perforation from NG intubation, lavage is discouraged in children unless intubation is performed under endoscopic guidance.

Toxic vomitus or gastric washings should be isolated (e.g., by attaching the lavage tube to isolated wall suction or another closed container).

Antidotes and Other Treatments

Methylene blue (tetramethylthionine chloride) should be considered for patients who have signs and symptoms of hypoxia (other than cyanosis) or for patients who have methemoglobin levels >30%. Cyanosis alone does not require treatment. Methylene blue may not be effective in patients who have G6PD deficiency and may cause hemolysis.

The standard dose of methylene blue is 1 to 2 mg/kg body weight (0.1 to 0.2 mL/kg of a 1% solution) intravenously over 5 to 10 minutes, repeated in one hour if needed. The total 24 hour dose should not exceed 7 mg/kg. (Doses greater than 15 mg/kg may cause hemolysis.) Clinical response to methylene blue treatment is usually observed within 30 to 60 minutes. Side effects include nausea, vomiting, abdominal and chest pain, dizziness, diaphoresis, and dysuria.

Consider hyperbaric oxygen therapy in patients who are refractory to methylene blue therapy.

Consider exchange transfusions for severely poisoned patients who are deteriorating clinically in spite of methylene blue treatment. Intravenous ascorbic acid administered to severely poisoned patients has not proved to be effective.

Laboratory Tests

Routine laboratory studies for all exposed patients include CBC, glucose, and electrolyte determinations. Additional studies for patients exposed to aniline include peripheral blood smear, renal-function tests, and determination of methemoglobin and unconjugated bilirubin levels. ABG measurements, chest radiography, and ECG should be performed if cyanosis or dyspnea are present. Methemoglobin causes absorption interference with pulse oximetry reading, rendering falsely high values as with the calculated value from the arterial blood gas

(ABG) analyzer. Accurate oxygen saturation determinations require co-oximeter measurements.

Methemoglobinemia can be detected at the bedside by the characteristic chocolate-brown color that it imparts to blood. Methemoglobin levels greater than 10% can usually be detected by comparing a drop of the patient's blood with a drop of normal blood on white filter paper or gauze.

Measurement of methemoglobin should be repeated at frequent intervals for 24 hours to ensure that the level is decreasing.

Disposition and Follow-up

Patients should be observed for at least 6 hours for the delayed development of methemoglobinemia. Consider hospitalization for symptomatic patients who have elevated methemoglobin levels.

Delayed Effects

Hemolysis may begin 24 or more hours after exposure. Observe hospitalized patients for signs of acute renal failure and arrhythmias.

Patient Release

Patients who have remained asymptomatic for 6 to 12 hours after exposure may be discharged and advised to seek medical care promptly if symptoms develop (see the *Aniline—Patient Information Sheet* below).

Follow-up

Obtain the name of the patient's primary care physician so that the hospital can send a copy of the ED visit to the patient's doctor.

Monitor patients who have received significant exposure (as determined by symptoms and methemoglobin levels) for effects of hypoxia and hemolysis. A Heinz-body hemolytic crisis may follow the development of methemoglobinemia by 2 to 7 days. Heart, liver, and kidney effects may be secondary to hemolysis.

Patients who have corneal injuries should be reexamined within 24 hours.

Reporting

If a work-related incident has occurred, you may be legally required to file a report; contact your state or local health department.

Other persons may still be at risk in the setting where this incident occurred. If the incident occurred in the workplace, discussing it with company personnel may prevent future incidents. If a public health risk exists, notify your state or local

health department or other responsible public agency. When appropriate, inform patients that they may request an evaluation of their workplace from OSHA or NIOSH. See Appendices III and IV for a list of agencies that may be of assistance.

Aniline
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to aniline.

What is aniline?
Aniline is a manufactured chemical used to make a variety of products including polyurethane foam, photographic developers, rubber, dyes, and pesticides. At room temperature, it is a clear to slightly yellow, oily liquid that may turn brown if left in contact with air. It has a weak fishy odor.

What immediate health effects can be caused by exposure to aniline?
Aniline can cause effects when it is breathed or swallowed. It can also pass rapidly through the skin. Aniline causes changes in hemoglobin, which carries oxygen in the blood; hence, the blood turns brown and tissues are unable to get enough oxygen (a condition known as methemoglobinemia). Headaches, weakness, drowsiness, and shortness of breath can occur. The skin, lips, and nailbeds can turn blue or slate gray. Aniline can cause the membrane of the red blood cells to burst (hemolysis), which also will prevent oxygen from reaching tissues. Generally, the more serious the exposure, the more severe the symptoms.

Can aniline poisoning be treated?
A solution of methylene blue may be given through a vein to patients who have been seriously exposed to aniline. Most patients recover within 24 hours, but they may need to be hospitalized for several days. The urine of a patient who has received methylene blue treatment may temporarily become blue to blue-green.

Are any future health effects likely to occur?
A single small exposure from which a person recovers quickly is not likely to cause delayed or long-term effects. After a serious exposure or repeated exposures to aniline, anemia can occur. There is no evidence that aniline causes cancer. Some workers exposed to aniline over many years developed bladder cancer, but this was probably due to simultaneous exposure to other chemicals. High incidences of gynecological disorders and excess frequency of spontaneous abortions have been reported for women chemically exposed to aniline.

What, tests can be done if a person has been exposed to aniline?
Specific blood tests for the presence of methemoglobin may be useful. If a severe exposure has occurred, blood and urine analyses, and other tests may show whether damage has been done to the liver, heart, and brain. Testing is not needed in every case.

Where can more information about aniline be found?
More information about aniline can be obtained from your regional poison control center; your state, county, or local health department; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor or a clinic in your area that specializes in occupational and environmental health. If the exposure happened at work, you may wish to discuss it with your employer, the Occupational Safety and Health Administration (OSHA), or the National Institute for Occupational Safety and Health (NIOSH). Ask the person who gave you this form for help in locating these telephone numbers.

Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow *only* the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:

- difficulty breathing, shortness of breath, or chest pain
- weakness, nausea, or vomiting
- blood in the urine (brown- or bronze-colored urine)
- blue, brown, or gray color of the skin, lips, or nailbeds

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.
[ ] Call for an appointment with Dr. _____ in the practice of _____. When you call for your appointment, please say that you were treated in the Emergency Department at _ _____ Hospital by _____ and were advised to be seen again in _____ days.
[ ] Return to the Emergency Department/ _____ Clinic on (date) _____ at _____ AM/PM for a follow-up examination.
[ ] Do not perform vigorous physical activities for 1 to 2 days.
[ ] You may resume everyday activities including driving and operating machinery.
[ ] Do not return to work for _____ days.
[ ] You may return to work on a limited basis. See instructions below.
[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.
[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.
[ ] Avoid taking the following medications: _____
[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: _____
_____
_____
[ ] Other instructions: _____
_____
_____

- Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.

- You or your physician can get more information on the chemical by contacting: _____ _____ or _____, or by checking out the following Internet Web sites: _____; _____.

Signature of patient _____ Date _____

Signature of physician _____ Date _____

Arsenic Trioxide (As_2O_3)
CAS 1327-53-3; UN 1561

Synonyms include arsenic oxide, arsenious acid, arsenious oxide, arsenious trioxide, arsenous acid anhydride, crude arsenic, arsenolite, and white arsenic.

- **Persons whose clothing or skin is contaminated with arsenic trioxide can secondarily contaminate rescuers by direct contact or through release of inhalable dust.**
- **Arsenic trioxide is an odorless, tasteless, white or transparent nonflammable solid.**
- **Arsenic trioxide is readily absorbed if inhaled or ingested, but only slowly absorbed through the skin. Toxicity usually results from ingestion.**

Description

There are many forms of arsenic, but this medical Management Guideline focuses specifically on arsenic trioxide (As_2O_3), one of the most toxic and prevalent forms. Arsenic trioxide is a white or transparent solid in the form of glassy, shapeless lumps or a crystalline powder that resembles sugar. It has no odor or taste. It forms readily when elemental metallic arsenic is heated to high temperatures or burned. When arsenic trioxide is burned, it releases toxic fumes and arsine gas which is highly toxic.

Routes of Exposure

Inhalation

Arsenic trioxide dust is readily absorbed from the lungs, but inhaled quantities are usually insufficient to cause acute systemic toxicity. Arsenic trioxide has no odor. Thus, odor provides no warning of hazardous airborne concentrations.

Skin/Eye Contact

Direct contact with arsenic trioxide dust can cause localized skin irritation, but systemic absorption through the skin is negligible. Skin contact is unlikely to cause systemic effects unless the dermal barrier is compromised. Arsenic trioxide dust is irritating to the eyes.

Ingestion

Ingestion is the most important route of acute exposure of arsenic trioxide. Ingested arsenic trioxide is quickly absorbed and can be extremely hazardous. Significant tissue and organ damage and death may result. Most acute intoxications are from suicidal or homicidal ingestion.

Sources/Uses

Arsenic is ubiquitous in the natural environment. Arsenic trioxide is one of the arsenites (inorganic forms of arsenic in the trivalent state [As^{3+}]), found in nature and is produced mainly from by-products of copper smelting. It is no longer commercially manufactured in the United States, but is imported primarily for use in manufacturing other arsenic compounds used as wood preservatives, insecticides, and herbicides. It is also used in metallurgical processes, and in the manufacturing of glass and ceramics. Arsenic compounds were formerly used medicinally in humans (e.g., Fowler's solution), but these uses have largely been abandoned. Inorganic arsenic compounds, however, can be found in some homeopathic and folk remedies.

Standards and Guidelines

OSHA PEL (permissible exposure limit) = 10 $\mu g/m^3$ (averaged over an 8-hour workshift) for inorganic arsenic compounds.

NIOSH IDLH (immediately dangerous to life or health) = 5 mg As/m^3 (for all inorganic arsenic compounds).

Physical Properties

Description: white or transparent solid in the form of glassy, shapeless lumps or a crystalline powder that resembles sugar.

Warning properties: inadequate; odorless and tasteless; airborne arsenic trioxide may produce a burning sensation to the nose, mouth, and eyes and cause coughing, shortness of breath, headache, sore throat, and dizziness.

Molecular weight: 197.84 daltons

Boiling point (760 mm Hg): 869 °F (465°C)

Sublimes at 379 °F (193°C)

Melting point: 594 °F (312°C)

Vapor pressure: 66.1 mm Hg at 594 °F (312 °C)

Density (solid): 3.74 (water = 1.00)

Water solubility: Low solubility in water (37 g/L at 20 °C, 115 g/L at 100 °C); slightly soluble in alcohol; soluble in dilute HCl solutions.

Flammability: not flammable, but emits highly toxic arsine gas and oxides of arsenic fumes when burned.

Incompatibilities

Flammable reactions can occur in the presence of strong oxidizers. If arsenic trioxide is exposed to hydrogen gas or to the combination of acid (acid fumes) or water and active metals, the reaction can form toxic arsine gas (see *Medical Management Guideline for Arsine)*.

Health Effects

- **Toxic effects of arsenic trioxide usually result from ingestion. Small amounts of arsenic trioxide can lead to multiple organ damage and death. Acute signs and symptoms include nausea, vomiting, diarrhea, gastrointestinal hemorrhage, cerebral edema, tachycardia, dysrhythmias, and hypovolemic shock. Symptoms are dose dependent and can be delayed.**

- **Dermal contact and inhalation of airborne arsenic trioxide can cause localized irritation and usually does not result in systemic effects.**

Acute Exposure

The toxic effects caused by acute exposure to arsenic trioxide are due in large part to its ability to bind to cellular proteins containing sulfhydryl groups. This inhibits the production of energy needed to maintain tissue functions, and results in a decrease in glutathione, which is necessary for the metabolic detoxification of arsenic. The primary target organs are the gastrointestinal tract, heart, brain and kidney. Eventually the skin, bone marrow and peripheral nervous system are also affected. Arsenic trioxide has direct toxic effects on endothelial cells, increasing the permeability of small blood vessels.

Children do not always respond to chemicals in the same way that adults do. Different protocols for managing their care may be needed.

This medical management guide focuses specifically on arsenic trioxide (an arsenite), which is one of the most toxic forms of arsenic. As little as 1 to 2.5 mg/kg of arsenic trioxide is a potentially fatal dose. Toxicity from natural sources of arsenic is rare except from drinking highly contaminated groundwater or from breathing highly contaminated air (e.g., from burning of arsenic-containing coal indoors without adequate ventilation). Other inorganic forms of arsenic called arsenates are in the pentavalent state (As^{5+}) and are several times less toxic than the arsenites. Elemental arsenic has a gray metal-like appearance, is insoluble in water or body fluids, and is not considered poisonous. Organic arsenic, also known as fish or seaweed arsenic (arsenocholine, arsenobetaine, or arsenosugars) is mostly found in seafood such as bivalves, bottom-feeding fish, and seaweed and has a lower toxicity.

Gastrointestinal

Initial symptoms occurring within 30 minutes to several hours include burning of the lips, pharyngeal constriction, severe abdominal pain and nausea. A metallic or garlic taste and intense

thirst also occur. Inflammation and necrosis of the mucosa and submucosa can lead to bloody or "rice water" diarrhea, vomiting, and gastrointestinal perforation and bleeding. Bleeding and/or fluid loss can result in electrolyte abnormalities, shock, and death.

CNS — Encephalopathy (cerebral edema), headache, lethargy, delirium, hallucinations, seizures, or coma can occur. Cerebral lesions consisting of multiple, symmetrical foci of hemorrhagic necrosis occur in the gray and white matter.

Peripheral Neurologic — Peripheral neuropathy resembling Guillain-Barré syndrome (ascending flaccid paralysis) is common acutely or subacutely. Sensory symptoms predominate early, with patients complaining of "pins and needles" or electrical shock like pains in the lower extremities. This may be followed by numbness and motor weakness.

Cardiovascular — Increased capillary permeability (third-spacing and vasodilation) can result in hypovolemic shock. Sinus tachycardia can be an early sign of poisoning. Polymorphous ventricular tachycardia, ventricular fibrillation, and congestive heart failure can occur. Electrocardiographic findings can include, prolongation of the QT interval, ST depression, and flattened T waves.

Respiratory — Pulmonary edema, acute respiratory distress syndrome (ARDS), and respiratory failure due to weakness of the respiratory muscles can occur following ingestion. Coughing, chest pain, dyspnea, and general irritation of the upper respiratory tract can occur following inhalation.

Exposure to certain chemicals can lead to Reactive Airway Dysfunction Syndrome (RADS), a chemically- or irritant-induced type of asthma.

Children may be more vulnerable because of relatively increased minute ventilation per kg and failure to evacuate an area promptly when exposed.

Musculoskeletal — Myalgia, weakness, muscular atrophy and rhabdomyolysis can occur.

Renal — Initial glomerular damage leading to proteinuria is common following high arsenic exposure. Tubular necrosis and degeneration, oliguria with proteinuria, hematuria and acute renal failure are also frequently observed.

Hepatic

Hepatocellular injury after acute exposure to inorganic arsenicals is uncommon, but fatty infiltration of the liver, central necrosis, and cirrhosis may occur. Hepatitis may also develop due to altered intrahepatic heme metabolism, increased synthesis of bilirubin, and altered interhepatocyte protein transport.

Dermal

Flushing, diaphoresis, edema (especially periorbital), hyperkeratosis, and brawny desquamation or exfoliative dermatitis can occur.

Ocular

Conjunctivitis, photophobia, and dimness of vision, diplopia, and lacrimation can occur.

Potential Sequelae

If the immediate effects of acute arsenic poisoning are survived, a variety of delayed effects, including peripheral neuropathy and bone marrow suppression (anemia, leukopenia, pancytopenia), may develop. New or persistent encephalopathy, dysrhythmias, and nail changes (Mee's lines) can also occur. Peripheral neuropathy involves sensory and motor neurons in a stocking-glove distribution. Initially painful dysesthesias (i.e., "pins and needles" or an electric shock-like sensation) are prominent. Early treatment with the chelator dimercaprol, also known as BAL (British AntiLewisite), may not eliminate the risk of delayed effects. Survival of the acute phase of arsenic poisoning is highly dependent on the dose received and the timing and extent of treatment. Recovery from subsequent peripheral neuropathy is usually only partial and may require months to years.

Chronic Exposure

Chronic exposure is characterized by malaise, peripheral sensorimotor neuropathy, anemia, jaundice, gastrointestinal complaints, and characteristic skin lesions including hyperkeratosis (small corn-like elevations) and hyperpigmentation. Hyperkeratosis usually appears on the palms or soles. Pigmentation changes and hyperkeratosis can take 3 to 7 years to appear. Chronic inhalation can also lead to conjunctivitis, irritation of the throat and respiratory tract, and perforation of the nasal septum. Chronic exposure can cause allergic contact dermatitis. Chronic exposure may be more serious for children because of their potential longer latency period.

Carcinogenicity

The Department of Health and Human Services (DHHS), the International Agency for Research on Cancer (IARC), the Environmental Protection Agency (EPA), and the National Toxicology Program (NTP) have classified arsenic as a human carcinogen based on sufficient evidence from human data. Arsenic trioxide causes skin and lung cancer, and may cause

internal cancers such as liver, bladder, kidney, colon, and prostate cancers.

Reproductive and Developmental Effects

Arsenic ions released from arsenic trioxide within the body can cross the placenta and affect the developing fetus; arsenic is also excreted in breast milk. Experimental animal studies support an association between high ingested arsenic dose and fetal toxicity. Arsenic trioxide is not included in *Reproductive and Developmental Toxicants*, a 1991 report published by the General Accounting Office (GAO) that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences.

Special consideration regarding the exposure of pregnant women may be warranted, since arsenic trioxide has been shown to be mutagenic and clastogenic, and is suspected of being teratogenic; thus, medical counseling is recommended for the acutely exposed pregnant woman.

Prehospital Management

- **Exposed persons whose skin or clothing is contaminated with arsenic trioxide can contaminate rescuers by direct contact or through release of inhalable dust.**
- **There is no serious risk of secondary contamination after clothing is removed and the skin is washed.**
- **Arsenic trioxide is irritating to the skin, eyes, and respiratory tract. Systemic effects can occur from all routes of exposure and may include severe gastrointestinal injury, life-threatening shock, and nerve damage.**
- **There is no specific antidote for arsenic trioxide. Prehospital treatment consists of supportive care and gastric decontamination. Chelation therapy is strongly recommended.**

Hot Zone

Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if the rescuers have not been trained in its use, call for assistance from a local or regional HAZMAT team or other properly equipped response organization.

Rescuer Protection

Arsenic trioxide dust is readily absorbed through inhalation and can irritate the respiratory tract. Although it is poorly absorbed dermally, skin contact should be avoided because arsenic trioxide can irritate the skin.

Respiratory Protection: Positive-pressure, self-contained breathing apparatus (SCBA) is recommended in response situations that involve exposure to potentially unsafe levels of arsenic trioxide or combustion products (arsine and arsenic trioxide fumes).

Skin Protection: Chemical-protective clothing is recommended when contact with arsenic trioxide is expected because skin irritation might occur.

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. If trauma is suspected, manually maintain cervical immobilization and apply a cervical collar and a backboard when feasible. Apply direct pressure to stop any heavy bleeding. Maintain adequate circulation.

Victim Removal

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk should

be removed on backboards or gurneys. If these are not available, carefully carry or drag victims to safety.

Consider appropriate management of chemically contaminated children, anticipate separation anxiety if a child is separated from a parent or other adult.

Decontamination Zone

All victims exposed to arsenic trioxide require decontamination (see *Basic Decontamination*, below).

Rescuer Protection

If exposure levels are determined to be safe, decontamination may be conducted by personnel wearing a lower level of protection than that required in the Hot Zone (described above).

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. Maintain adequate circulation. If trauma is suspected, manually maintain cervical immobilization and apply a cervical collar and a backboard when feasible. Administer supplemental oxygen as required. Assist ventilation with a bag-valve-mask device if necessary. Apply direct pressure to control any bleeding.

Basic Decontamination

Victims who are able may assist with their own decontamination. Remove and double-bag contaminated clothing and all personal belongings.

Wash exposed skin and hair with mild soap and water (preferably under a shower). Rinse thoroughly with water. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Flush exposed or irritated eyes with plain water or saline for at least **15 minutes**. Remove contact lenses if easily removable without additional trauma to the eye. If pain or injury is evident, continue irrigation while transferring the victim to the Support Zone.

In cases of ingestion, **do not induce emesis**. Aggressive decontamination with gastric lavage is recommended within 1 hour of ingestion of a life-threatening amount of poison. The effectiveness of activated charcoal in binding arsenic trioxide is questionable, but administration of a charcoal slurry is recommended pending further evaluation in cases of ingestion of unknown quantities (at 1 gm/kg, usual adult dose 60–90 g, child dose 25–50 g). A soda can and straw may be of assistance when offering charcoal to a child.

Consider appropriate management of chemically contaminated children at the exposure site. Also, provide reassurance to the child during decontamination, especially if separation from a parent occurs. If possible, seek assistance from a child separation expert.

Transfer to Support Zone

As soon as basic decontamination is complete, move the victim to the Support Zone.

Support Zone

Be certain that victims have been decontaminated properly (see *Decontamination Zone*, above). Victims who have undergone decontamination pose no serious risk of secondary contamination to rescuers. In such cases, Support Zone personnel require no specialized protective gear.

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. If trauma is suspected, manually maintain cervical immobilization and apply a cervical collar and a backboard when feasible. Administer supplemental oxygen as required. Assist ventilation with a bag-valve-mask device, if necessary. Maintain adequate circulation. Apply direct pressure to control any bleeding. Establish intravenous access, if necessary. Place on a cardiac monitor.

If evidence of shock or hypotension is observed begin fluid administration. For adults, bolus 1,000 mL/hour if blood pressure is under 80 mm Hg; if systolic pressure is over 90 mm Hg, an infusion rate of 150 to 200 mL/hour is sufficient. For children with compromised perfusion administer a 20 mL/kg bolus of normal saline over 10 to 20 minutes, then infuse at 2 to 3 mL/kg/hour.

Additional Decontamination

Continue irrigating exposed skin and eyes, as appropriate. In cases of ingestion, **do not induce emesis**. Aggressive decontamination with gastric lavage is recommended within 1 hour of ingestion of a life-threatening amount of poison. The effectiveness of activated charcoal in binding arsenic trioxide is questionable, but administration of a charcoal slurry is recommended pending further evaluation in cases of ingestion of unknown quantities (at 1 gm/kg, usual adult dose 60–90 g, child dose 25–50 g). A soda can and straw may be of assistance when offering charcoal to a child.

Advanced Treatment

In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, perform cricothyroidotomy if equipped and trained to do so.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Also consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Arsenic trioxide poisoning is not known to pose additional risk during the use of bronchial or cardiac sensitizing agents.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed cautioning for myocardial variability.

Patients who are comatose, hypotensive, or have seizures or cardiac dysrhythmias should be treated according to advanced life support (ALS) protocols.

If massive exposure is suspected or if the patient is hypotensive, infuse intravenous saline or lactated Ringer's solution. For adults, bolus 1,000 mL/hour if blood pressure is under 80 mm Hg; if systolic pressure is over 90 mm Hg, an infusion rate of 150 to 200 mL/hour is sufficient. For children with compromised perfusion administer a 20 mL/kg bolus of normal saline over 10 to 20 minutes, then infuse at 2 to 3 mL/kg/hour.

Transport to Medical Facility

Only decontaminated patients or patients not requiring decontamination should be transported to a medical facility. "Body bags" are not recommended.

Report to the base station and the receiving medical facility the condition of the patient, treatment given, and estimated time of arrival at the medical facility.

If the patient has ingested arsenic trioxide, prepare the ambulance in case the patient vomits toxic material or has diarrhea. Have ready several towels and open plastic bags to quickly clean up and isolate vomitus.

Multi-Casualty Triage

Consult with the base station physician or the regional poison control center for advice regarding triage of multiple victims.

Patients with evidence of significant exposure and all patients who have ingested arsenic trioxide should be transported to a medical facility for evaluation.

Asymptomatic patients who have not had direct exposure to arsenic trioxide may be discharged from the scene, after their names, addresses, and telephone numbers are recorded. These patients should be advised to seek medical care promptly if symptoms develop (see *Patient Information Sheet* below).

Emergency Department Management

- **Patients whose skin or clothing is contaminated with arsenic trioxide can contaminate rescuers by direct contact or through release of inhalable dust.**
- **Patients do not pose a serious risk of secondary contamination after their clothing is removed and their skin is washed.**
- **Arsenic trioxide is irritating to the skin, eyes, and respiratory tract. Systemic effects can occur from all routes of exposure and may include gastrointestinal injury, life-threatening shock, and nerve damage.**
- **There is no specific antidote for arsenic trioxide. Treatment consists of supportive care and gastric decontamination. Chelation therapy is strongly recommended.**

Decontamination Area

Previously decontaminated patients may be transferred directly to the Critical Care Area. Others require decontamination as described below. Because arsenic trioxide can irritate the skin, thus increasing the probability of dermal absorption, chemical-protective clothing is recommended when contact with arsenic trioxide is expected.

Be aware that use of protective equipment by the provider may cause fear in children, resulting in decreased compliance with further management efforts.

Because of their relatively larger surface area:weight ratio, children are more vulnerable to toxicants absorbed through the skin. Also, emergency room personnel should examine children's mouths because of the frequency of hand-to-mouth activity among children.

ABC Reminders

Evaluate and support the airway, breathing, and circulation. Secure airway and respiration via endotracheal intubation. If not possible, perform cricothyroidotomy if equipped and trained to do so.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Also consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Arsenic trioxide poisoning is not known to pose

additional risk during the use of bronchial or cardiac sensitizing agents.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed cautioning for myocardial variability.

Patients who are comatose, hypotensive, or have seizures or cardiac dysrhythmias should be treated in the conventional manner.

Basic Decontamination

Patients who are able and cooperative may assist with their own decontamination. Remove and double-bag contaminated clothing and all personal belongings.

Wash exposed skin and hair with mild soap and water (preferably under a shower). Rinse thoroughly with water.

Flush exposed or irritated eyes with plain water or saline for at least **15 minutes**. Remove contact lenses if present and easily removable without additional trauma to the eye. If ocular pain or injury is evident, continue irrigation while transferring the victim to the Critical Care Area**.**

In cases of ingestion, **do not induce emesis**. Consider gastric lavage for recent large ingestion. (More information is provided in *Ingestion Exposure* under *Critical Care Area* below).

Critical Care Area

Be certain that appropriate decontamination has been carried out (see *Decontamination Area* above).

ABC Reminders

Evaluate and support the airway, breathing, and circulation as in ABC Reminders above. Children may be more vulnerable to corrosive agents than adults because of the relatively smaller diameter of their airways. Establish intravenous access in symptomatic patients. Continuously monitor cardiac rhythm.

Patients who are comatose, hypotensive, or have seizures or cardiac dysrhythmias should be treated in the conventional manner.

Inhalation Exposure

Administer supplemental oxygen by mask to patients who have respiratory complaints. For serious exposure, respiratory tract irritation can progress to pulmonary edema, maintain adequate oxygenation and provide mechanical support if needed. Treat patients who have bronchospasm with aerosolized

bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Also consider the health of the myocardium before choosing which type of bronchodilator should be administered. Dopamine or norepinephrine may be appropriate in management of shock; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Arsenic trioxide poisoning is not known to pose additional risk during the use of bronchial or cardiac sensitizing agents.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed cautioning for myocardial variability.

Skin Exposure

Dermal exposure to arsenic trioxide may cause skin irritation. Treat symptomatically.

Eye Exposure

Ensure that adequate eye irrigation has been completed. Test visual acuity. Examine the eyes for corneal damage and treat appropriately. Consult an ophthalmologist for patients who have apparent or suspected corneal injury.

Ingestion Exposure

Fluid repletion should begin as soon as possible in severe acute poisoning. Central venous or pulmonary wedge pressure monitoring can be useful in managing severe exposures where hypotension is a risk.

Do not induce emesis. In case of recent ingestion (less than 1 hour), and if spontaneous emesis has not occurred, consider performing gastric lavage to prevent further absorption. Insert an orogastric tube and begin lavage with water or normal saline as soon as possible. Continue lavage until the return is clear. Activated charcoal may not bind significant amounts but is recommended (at 1 gm/kg, usual adult dose 60–90 g, child dose 25–50 g).

Arsenic is radiopaque and an abdominal radiograph should be obtained in cases of ingestion. If opacities compatible with arsenic are noted on the radiograph, consider whole bowel irrigation (e.g., with a polyethylene glycol [PEG-3350] electrolyte lavage solution).

Consider alkalization of urine (pH 7.5) to protect kidney from deposition of red cell breakdown products. Assure adequate renal function before administering sodium bicarbonate.

Antidotes and Other Treatments

Chelation therapy curtails the distribution of arsenic in the body and reduces the body burden. The decision to chelate for a patient should be made only by professionals experienced in the use of chelation, preferably in consultation with a regional poison control center or a medical toxicologist. Patients with a clear history of exposure to arsenic with significant GI and/or cardiovascular symptoms may require chelation before laboratory confirmation. As time increases after exposure, chelation therapy becomes less effective in reducing the severity of poisoning and in reducing the risks of serious delayed effects. Do not chelate asymptomatic patients without the guidance of a 24-hour urinary arsenic level.

In acutely ill patients, the agent most frequently recommended is dimercaprol, also known as BAL (British AntiLewisite). The standard dosage regimen is 3 to 5 mg/kg IM every 4–6 hours until the 24-hour urinary arsenic level falls below 50 µg/L, unless an orally administered chelating agent (e.g., DMSA, see below) is substituted. This regimen may be adjusted depending upon the severity of the exposure and the symptoms.

Contraindications to BAL include preexisting renal disease, pregnancy (except in life-threatening circumstances) and concurrent use of medicinal iron (BAL and iron together form a complex that is very toxic).

An increased risk for hemolysis should also be considered when administering BAL to patients with glucose-6-phosphate dehydrogenase deficiency; arsenic trioxide is itself an inhibitor of G-6-PD.

Chelation therapy should be continued until the 24-hour urinary arsenic level falls below 50 µg/L. Alkalization of the urine stabilizes the dimercaprol-metal complex and has been proposed to protect the kidneys during chelation therapy. If any degree of acute renal insufficiency develops during chelation, hemodialysis should be considered to remove the dimercaprol-arsenic complex. Side effects of BAL administered at 2.5 mg/kg are mostly pain at the injection site. At an intramuscular dose of 5 mg/kg, the effects can include hypertension, nausea, vomiting, headache, lacrimation, rhinorrhea, salivation, and diaphoresis.

Oral agents such as 2,3-demercaptosuccinic acid (DMSA or Succimer®) or D-penicillamine have been used as alternatives to BAL. DMSA is approved for the treatment of pediatric lead poisoning in the United States; it also has been used successfully to chelate arsenic in humans, and is being further evaluated for

this use. Water-soluble chelating agents like DMSA are less toxic than BAL and are often substituted when the patient's condition improves. DMSA might also be preferable for patients with renal insufficiency, but GI motility is a prerequisite, as well as GI decontamination (to prevent increased arsenic absorption).

The use of D-penicillamine as an oral chelating agent is controversial. It has been used successfully in children, but should be avoided in penicillin allergic patients.

Laboratory Tests

Routine laboratory studies for seriously exposed patients include CBC, serum electrolytes, urinalysis and liver enzyme and kidney function tests. Chest radiographs and pulse oximetry (or ABG measurements) are recommended for patients who have respiratory symptoms. An abdominal radiograph can detect radiopaque ingested arsenic. Additionally, 24-hour urine arsenic levels are useful for monitoring symptomatic patients. A chelated or non-chelated level above 100 µg is usually considered abnormal. Normal total urinary arsenic levels are less than 50 µg/L in the absence of recent consumption of seafood that contains organic forms of arsenic (i.e., fish arsenic).

A high blood arsenic level (normal being less than 7 µg/100 mL) might confirm a diagnosis of poisoning. However, arsenic moves quickly out of the bloodstream (its initial half-life in blood is 1 to 2 hours) and a normal value does not exclude poisoning. If the blood arsenic level is normal, but the 24-hour urinary arsenic excretion is elevated, and there is a compatible clinical presentation, the diagnosis can still be made.

Note: If the patient has eaten seafood containing organic arsenic (fish arsenic) within the past 48 hours, total urinary arsenic might be significantly elevated (urinary arsenic of up to 1,700 µg/L has been measured following a large shellfish meal). Some laboratories can speciate arsenic into the nontoxic organic arsenics found in seafood and the toxic inorganic forms, although results are often not quickly available.

Disposition and Follow-up

Hospitalize patients who have ingested a significant amount of arsenic trioxide, those who have had significant inhalation exposure, and those who require chelation therapy.

Delayed Effects

Delayed effects can occur after an acute arsenic exposure that resulted in significant acute effects. Delayed effects include peripheral neuropathy, bone marrow suppression (anemia, leukopenia, pancytopenia), encephalophathy, cardiomyopathy, and dermatologic lesions. Although timely chelation therapy

reduces the occurrence of delayed effects, follow-up should include particular attention to these organ systems.

Patient Release

Asymptomatic patients who have minimal exposure, normal initial examinations, and no signs of toxicity after 6 to 8 hours of observation may be discharged with instructions to seek medical attention promptly if symptoms develop (see the *Arsenic Trioxide—Patient Information Sheet* below).

Follow-up

Obtain the name of the patient's primary care physician so that the hospital can send a copy of the ED visit to the patient's doctor.

Patients who remain asymptomatic after exposure require no follow-up. Discharged patients who had relatively minor or transient symptoms following an ingestion exposure should initiate a 24-hour urine collection for arsenic measurement. Follow-up should include evaluation of urinary arsenic levels, and consultation with the regional poison center regarding outpatient chelation. For severely exposed patients with significant symptoms of acute poisoning, follow-up evaluation of neurologic, circulatory, renal, pulmonary, hematologic, and hepatic function should be arranged. Patients who have corneal lesions should be reexamined within 24 hours.

Reporting

If a work-related incident has occurred, you may be legally required to file a report; contact your state or local health department.

Other persons may still be at risk in the setting where this incident occurred. If the incident occurred in the workplace, discussing it with company personnel may prevent future incidents. If a public health risk exists, notify your state or local health department or other responsible public agency. When appropriate, inform patients that they may request an evaluation of their workplace form OSHA or NIOSH. See Appendices III and IV for a list of agencies that may be of assistance.

Arsenic Trioxide (As_2O_3)
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to arsenic trioxide.

What is arsenic trioxide?
Arsenic is an element found naturally in the environment. There are many arsenic compounds of commercial importance. One of the most toxic of these is arsenic trioxide. Arsenic trioxide is a white or transparent solid that has no taste or odor and low flammability. Arsenic trioxide is used in the manufacture of wood preservatives, as an insecticide and herbicide, in metallurgy, and in glass and ceramic manufacturing.

What immediate health effects can be caused by exposure to arsenic trioxide?
Breathing arsenic trioxide can cause nose and throat irritation, but generally, a person cannot inhale enough to severely harm internal organs. Skin or eye contact can cause irritation.

Intentional or unintentional swallowing of even a tiny amount of arsenic trioxide can cause severe vomiting, diarrhea, abdominal cramps, and shock, as well as seizures; coma; damage to the liver, kidneys, nerves, and bone marrow; and death.

Can arsenic trioxide poisoning be treated?
Washing arsenical residues from the skin or eyes usually reduces the irritant effect. If arsenic trioxide is swallowed, measures can be taken to remove it from the body. In severe cases, medicines called chelating agents are given to remove arsenic from the body and eliminate it in the urine. Severely affected individuals must be hospitalized. In some cases, permanent nerve damage can result even if chelation therapy is used.

Are any future health effects likely to occur?
Arsenic trioxide can cause adverse health effects in the liver, kidney, brain, nervous system, or bone marrow for months or years after a severe poisoning.

What tests can be done if a person is exposed to arsenic trioxide?
Blood and urine tests for arsenic can be done to confirm exposures. In cases of ingestion, arsenic might show up in the intestines or stomach on x-rays. Arsenic levels in urine can be monitored to tell when the arsenic has been eliminated form the body. Monitoring for past or long-term exposure can be carried out by analysis of arsenic levels in hair or nails.

Where can more information about arsenic trioxide be found?
More information about arsenic trioxide can be obtained from your regional poison control center; your state, county, or local health department; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in occupational and environmental health. If the exposure happened at work, you may wish to discuss it with your employer, the Occupational Safety and Health Administration (OSHA) or the National Institute for Occupational Safety and Health (NIOSH). Ask the person who gave you this form for help in locating these telephone numbers.

Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow *only* the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:

- vomiting, abdominal cramps, diarrhea
- severe weakness
- rapid heart rate
- shortness of breath, coughing, or wheezing
- increased pain or discharge from injured eyes

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.

[ ] Call for an appointment with Dr. _____ in the practice of _____. When you call for your appointment, please say that you were treated in the Emergency Department at _ _____ Hospital by _____ and were advised to be seen again in _____ days.

[ ] Return to the Emergency Department/ _____ Clinic on (date) _____ at _____ AM/PM for a follow-up examination.

[ ] Do not perform vigorous physical activities for 1 to 2 days.

[ ] You may resume everyday activities including driving and operating machinery.

[ ] Do not return to work for _____ days.

[ ] You may return to work on a limited basis. See instructions below.

[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.

[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.

[ ] Avoid taking the following medications: _____

[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: __ _____ _____

[ ] Other instructions: _____ _____ _____

- Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.

- You or your physician can get more information on the chemical by contacting: _____ _____ or _____, or by checking out the following Internet Web sites: _____; _____.

Signature of patient _____ Date _____

Signature of physician _____ Date _____

Arsine (AsH_3)
CAS 7784-42-1; UN 2188

Synonyms include arsenic hydride, arsenic trihydride, arseniuretted hydrogen, arsenious hydride, and hydrogen arsenide.

- **Persons exposed to arsine pose no serious risks of secondary contamination to personnel outside the Hot Zone.**
- **Arsine is a flammable and highly toxic gas with a garlic-like or fishy odor that does not provide adequate warning of hazardous levels.**
- **Inhalation is the major route of arsine exposure. There is little information about absorption through the skin or toxic effects on the skin or eyes. However, contact with liquid arsine may result in frostbite injury.**

Description

Arsine is a colorless, flammable, and highly toxic gas. It has a garlic-like or fishy odor that can be detected at concentrations of 0.5 ppm and above. Because arsine is nonirritating and produces no immediate symptoms, persons exposed to hazardous levels may be unaware of its presence. Arsine is water soluble. It is generally shipped in cylinders as a liquefied compressed gas. Exposure frequently occurs when arsine gas is generated while metals or crude ores containing arsenic impurities are treated with acid and this is a common source of exposure.

Routes of Exposure

Inhalation

Inhalation is the major route of exposure. The odor threshold of arsine is 10-fold greater than the OSHA permissible exposure limit. **Odor is not an adequate indicator of arsine's presence and does not provide reliable warning of hazardous concentrations.** Arsine is heavier than air and hazardous concentrations may develop quickly in enclosed, poorly ventilated, or low-lying areas. Initial symptoms (malaise, dizziness, nausea, abdominal pain, and dyspnea) may develop within several hours of exposure to 3 ppm of arsine.

Children exposed to the same levels of arsine as adults may receive larger dose because they have greater lung surface area:body weight ratios and increased minute volumes:weight ratios. In addition, they may be exposed to higher levels than adults in the same location because of their short stature and the higher levels of arsine found nearer to the ground.

Skin/Eye Contact

There is little information about direct toxic effects of arsine on the skin or eyes, or about absorption through the skin. Exposure to liquid arsine (the compressed gas) can result in frostbite.

Ingestion

Ingestion of arsine itself is unlikely because it is a gas at room temperature. However, metal arsenides are solids that can react with acidic gastric contents, releasing arsine gas in the stomach.

Sources/Uses

Arsine gas is formed when arsenic-containing materials react with freshly formed hydrogen in water or acids. Frequently exposure results when arsenic containing metals (i.e., metal vats) undergo acid washes. Unintentional exposures have also occurred during refining of ores (e.g., lead, copper, zinc, iron, and antimony ores) that contain arsenic. Arsine is used as a dopant in the semiconductor industry and in the manufacture of crystals for fiberoptics and computer chips. It is used infrequently in galvanizing, soldering, etching, burnishing, and lead plating.

Standards and Guidelines

OSHA PEL (permissible exposure limit) = 0.05 ppm (averaged over an 8-hour workshift)

NIOSH IDLH (immediately dangerous to life or health) = 3 ppm

AIHA ERPG-2 (emergency response planning guideline) = 0.5 ppm (maximum airborne concentration below which it is believed that nearly all persons could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action).

Physical Properties

Description: Colorless, nonirritating gas at room temperature

Warning properties: Inadequate; garlic-like or fishy odor at 0.5 ppm

Molecular weight: 78.0 daltons

Boiling point (760 mm Hg): -80.4 ° F (-62.5 °C)

Vapor pressure: >760 mm Hg at 68 °F (20 °C)

Gas density: 2.7 (air = 1)

Water solubility: Soluble, 20% at 68 °F (20 °C)

Flammability: Extremely flammable; may be ignited by heat, sparks, or flames. Vapors may travel to a source of ignition and flash back.

Incompatibilities

Arsine reacts with strong oxidizers, chlorine, and nitric acid. Arsine decomposes above 446 °F (230 °C).

Health Effects

- **Arsine is a highly toxic gas and may be fatal if inhaled in sufficient quantities. Its primary toxic effect is due to hemolysis resulting in renal failure.**
- **Initially some patients may look relatively well. Common initial symptoms of exposure include malaise, headache, thirst, shivering, abdominal pain and dyspnea. These symptoms usually occur within 30 to 60 minutes with heavy exposure, but can be delayed for 2 to 24 hours.**
- **Hemoglobinuria usually occurs within hours, jaundice within 1 or 2 days.**

Acute Exposure

After absorption by the lungs, arsine enters red blood cells (RBC) where different processes may contribute to hemolysis and impairment of oxygen transport. Inhibition of catalase may lead to accumulation of hydrogen peroxide which, as an oxidizer, destroys red cell membranes and may contribute to arsine-induced conversion of Fe^{+2} to Fe^{+3}, which also impairs oxygen transport. Arsine preferentially binds to hemoglobin, and is oxidized to an arsenic dihydride intermediate and elemental arsenic, both of which are hemolytic agents. Arsine toxicity involves depletion of reduced glutathione. Therefore, people deficient in the enzyme glucose-6-phosphate-dehydrogenase (G6PD) are more susceptible to hemolysis following arsine exposure. Pre-existing cardiopulmonary or renal conditions, iron deficiency, and/or pre-existing anemia may result in more severe outcomes if hemolysis occurs.

Contact with the skin or eyes does not result in systemic toxicity. Ingestion of arsine is unlikely, but ingestion of metallic arsenides can lead to arsine gas production and toxicity.

Hematologic

Acute intravascular hemolysis develops within hours and may continue for up to 96 hours. Haptoglobin levels decline rapidly. Free hemoglobin levels in plasma rise (levels greater than 2 g/dL have been reported). Anemia develops; the peripheral smear shows variation in the size of the red blood cells, irregularly shaped blood cells, red-cell fragments, components that have an affinity for basic dyes, Heinz bodies, and ghost cells. The bone marrow usually shows no abnormalities. Coombs and Ham tests are negative, and RBC fragility is normal.

Methemoglobinemia can be of concern in infants up to 1 year old. Children may be more vulnerable to loss of effectiveness of hemoglobin because of their relative anemia compared to adults.

Respiratory

Difficult breathing is among the early symptoms of arsine poisoning. A garlic odor may be present on the breath. Delayed accumulation of fluid in the lungs may occur after massive exposure. Dyspnea may be due to lack of oxygen secondary to hemolysis.

Children may be more vulnerable because of increased minute ventilation per kg and failure to evacuate an area promptly when exposed.

Renal

Kidney failure due to acute tubular destruction is a significant sequela of arsine exposure. Hemoglobin in the urine is thought to be the major cause of damage to the kidneys; however, a direct toxic effect of arsine or deposition of the arsine-hemoglobin-haptoglobin complex may also play a role. Urinalysis shows large amounts of protein and free hemoglobin usually without intact RBCs. Urine may be colored (e.g., brown, red, orange, or greenish). Decreased urinary output may develop within 24 to 48 hours.

Gastrointestinal

Nausea, vomiting, and crampy abdominal pain are among the **first signs** of arsine poisoning. Onset varies from a few minutes to 24 hours after exposure.

Dermal

The characteristic bronze tint of the skin caused by arsine toxicity is induced by hemolysis and may be caused by hemoglobin deposits. This is not true jaundice which can occur in severe cases.

Contact with the liquid (compressed gas) can cause frostbite.

CNS

Headache is often an early sign of exposure. CNS disorders can develop several days after severe exposure; signs include restlessness, memory loss, disorientation, and agitation. Some exposed persons experience signs of peripheral nerve damage 1 to 2 weeks after exposure. There are case reports of polyneuropathy developing 1 to 6 months after arsine exposure.

Hepatic

Right upper quadrant pain, hepatomegaly, elevated serum globulin, elevated liver enzymes and prolonged prothrombin time have been observed.

Musculoskeletal

Skeletal muscle injury or necrosis have been reported. Muscle pain and twitches, myoglobinuria, elevated levels of serum creatine phosphokinase (CPK) and aldolase have been observed.

Cardiovascular

Hypotension may occur with severe exposures. EKG changes and dysrhythmias associated with hypocalaemia can occur.

Ocular

Red staining of the conjuctiva may be an early sign of arsine poisoning.

Chronic Exposure

Chronic arsine exposure can result in gastrointestinal upset, anemia, and damage to lungs, kidneys, liver, nervous system, heart, and blood-forming organs. There is little information regarding health effects of chronic low-level exposures to arsine.

Carcinogenicity

Arsine has not been classified for carcinogenic effects. However, arsenic compounds and metabolites have been classified as known human carcinogens by IARC and EPA.

Reproductive and Developmental Effects

Arsine should be treated as a potential teratogenic agent. Although the reproductive effects of acute or chronic exposure to arsine are unknown, some related inorganic arsenicals produce a broad spectrum of adverse developmental effects in animals. Arsine is not included in *Reproductive and Developmental Toxicants*, a 1991 report published by the General Accounting Office (GAO) that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences. Animal studies indicated that in arsine-exposed mothers, arsenic crosses the placenta and reaches the fetus; however, no adverse developmental effects were observed.

Prehospital Management

- **Although small amounts of arsine gas can be trapped in the victim's clothing or hair after an overwhelming exposure, these quantities are not likely to create a hazard for response personnel outside the Hot Zone.**
- **The odor of arsine is not always detected during serious exposures; since symptoms may be delayed, ALL exposure victims should be evaluated at a medical facility.**
- **Toxic effects may be delayed for up to 2 to 24 hours after exposure.**
- **There is no specific antidote for arsine. Treatment is symptomatic and consists of measures to support respiratory, vascular, and renal function.**

Hot Zone

Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if rescuers have not been trained in its use, assistance should be obtained from a local or regional HAZMAT team or other properly equipped response organization.

Rescuer Protection

Arsine is a highly toxic systemic poison.

Respiratory Protection: Positive-pressure, self-contained breathing apparatus (SCBA) is recommended in response situations that involve exposure to potentially unsafe levels of arsine. Full-facepiece respirators are recommended.

Skin Protection: Chemical-protective clothing is not generally required because arsine gas is not absorbed through the skin and does not cause skin irritation. However, contact with the liquid (compressed gas) can cause frostbite injury to the skin or eyes.

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible.

Victim Removal

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be removed on backboards or gurneys; if these are not available, carefully carry or drag victims to safety.

Consider appropriate management of chemically contaminated children, such as measures to reduce separation anxiety if a child is separated from a parent or other adult.

Decontamination Zone

Victims who have exposure only to arsine gas do not need decontamination. They may be transferred immediately to the Support Zone.

Support Zone

Support Zone personnel require no specialized protective gear if the victim has been exposed only to arsine gas.

ABC Reminders

Quickly access for a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Evaluate for respiratory tract irritation, bronchitis, or pneumonitis. Ensure adequate respiration and pulse. Administer supplemental oxygen as required. Establish intravenous access if necessary. Place on a cardiac monitor.

In cases of contact with liquid (compressed gas), gently wash frosted skin with water; gently remove clothing from affected area. Dry with clean towels and keep victim warm and quiet.

Advanced Treatment

In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, perform cricothyroidotomy if equipped and trained to do so.

If massive exposure is suspected or if the patient is hypotensive, ensure adequate hydration by infusing intravenous saline or lactated Ringer's solution. For adults, bolus 1,000 mL/hour if blood pressure is under 80 mm Hg; if systolic pressure is over 90 mm Hg, an infusion rate of 150 to 200 mL/hour is sufficient. For children with compromised perfusion administer a 20 mL/kg bolus of normal saline over 10 to 20 minutes, then infuse at 2 to 3 mL/kg/hour. Monitor fluid balance and avoid fluid overload if renal failure supervenes; monitor plasma electrolytes to detect disturbances (particularly hyperkalemia) as early as possible. Monitor hematocrit.

Because of possible severe hemolysis ensure adequate oxygenation by arterial blood gas measurement or pulse oxygenation monitoring. The use of diuretics such as furosimide to maintain urinary flow is an important consideration and should be performed under medical base control.

Transport to Medical Facility

Report to the base station and the receiving medical facility the condition of the patient, treatment given, and estimated time of arrival at the medical facility.

Multi-Casualty Triage

Consult with the base station physician or the regional poison control center for advice regarding triage of multiple victims.

It is difficult to determine at the scene which persons have had the most serious exposures and are likely to develop severe hemolysis; therefore, *all* persons who have potential exposure should be transported to a medical facility for evaluation.

Persons who have smelled a garlic- or fish-like odor should be transported first.

Emergency Department Management

- **Although small amounts of arsine gas can be trapped in the victim's clothing or hair after an overwhelming exposure, these quantities are not likely to create a hazard for hospital personnel away from the scene.**
- **Arsine poisoning causes acute intravascular hemolysis, which may lead to renal failure. Arsine gas does not produce arsenic intoxication.**
- **Even if arsine's odor was not detected at the scene, those present could have been seriously exposed. All exposure victims should be evaluated and observed.**
- **There is no specific antidote for arsine. Treatment consists of measures to support vascular, renal, hematologic and respiratory function.**

Critical Care Area

Patients exposed only to arsine gas do not need decontamination.

ABC Reminders

Evaluate and support airway, breathing, and circulation. Establish intravenous access in symptomatic patients. Monitor cardiac rhythm.

Monitor fluid balance carefully to avoid fluid overload if renal failure supervenes; monitor plasma electrolytes to detect disturbances (particulary hyperkalemia) as early as possible, and monitor hematocrit.

Patients who are comatose or hypotensive should be treated in the conventional manner.

Consider dopamine for hypotension or oligonuria, or norepinephrine in cases of severe resistant shock.

Observe patients who have inhaled arsine for up to 24 hours. Follow up as clinically indicated.

Inhalation Exposure

Administer supplemental oxygen by mask to patients who have respiratory symptoms. Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Also consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Arsine poisoning is not

known to pose additional risk during the use of bronchial or cardiac sensitizing agents.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed cautioning for myocardial variability.

If hemolysis develops, initiate urinary alkalinization. Add 50 to 100 mEq of sodium bicarbonate to one liter of 5% dextrose in 0.25 normal saline and administer intravenously at a rate that maintains urine output at 2 to 3 mL/kg/hour. Maintain alkaline urine (i.e., pH >7.5) until urine is hemoglobin free. Closely monitor serum electrolytes, calcium, BUN, creatinine, hemoglobin, and hematocrit.

Consider hemodialysis if renal failure is severe. (Although hemodialysis will assist the patient who has renal failure, it will not effectively remove the arsine-hemoglobin or arsine-haptoglobin complexes deposited in the renal tubules.) Blood transfusions may be necessary if hemolysis causes severe anemia.

Skin Exposure

In case of frostbite injury, irrigate with lukewarm (42 °C) water according to standard treatment.

Eye Exposure

In case of frostbite injury, ensure that thorough warming with lukewarm water or saline has been completed. Examine the eyes for corneal damage and treat appropriately. Immediately consult an ophthalmologist for patients who have corneal injuries.

Antidotes and Other Treatments

There are no antidotes for arsine poisoning.

Do not administer arsenic chelating drugs. Although BAL (British Anti-Lewisite, dimercaprol) and other chelating agents are acceptable for arsenic poisoning, they are not effective antidotes for arsine poisoning and are not recommended.

Laboratory Tests

If significant exposure is a possibility and transfusion is considered, obtain a blood sample for type and screen. Laboratory tests to determine hemolysis include CBC with peripheral smear, urinalysis, and plasma free hemoglobin and haptoglobin analyses. Other useful studies include renal-function tests (e.g., BUN, creatinine), and determinations of serum electrolytes and bilirubin levels.

Consider monitoring urinary arsenic excretion to assess the severity of poisoning. Note that the amount of arsine that must be absorbed to cause significant poisoning may not be large.

Disposition and Follow-up

Decisions to admit or discharge a patient should be based on exposure history, physical examination, and test results.

Delayed Effects

All patients who have suspected arsine exposure should be carefully observed for 24 hours, including hourly urine output. Onset of hemolysis may be delayed for up to 24 hours, and acute renal failure may not become evident for as long as 72 hours after exposure.

Patient Release

Patients who have no signs of hemolysis may be discharged after 24 hours of observation with instructions to seek medical care promptly if symptoms develop (see the *Arsine—Patient Information Sheet* below). Released patients should also be instructed to rest and to drink plenty of fluids.

Follow-up

Obtain the name of the patient's primary care physician so that the hospital can send a copy of the ED visit to the patient's doctor.

All patients should have repeat urine and blood laboratory tests in 12 to 24 hours. Patients who have corneal injuries should be reexamined within 24 hours.

If severe hemolysis has occurred, anemia may persist for several weeks.

Polyneuropathy and alteration in mental status are reported to have followed arsine poisoning after a latency of 1 to 6 months. Patients should be evaluated periodically by their physician for several months; these examinations should include hematological and urinalysis tests.

Reporting

If a work-related incident has occurred, you may be legally required to file a report; contact your state or local health department.

Other persons may still be at risk in the setting where this incident occurred. If the incident occurred in the workplace, discussing it with company personnel may prevent future incidents. If a public health risk exists, notify your state or local health department or other responsible public agency. When appropriate, inform patients that they may request an evaluation

of their workplace from OSHA or NIOSH. See Appendices III and IV for a list of agencies that may be of assistance.

Arsine
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to arsine.

What is arsine?
Arsine is a colorless, flammable gas that does not burn the eyes, nose, or throat. At high concentrations it has a garlic-like or fishy smell, but a person can be exposed to a hazardous concentration of arsine and may not be able to smell it. Arsine is widely used in the manufacturing of fiberoptic equipment and computer microchips. It is sometimes used in galvanizing, soldering, etching, and lead plating. Certain ores or metals may contain traces of arsenic. If water or acid contacts these ores or metals, they may release arsine gas at hazardous levels.

What immediate health effects can result from arsine exposure?
Breathing in arsine gas can be very harmful, even in small quantities. The main effect of arsine poisoning is to destroy red blood cells, causing anemia (lack of red blood cells) and kidney damage (from circulating red-blood-cell debris). Initially, exposed individuals may feel relatively well. Within hours after a serious exposure, the victim may develop headache, weakness, shortness of breath, and back or stomach pain with nausea and vomiting; the urine may turn a dark red, brown or greenish color. The skin may become yellow or bronze in color, the eyes red or green. Generally, the more serious the exposure, the worse the symptoms. Although arsine is related to arsenic, it does not produce the usual signs and symptoms of arsenic poisoning.

Can arsine poisoning be treated?
There is no antidote for arsine, but its effects can be treated. A doctor may give the exposed patient fluids through a vein to protect the kidneys from damage. For severe poisoning, blood transfusions and cleansing of the blood (hemodialysis) may be needed to prevent worsening kidney damage.

Are any future health effects likely to occur?
After a serious exposure, symptoms usually begin within 2–24 hours (see the *Follow-up Instructions*). Most people do not develop long-term effects from a single, small exposure to arsine. In rare cases, permanent kidney damage or nerve damage has developed after a severe exposure. Repeated exposures to arsine over a long period of time might cause skin or lung cancer, but this has not been studied.

What tests can be done if a person has been exposed to arsine?
Specific tests can show the amount of arsenic in urine, but this information may or may not be helpful to the doctor. Standard tests of blood, urine, and other measures of health may show whether exposure has caused serious injury to the lungs, blood cells, kidneys, or nerves. Since toxic effects of arsine poisoning may be delayed, testing should be done in all cases of suspected exposure to arsine.

Where can more information about arsine be found?
More information about arsine can be obtained from your regional poison control center; your state, county, or local health department; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in occupational and environmental health. If the exposure happened at work, you may wish to discuss it with your employer, the Occupational Safety

and Health Administration (OSHA), or the National Institute for Occupational Safety and Health (NIOSH). Ask the person who gave you this form for help in locating these telephone numbers.

Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow *only* the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24–72 hours, especially:
- unusual fatigue or weakness
- shortness of breath
- abnormal urine color (red or brown)
- stomach pain or tenderness
- unusual skin color (yellow or bronze)

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.
[ ] Call for an appointment with Dr. _____ in the practice of _____. When you call for your appointment, please say that you were treated in the Emergency Department at _ _____ Hospital by _____ and were advised to be seen again in _____ days.
[ ] Return to the Emergency Department/ _____ Clinic on (date) _____at __ _____ AM/PM for a follow-up examination.
[ ] Do not perform vigorous physical activities for 1 to 2 days.
[ ] You may resume everyday activities including driving and operating machinery.
[ ] Do not return to work for _____ days.
[ ] You may return to work on a limited basis. See instructions below.
[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.
[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.
[ ] Avoid taking the following medications: _____
[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: _____ _____ _____
[ ] Other instructions: _____ _____ _____

- Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.

- You or your physician can get more information on the chemical by contacting: _____ _____ or _____, or by checking out the following Internet Web sites: _____; _____.

Signature of patient _____ Date _____

Signature of physician _____ Date _____

Benzene (C_6H_6)
CAS 71-43-2; UN 1114

Synonyms include benzol, coal tar naphtha, phenyl hydride, and cyclohexatriene.

- **Persons exposed only to benzene vapor do not pose substantial risks of secondary contamination to others. Persons whose clothing or skin is contaminated with liquid benzene can cause secondary contamination by direct contact or through off-gassing vapor.**
- **Benzene is a highly volatile, flammable liquid. Its vapor is heavier than air and may accumulate in low-lying areas. Benzene's sweet aromatic odor generally provides adequate warning of hazardous concentrations for acute exposure.**
- **Benzene is absorbed rapidly and extensively after inhalation and ingestion. It is absorbed less extensively through intact skin; however, percutaneous absorption may contribute to total body burden.**

Description

At room temperature, benzene is a clear, colorless-to-light yellow liquid that is highly flammable. Because it is volatile, it can spread to a distant source of ignition. Benzene has a sweet aromatic odor. It is only slightly soluble in water but readily soluble with most organic solvents. Benzene is less dense than water and will float on the surface of water.

Routes of Exposure

Inhalation

Most exposures to benzene occur by inhalation. Its odor threshold generally provides adequate warning of acutely hazardous concentrations (odor threshold 1.5–5 ppm). Benzene vapor is heavier than air and may cause asphyxiation in enclosed, poorly ventilated, or low-lying areas.

Children exposed to the same levels of benzene vapor as adults may receive larger dose because they have greater lung surface area:body weight ratios and increased minute volumes:weight ratios. In addition, they may be exposed to higher levels than adults in the same location because of their short stature and the higher levels of benzene vapor found nearer to the ground.

Skin/Eye Contact

Benzene splashed in the eyes can result in pain and corneal injury. Repeated or prolonged skin contact with liquid benzene can degrease the skin, causing it to crack and peel. Percutaneous absorption is slow through intact skin; however, benzene absorbed through the skin may contribute to systemic toxicity.

Children are more vulnerable to toxicants absorbed through the skin because of their larger surface area:weight ratio.

Ingestion

Acute toxic effects can result from ingestion of benzene. A burning sensation of the oral mucous membranes, esophagus, and stomach may occur after ingestion. Nausea, vomiting, and abdominal pain may also result from oral ingestion.

Source/Uses

Benzene is the 17th most abundantly produced chemical in the United States. It is obtained primarily from crude petroleum. Benzene is used mainly as a raw material for synthesizing chemicals such as styrene, phenol, and cyclohexane and for manufacturing dyes, detergents, explosives, rubber, plastics, and pharmaceuticals. It is found in trace amounts in cigarette smoke and drinking water, as a contaminant in some industrial solvents, and as a constituent of motor fuels, unleaded gasoline in particular.

Standards and Guidelines

OSHA PEL (permissible exposure limit) = 1 ppm (averaged over an 8-hour workshift).

OSHA STEL (short-term exposure limit) = 5 ppm (15-minute sample).

NIOSH IDLH (immediately dangerous to life or health) = 500 ppm.

AIHA ERPG-2 (maximum airborne concentration below which it is believed that nearly all persons could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action) = 150 ppm.

Physical Properties

Description: Clear, colorless-to-light-yellow liquid

Warning properties: Sweet solvent odor at 1.5 to 5 ppm. Adequate warning for acute exposure; inadequate for chronic exposure as olfactory fatigue can occur.

Molecular weight: 78.1 daltons

Boiling point (760 mm Hg): 176 °F (80.1 °C)

Freezing point: 41.9 °F (5.5 °C)

Specific gravity: 0.88 (water = 1)

Vapor pressure: 75 mm Hg at 68 °F (20 °C)

Gas density: 2.8 (air = 1)

Water solubility: Slightly water soluble (0.07% at 68 °F) (20 °C)

Flammability: Flammable at temperatures ~12 °F (-11 °C)

Flammable range: 1.2 to 7.8% (concentration in air).

Incompatibilities

Benzene reacts explosively with strong oxidizers, such as perchlorates and nitric acid, and many fluorides.

Health Effects

- **Benzene is mildly irritating to the skin, eyes, and respiratory tract.**
- **Benzene may cause central nervous system depression and arrhythmias to persons acutely exposed. Longer-term exposure to benzene may cause anemia, alterations to the immune system, and leukemia.**

Acute Exposure

The effects of acute exposure to high concentrations of benzene (neurological, dermal, respiratory, gastrointestinal) can be evident immediately after exposure. Neurological effects appear to be due primarily to the direct effects of benzene on the central nervous system. The anesthetic action of benzene on the central nervous system is similar to that of other anesthetic gases, first inducing excitation followed by depression, and if exposure continues, death through respiratory failure. Dermal, respiratory, and gastrointestinal effects are due to benzene's irritative properties.

Benzene is metabolized by the liver and its metabolites are excreted by the kidney. Benzene toxicity in large part is due to generation of oxygen radicals via cytochrome P450. Benzene's water soluble metabolites which are formed in the liver are responsible for its hematopoietic effects. Benzene can cause death in acute exposure primarily by its anesthetic properties (respiratory arrest) or its myocardial sensitizing properties (fatal arrhythmias).

Children do not always respond to chemicals in the same way that adults do. In addition, children of different ages (e.g., *in utero*, infants, toddlers, older children) may have different responses to certain chemical exposures, and thus, different protocols for managing their care may be needed.

CNS

Generally, symptoms of CNS toxicity are apparent immediately after inhalation of high concentrations of benzene (3,000 ppm for 5 minutes), and 30 to 60 minutes after ingestion. Mild effects include headache, lightheadedness, dizziness, confusion, nausea, impaired gait, and blurred vision. More severe effects include tremors, respiratory depression, confusion, loss of consciousness, coma, and death. Unconsciousness may be prolonged, although most victims regain consciousness rapidly after they are removed from exposure.

Respiratory

Acute exposure to benzene vapor may irritate the mucous membranes of the respiratory tract. With massive exposure (20,000 ppm for 5 minutes), accumulation of fluid in the lungs and respiratory arrest may ensue. Pulmonary aspiration of toxic vomitus or ingested liquid benzene may cause severe hemorrhagic inflammation of the lungs.

Cardiovascular

Exposure to very high concentrations (more than 1,000 ppm) of benzene may lower the threshold of the heart muscle to the effects of epinephrine, resulting in life threatening arrhythmias such as ventricular fibrillation. These effects are usually reversible if exposure is terminated.

Dermal

Benzene can cause skin irritation and because it is a lipid solvent it degreases the skin, particularly after prolonged or repeated contact with the liquid. Locally, benzene can produce erythema, a burning sensation, and in more severe cases, edema and even blistering.

Because of their larger surface area:body weight ratio, children are more vulnerable than adults to toxicants absorbed through the skin.

Gastrointestinal

If swallowed, benzene can irritate the stomach, causing nausea, vomiting, and diarrhea. The estimated lethal oral dose is 100 mL (about 1 g/kg, for a 75 kg man), although as little as 15 mL or 50 mg/kg has caused death.

Ocular

High concentrations of benzene vapor can cause eye irritation and visual blurring. When splashed in the eyes, benzene may cause burning pain and sloughing of the eye surface.

Potential Sequelae

Recovery from moderate exposure to benzene may take 1 to 4 weeks. During this time, patients may continue to experience impaired gait, nervous irritability, and breathlessness for 2 weeks. Cardiac distress and yellow coloration of the skin may persist for up to a month.

Chronic Exposure

Repeated exposure to high levels of benzene (200 ppm) can result in persistent CNS effects. Chronic benzene exposure in the workplace has been associated with hematologic disorders (i.e., thrombocytopenia, aplastic anemia, pancytopenia, and acute myelgenous leukemia). Chronic exposure may be more serious for children because of their potential longer latency period.

Carcinogenicity

The Department of Health and Human Services has determined that benzene is a known human carcinogen. Hematologic neoplasms such as acute myelogenous leukemia have been documented to occur with chronic exposures as low as 10 ppm benzene. Other neoplasms have been documented in animal models.

Reproductive and Developmental Effects

Benzene is not included in *Reproductive and Developmental Toxicants*, a 1991 report published by the U.S. General Accounting Office (GAO) that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences. However, it has been shown to cross the placenta in humans and to be fetotoxic in animals. No information was located as to the presence of benzene in breast milk or of the potential transfer to nursing infants.

Benzene has very weak genotoxicity, Nonetheless, special consideration regarding the exposure of pregnant women is warranted. Medical counseling is recommended for the acutely exposed pregnant woman.

Prehospital Management

- **Victims exposed only to benzene vapor do not pose significant risks of secondary contamination to rescuers outside the Hot Zone. Victims whose clothing or skin is contaminated with liquid benzene can secondarily contaminate response personnel by direct contact or through off-gassing vapor.**
- **Benzene may cause central nervous system depression, cardiac arrhythmias, cutaneous burns and respiratory irritation.**
- **There is no specific antidote for benzene. Treatment consists of support of respiratory and cardiovascular functions.**

Hot Zone

Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if rescuers have not been trained in its use, assistance should be obtained from a local or regional HAZMAT team or other properly equipped response organization.

Rescuer Protection

Benzene vapor is absorbed well by inhalation and is a mild respiratory-tract irritant. The liquid is a mild skin irritant with slow skin absorption.

Respiratory Protection: Positive-pressure, self-contained breathing apparatus (SCBA) is recommended in response situations that involve exposure to potentially unsafe levels of benzene vapor (i.e., greater than 300 ppm for 1 hour).

Skin Protection: Chemical-protective clothing is not generally required when only vapor exposure is expected because benzene vapor is neither irritating nor absorbed well through the skin. Chemical-protective clothing is recommended when contact with liquid benzene is anticipated because skin irritation and dermal absorption occur.

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible.

Victim Removal

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be removed on backboards or gurneys; if these are not available, carefully carry or drag victims to safety.

Consider appropriate management of chemically-contaminated children, such as measures to reduce separation anxiety if a child is separated from a parent or other adult.

Decontamination Zone

Victims exposed only to benzene vapor who have no skin or eye irritation do not need decontamination. They may be transferred immediately to the Support Zone. All others require decontamination as described below.

Rescuer Protection

If exposure levels are determined to be safe, decontamination may be conducted by personnel wearing a lower level of protection than that worn in the Hot Zone (described above).

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. Stabilize the cervical spine with a collar and a backboard if trauma is suspected. Administer supplemental oxygen as required. Assist ventilation with a bag-valve-mask device if necessary.

Basic Decontamination

Victims who are able and cooperative may assist with their own decontamination. Remove and double-bag contaminated clothing and personal belongings. Leather absorbs benzene; items such as leather shoes, gloves, and belts may require disposal by incineration.

Flush liquid-exposed skin and hair with plain water for 2 to 3 minutes, then wash with mild soap. Rinse thoroughly with water.

Flush exposed or irritated eyes with plain water or saline for at least 15 minutes or until pain resolves. Remove contact lenses if easily removable without additional trauma to the eye.

In case of ingestion, **do not induce emesis**. Administer a slurry of activated charcoal if the victim is alert and is able to swallow (at 1 gm/kg, usual adult dose 60–90 g, child dose 25–50 g).

If patient exhibits seizures, administer a benzodiazaepine; Diazepam (adult: 5 to 10 mg i.v., repeat every 10 to 15 minutes as needed; child: 0.2 to 0.5 mg/kg i.v., repeat every 5 minutes as needed) or Lorazepam (adult: 4 to 8 mg i.v.; child: 0.05 to 0.1 mg/kg i.v.). Consider phenobarbital and/or phenytoin or fosphenytoin if seizures are uncontrollable or recur after diazepam 30 mg (adults) or 10 mg (children >5 years).

Consider appropriate management of chemically contaminated children at the exposure site. Also, provide reassurance to the

child during decontamination, especially if separation from a parent occurs. If possible, seek assistance from a child separation expert.

Transfer to Support Zone

As soon as basic decontamination is complete, move the victim to the Support Zone.

Support Zone

Be certain that victims have been decontaminated properly (see Decontamination Zone above). Persons who have undergone decontamination or have been exposed only to vapor pose no serious risks of secondary contamination. Support Zone personnel require no specialized protective gear in such cases.

ABC Reminders

Quickly access for a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Ensure adequate respiration and pulse. Administer supplemental oxygen as required. Establish intravenous access if necessary. Place on a cardiac monitor.

Additional Decontamination

Continue irrigating exposed skin and eyes, as appropriate.

In cases of ingestion, **do not induce emesis**. If activated charcoal has not been given previously, administer a slurry (at 1 gm/kg, usual adult dose 60–90 g, child dose 25–50 g) if the patient is alert and able to swallow.

Advanced Treatment

Monitor for arrhythmia, hypotension, respiratory depression, and hypoxia. Evaluate for hypoglycemia and electrolyte disturbances.

Patients who are comatose or have cardiac arrhythmias should be treated according to ALS protocols.

In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, perform cricothyroidotomy if equipped and trained to do so.

Use extreme caution when treating patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Wherever possible avoid the use of sympathomimetics in benzene exposed patients. Try

to avoid administering epinephrine due to the possible myocardial sensitizing effect of benzene.

If massive exposure is suspected or if the patient is hypotensive, intravenous saline or lactated Ringer's solution should be infused. For adults, bolus 1,000 mL/hour intravenous saline or lactated Ringer's solution if blood pressure is under 80 mm Hg; if systolic pressure is over 90 mm Hg, an infusion rate of 150 to 200 mL/hour is sufficient. For children with compromised perfusion administer a 20 mL/kg bolus of normal saline over 10 to 20 minutes, then infuse at 2 to 3 mL/kg/hour.

Transport to Medical Facility

Only decontaminated patients or patients not requiring decontamination should be transported to a medical facility. "Body bags" can increase exposure and are not recommended.

Report to the base station and the receiving medical facility the condition of the patient, treatment given, and estimated time of arrival at the medical facility.

If benzene has been ingested, prepare the ambulance in case the victim vomits toxic material. Have ready several towels and open plastic bags to quickly clean up and isolate vomitus. Take measures to avoid pulmonary aspiration, i.e., place patient in lateral position.

Multi-Casualty Triage

Consult with the base station physician or the regional poison control center for advice regarding triage of multiple victims.

Patients who have histories or evidence of substantial exposure and all persons who have ingested benzene should be transported to a medical facility for evaluation. Patients who have histories of cardiac dysrhythmias or other heart conditions are at special risk. These patients should also be transported for evaluation.

Patients who have inhalation exposure who did not experience alteration of consciousness (e.g., confusion, syncope, unconsciousness) are not likely to have had a significant exposure. After their names, addresses, and telephone numbers are recorded, these patients may be released from the scene with instructions to rest and to seek medical care promptly if symptoms develop (see *Patient Information Sheet* below).

Emergency Department Management

- **Hospital personnel can be secondarily exposed by direct contact or by vapor off-gassing from heavily contaminated clothing or skin. Patients do not pose contamination risks after clothing is removed and the skin is washed. Toxic vomitus from patients who have ingested benzene may off-gas benzene vapor.**
- **Benzene may cause central nervous system depression, cardiac dysrhythmias, cutaneous burns, and respiratory irritation.**
- **There is no specific antidote for benzene. Treatment consists of supportive measures.**

Decontamination Area

Previously decontaminated patients and patients exposed only to benzene vapor who have no skin or eye irritation may be transferred immediately to the Critical Care Area. Other patients will require decontamination as described below.

Be aware that use of protective equipment by the provider may cause fear in children, resulting in decreased compliance with further management efforts.

Because of their relatively larger surface area:weight ratio, children are more vulnerable to toxicants absorbed through the skin. Also, emergency room personnel should examine children's mouths because of the frequency of hand-to-mouth activity among children.

ABC Reminders

Evaluate and support airway, breathing, and circulation. Children may be more vulnerable to corrosive agents than adults because of the smaller diameter of their airways. In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, perform cricothyroidotomy if equipped and trained to do so.

Use extreme caution when treating patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Wherever possible avoid

the use of sympathomimetics in benzene exposed patients. Try to avoid administering epinephrine due to the possible myocardial sensitizing effect of benzene.

Patients who are hypotensive or have seizures should be treated in the conventional manner.

In the patient who has suffered from seizures, coma, or cardiac arrhythmia evaluate for acidosis and treat appropriately by administering intravenously sodium bicarbonate (initial adult dose = 1 ampule; pediatric dose = 1 Eq/kg). Further bicarbonate therapy should be guided by arterial blood gas measurements.

Basic Decontamination

Patients who are able and cooperative may assist with their own decontamination. If the patient's clothing is wet with benzene, remove and double-bag the contaminated clothing and personal belongings.

Flush exposed skin with soap and water for 2 to 5 minutes (preferably under a shower). Rinse thoroughly with water.

Irrigate irritated eyes with copious amounts of tepid water for at least 15 minutes or until pain resolves. Remove contact lenses if present and if removable without additional trauma to the eye.

In cases of ingestion, **do not induce emesis**. (More information is provided in Ingestion Exposure under *Critical Care Area* below.) If not already done, administer a slurry of activated charcoal (at 1 gm/kg, usual adult dose 60–90 g, usual child dose 25–50 g). A soda can and a straw may be of assistance when offering charcoal to a child.

Critical Care Area

Be certain that appropriate decontamination has been carried out (see *Decontamination Area* above).

ABC Reminders

Evaluate and support airway, breathing, and circulation as in ABC Reminders above. Children may be more vulnerable to corrosive agents than adults because of the smaller diameter of their airways. Establish intravenous access in seriously ill patients. Continuously monitor cardiac rhythm. Take measures to minimize patient excitation, excessive catecholamine release can induce life threatening arrhythmia due to benzene's sensitizing effect on the myocardium.

Patients who are comatose, hypotensive, or have seizures or cardiac arrhythmia should be treated in the conventional manner.

Inhalation Exposure

Administer supplemental oxygen by mask to patients who have respiratory symptoms. Use extreme caution when treating patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Wherever possible avoid the use of sympathomimetics in benzene exposed patients. Try to avoid administering epinephrine due to the possible myocardial sensitizing effect of benzene.

Skin Exposure

If the skin was in prolonged contact with liquid benzene, irritation may result; treat as thermal burns.

Because of their larger surface area:weight ratio, children are more vulnerable to toxicants absorbed through the skin.

Eye Exposure

Continue irrigation for at least 15 minutes. If eye irritation or injury is evident, test visual acuity. Examine the eyes for corneal damage and treat appropriately. Immediately consult an ophthalmologist for patients who have severe corneal injuries.

Ingestion Exposure

Do not induce emesis.

Consider gastric lavage with a small nasogastric tube if: (1) a large dose has been ingested; (2) the patient's condition is evaluated within 30 minutes; (3) the patient has oral lesions or persistent esophageal discomfort; and (4) the lavage can be administered within 1 hour of ingestion. Care must be taken when placing the gastric tube because blind gastric-tube placement may further injure the chemically damaged esophagus or stomach.

If the patient is alert, administer a slurry of activated charcoal if not done previously (at 1 gm/kg, usual adult dose 60–90 g, child dose 25–50 g). A soda can and straw may be of assistance when offering charcoal to a child. When small amounts of benzene have been ingested, activated charcoal may be administered orally without emptying the gut.

Consider endoscopy to evaluate the extent of gastrointestinal tract injury. Extreme throat swelling may require endotracheal intubation or cricothyroidotomy. Gastric lavage is useful in

certain circumstances to remove caustic material and prepare for endoscopic examination.

Because children do not ingest large amounts of corrosive materials, and because the risk of perforation from NG intubation, lavage is discouraged in children unless intubation is performed under endoscopic guidance.

Antidotes and Other Treatments

There is no antidote for benzene. Hemodialysis and hemoperfusion are not effective.

Laboratory Tests

The diagnosis of acute benzene toxicity is primarily clinical, based on effects on neurological signs and symptoms and respiratory effects. However, laboratory testing is useful for monitoring the patient and evaluating complications. Routine laboratory studies for all exposed patients include CBC, glucose, and electrolyte determinations. Additional tests for patients who have substantial benzene exposure include ECG monitoring, urinalysis, determinations of BUN, creatinine, and liver function test. Chest radiography and pulse oximetry (or ABG measurements) are recommended for severe inhalation exposure or if pulmonary aspiration is suspected.

Blood levels of benzene or phenol, a metabolite of benzene, may be used to document exposure, although they are not useful clinically. The OSHA benzene standard mandates that urinary phenol-testing be performed on all workers exposed to benzene in an emergency situation (see *Follow-up* below). However, other factors that may contribute to a high phenol level must be evaluated, such as ingestion of benzoate preservatives, certain medications (e.g., Pepto-Bismol and Chloraseptic), and smoking. Other urinary metabolites of benzene can also be used to document exposure. The ACGIH biological exposure index for benzene is 25 µg S-phenyl-N-acetyl cysteine (PhAC)/g creatinine, and muconic acid is also a sensitive marker of benzene.

Disposition and Follow-up

Consider hospitalizing symptomatic patients who have significant inhalation exposure and patients who have ingested large amounts of benzene.

Delayed Effects

Observe hospitalized patients for signs of acute tubular necrosis, encephalopathy, and dysrhythmias. In addition, patients exposed by inhalation should be observed for signs of pulmonary edema, and those who have ingested benzene should be watched for signs of aspiration pneumonitis, which can occur up to 72 hours after exposure.

Patient Release

Patients who have remained asymptomatic 6 to 12 hours after exposure may be discharged, advised to rest and to seek medical care promptly if symptoms develop (see the *Benzene—Patient Information Sheet* below).

Follow-up

Obtain the name of the patient's primary care physician so that the hospital can send a copy of the ED visit to the patient's doctor.

Patients who have received significant exposures (as determined by histories or clinical signs and symptoms such as dysrhythmias, syncope, or confusion) should be monitored for hematopoietic effects. OSHA mandates that acutely exposed workers who have urinary phenol levels above 75 mg/L receive periodic CBCs (at least monthly for 3 months) to monitor potential bone marrow effects. Patients who have corneal injuries should be reexamined within 24 hours.

Reporting

If a work-related incident has occurred, you may be legally required to file a report; contact your state or local health department.

Other persons may still be at risk in the setting where this incident occurred. If the incident occurred in the workplace, discussing it with company personnel may prevent future incidents. If a public health risk exists, notify your state or local health department or other responsible public agency. When appropriate, inform patients that they may request an evaluation of their workplace from OSHA or NIOSH. See Appendices III and IV for a list of agencies that may be of assistance.

Benzene
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to benzene.

What is benzene?
Benzene is a clear, colorless liquid with a sweet odor when in pure form. It burns readily. Benzene is obtained from crude petroleum. Small amounts may be found in products such as cigarette smoke, paints, glues, pesticides, and gasoline.

What immediate health effects can be caused by exposure to benzene?
Breathing benzene vapor in small amounts can cause headache, dizziness, drowsiness, or nausea. With more serious exposure, benzene may cause sleepiness, stumbling, irregular heartbeats, fainting, or even death. Benzene vapors are mildly irritating to the skin, eyes, and lungs. If liquid benzene contacts the skin or eyes, it may cause burning pain. Liquid benzene splashed in the eyes can damage the eyes. The degree of symptoms depends on the amount of exposure. Special consideration regarding the exposure of pregnant women is warranted since benzene has been shown to have a small negative effect on genes and crosses the placenta; thus, medical counseling is recommended for the acutely exposed pregnant woman.

Can benzene poisoning be treated?
There is no specific antidote for benzene, but its effects can be treated, and most exposed persons recover fully. Persons who have experienced serious symptoms may need to be hospitalized.

Are any future health effects likely to occur?
A single small exposure from which a person recovers quickly is not likely to cause delayed or long-term effects. After a severe exposure, some symptoms may take a few days to develop. Repeated exposure to benzene may cause a blood disorder (i.e., aplastic anemia and pancytopenia) and cancer of blood-forming cells (i.e., leukemia). Aplastic anemia and leukemia have been reported in some workers exposed repeatedly to benzene over long periods of time.

What tests can be done if a person has been exposed to benzene?
Specific tests for the presence of benzene in blood generally are not useful to the doctor. Phenol, muconic acid or S-phenyl-N-acetyl cysteine (PhAC), breakdown products of benzene, can be measured in urine to prove benzene exposure. Other tests may show whether injury has occurred in the heart, kidneys, blood, or nervous system. Testing is not needed in every case.

Where can more information about benzene be found?
More information about benzene can be obtained from your regional poison control center; the state, county, or local health department; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in occupational and environmental health. If the exposure happened at work, you may wish to discuss it with your employer, the Occupational Safety and Health Administration (OSHA), or the National Institute for Occupational Safety and Health (NIOSH). Ask the person who gave you this form for help in locating these telephone numbers.

Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow *only* the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:

- eye and skin irritation
- bronchial irritation, cough, hoarseness, tightness in chest
- drowsiness, dizziness, headache, convulsions
- irregular heart beats

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.
[ ] Call for an appointment with Dr. _____ in the practice of _____.
When you call for your appointment, please say that you were treated in the Emergency Department at _ _____ Hospital by _____ and were advised to be seen again in _____ days.
[ ] Return to the Emergency Department/ _____ Clinic on (date) _____
at _____ AM/PM for a follow-up examination.
[ ] Do not perform vigorous physical activities for 1 to 2 days.
[ ] You may resume everyday activities including driving and operating machinery.
[ ] Do not return to work for _____ days.
[ ] You may return to work on a limited basis. See instructions below.
[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.
[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.
[ ] Avoid taking the following medications: _____
[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: __
_____
_____
[ ] Other instructions: _____
_____
_____

- Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.

- You or your physician can get more information on the chemical by contacting: _____ _____ or _____, or by checking out the following Internet Web sites: _____; _____.

Signature of patient _____ Date _____

Signature of physician _____ Date _____

Blister Agents
Lewisite (L) ($C_2H_2AsCl_3$) CAS 541-25-3, UN 1556; and
Mustard-Lewisite Mixture (HL) CAS Number not available, UN 2810

Synonyms for Lewisite include L, arsine (2-chlorovinyl) dichloro-, arsenous dichloride (2-chloro-ethenyl)-, chlorovinylarsine dichloride, 2-chlorovinyldichloroarsine, beta-chlorovinyldichloroarsine, dichloro-(2-chlorovinyl)arsine, EA1034.

Synonyms for Mustard-Lewisite include HL and Sulfur Mustard/Lewisite.

Persons whose skin or clothing is contaminated with liquid Lewisite or Mustard-Lewisite Mixture can contaminate rescuers by direct contact or through off-gassing vapor.

- **Lewisite is an oily, colorless liquid with an odor like geraniums. Mustard-Lewisite Mixture is a liquid with a garlic-like odor. Volatility of both agents is significant at high ambient temperatures.**
- **Lewisite and Mustard-Lewisite Mixture are rapidly absorbed by the skin causing immediate pain and burning followed by erythema and blistering. Ocular exposure to Lewisite or the mixture may cause immediate incapacitating burning and inflammation of the cornea and conjunctiva. Inhalation damages the respiratory tract epithelium and may cause death.**

Description

Lewisite is an organic arsenical known for its vesicant properties. Pure Lewisite is an oily, colorless liquid, while impure Lewisite is amber to black. It remains a liquid at low temperatures and is persistent in colder climates. It has the odor of geraniums.

Mustard-Lewisite Mixture is a liquid mixture of distilled Mustard (HD) and Lewisite. Due to its low freezing point, the mixture remains a liquid in cold weather and at high altitudes. The mixture with the lowest freezing point consists of 63% Lewisite and 37% Mustard. It has a garlic-like odor.

Routes of Exposure

Inhalation

Exposure to Lewisite vapor at a concentration of 8 mg-min/m^3 causes immediate burning pain of the respiratory tract. Its odor is noted at about 20 mg-min/m^3. The LCt_{50} (the product of concentration times time that is lethal to 50% of the exposed population by inhalation) is approximately 1,500 mg-min/m^3. Exposure to Mustard-Lewisite Mixture vapor induces immediate respiratory tract irritation and severe inflammation after a few

hours latency period. Both agents are readily absorbed from the lungs.

Skin/Eye Contact

Absorption may occur after skin or eye contact with liquid or vapor Lewisite. Absorption across the skin begins within minutes. Vesication is caused by about 14 µg of liquid, and the LD_{50} of liquid on the skin is about 30-50 mg/kg. Liquid Lewisite causes severe eye damage within minutes of contact. The vapor also acts quickly, with pain on contact, followed by edema of the conjunctiva and eyelids, and iritis and corneal damage with high doses.

Systemic absorption may occur following skin or eye exposure to liquid or vapor Mustard-Lewisite Mixture. The mixture causes immediate stinging pain of the skin, with blistering delayed for hours. Graying of the skin will follow within a very short time if exposure is from liquid (because of Lewisite). Erythema and blisters will appear earlier than from mustard alone. Exposure of the eyes to Mustard-Lewisite Mixture produces lacrimation and inflammation of the conjunctiva and cornea. After exposure to low amounts of Lewisite or to the mixture, temporary loss of eyesight may occur because of blepharospasm or eyelid edema. After exposure to high amounts, permanent loss of sight may occur because of corneal damage; however, this is unusual.

Ingestion

Ingestion of either Lewisite or Mustard-Lewisite Mixture is an uncommon route for exposure but can lead to local effects and systemic absorption.

Sources/Uses

Lewisite is an arsenical vesicant that was first synthesized in 1918. Large amounts were produced by the United States to be used in Europe; however, World War I ended while the shipment was at sea and the vessel was sunk. There have been allegations that it was used by Japan against Chinese forces in the late 1930s; however, there are no confirmed reports that it has been used in warfare, although it may be stockpiled by some countries. Destruction of U.S. stockpiles of chemical agents, including Lewisite, was mandated by the Chemical Weapons Convention to take place before April 2007.

Mustard-Lewisite Mixture is a mixture of distilled Mustard and Lewisite developed to achieve a lower freezing point for ground dispersal and aerial spraying.

Standards and

Guidelines

Lewisite and Mustard-Lewisite Mixture: Airborne Exposure Limit (as recommended by the Surgeon General's Working Group, U.S. Department of Health and Human Services) = 0.003 mg/m^3 as a time-weighted average (TWA) for the workplace and a 72-hour TWA for the general population.

Physical Properties

Table 1. Physical Properties of Lewisite and Mustard-Lewisite Mixture

Property	Lewisite	Mustard-Lewisite Mixture
Description	Oily, colorless liquid	Dark, oily liquid
Warning properties	Odor like geraniums	Garlic-like odor
Molecular weight	207.32	
Boiling point	(760 mm Hg) = 374 °F (190 °C)	(760 mm Hg) = Indefinite, but below 374 °F (190 °C)
Freezing point	0.4 °F (-18 °C)	13 °F (-25.4 °C) (purified mix), -43.6 °F (-42 °C) (typical production batch)
Specific gravity	1.888 at 68 °F (20 °C) (water = 1.0)	1.60 at 68 °F (20 °C) (water = 1.0)
Vapor pressure	0.394 mm Hg at 68 °F (20 °C)	0.248 at 68 °F (20 °C)
Vapor density	7.1 (air = 1.0)	6.5 (air = 1.0)
Liquid density	1.89 g/cm^3 at 77 °F (25 °C)	1.66 g/cm^3 at 68 °F (20 °C)
Flash point	Does not burn easily. When heated, emits toxic fumes of hydrogen chloride and arsenic.	Data not available on flammability. Toxic fumes of hydrogen chloride, sulfur oxides, and arsenic may be produced in a fire.
Solubility in water	Neglible	Practically insoluble
Volatility	4,480 mg/m3 (20 °C)	No data
NAERG#	153	153

Incompatibilities

Heating causes Lewisite to yield arsenic trichloride, tris-(2-chlorovinyl)arsine, and bis-(2-chlorovinyl)chloroarsine.

Mustard-Lewisite Mixture is rapidly corrosive to brass at 65 °C and will corrode steel at a rate of 0.0001 inches of steel per month at 65 °C. It will hydrolyze into hydrochloric acid, thiodiglycol, and non-vesicant arsenic compounds.

Health Effects

Lewisite and Mustard-Lewisite Mixture are blister agents that are highly and immediately irritating to the skin, eyes, and airways. Contact with liquid or vapor forms may result in skin erythema and blistering, corneal damage and iritis, damage to the airway mucosa, and pulmonary edema.

- **Lewisite is a systemic poison binding with thiol groups in many enzymes and may cause pulmonary edema, diarrhea, capillary leakage, and subsequent hypotension.**
- **Systemic absorption of Mustard-Lewisite Mixture may cause bone marrow suppression due to the alkylating properties of the Mustard component.**

Acute Exposure

Lewisite damages skin, eyes, and airways by direct contact. It inhibits many enzymes, in particular those with thiol groups, such as pyruvic oxidase, alcohol dehydrogenase, succinic oxidase, hexokinase, and succinic dehydrogenase. The exact mechanism by which Lewisite damages cells is not known. Mustard-Lewisite Mixture shares the vesicant properties of Lewisite and the DNA alkylation and cross-linking properties of mustard.

Dermal

Lewisite liquid or vapor produces pain and skin irritation within seconds to minutes after contact. For liquid Lewisite, erythema occurs within 15 to 30 minutes after exposure and blisters start within several hours, developing fully by 12-18 hours. For the vapor, response times are a little longer. The Lewisite blister starts as a small blister in the center of the erythematous area and expands to include the entire inflamed area. Mustard-Lewisite Mixture also produces pain and irritation immediately, and erythema within 30 minutes. Blistering is delayed for hours and tends to cover the entire area of reddened skin.

Ocular

Lewisite vapor causes pain and blepharospasm on contact. Edema of the conjunctiva and eyelids follows, and the eyes may be swollen shut within an hour. With high doses, corneal damage and iritis may follow. Liquid Lewisite causes severe eye damage on contact. Mustard-Lewisite Mixture also causes ocular effects extremely rapidly. Lacrimation, photophobia, and inflammation of the conjunctiva and cornea may occur.

Respiratory

Lewisite and Mustard-Lewisite Mixture are extremely irritating to the respiratory tract mucosa. Burning nasal pain, epistaxis, sinus pain, laryngitis, cough and dyspnea may occur. Necrosis can cause pseudomembrane formation and local airway

obstruction. Pulmonary edema may occur following exposure to high concentrations.

Gastrointestinal

Ingestion or inhalation of Lewisite may cause nausea and vomiting. Ingestion of Mustard-Lewisite Mixture produces severe stomach pains, vomiting, and bloody stools after a 15-20 minute latency period.

Cardiovascular

High-dose exposure to Lewisite may cause "Lewisite shock," a condition resulting from increased capillary permeability and subsequent intravascular fluid loss, hypovolemia, and organ congestion.

Hepatic

Hepatic necrosis may occur due to shock and hypoperfusion following exposure to high levels of Lewisite.

Renal

Exposure to high levels of Lewisite may cause decreased renal function secondary to hypotension.

Hematopoietic

Systemic absorption of Mustard-Lewisite Mixture may induce bone marrow suppression and an increased risk for fatal complicating infections.

Potential Sequelae

Chronic respiratory and eye conditions may persist following exposure to large amounts of Lewisite or Mustard-Lewisite Mixture

Chronic Exposure

Chronic exposure to Lewisite may lead to arsenical poisoning (see Arsenic MMG). Chronic exposure to Mustard-Lewisite Mixture can cause immune sensitization and chronic lung impairment consisting of cough, shortness of breath, and chest pain.

Carcinogenicity

There is only anecdotal evidence for the potential carcinogenicity of Lewisite. However, the data are not definitive and do not support classifying Lewisite as a suspected carcinogen. Repeated exposures to Mustard-Lewisite Mixture over a long period of time may produce respiratory and skin cancer due to the mustard content. There are no specific data regarding the carcinogenicity of Mustard-Lewisite Mixture.

Reproductive and Developmental Effects

Human data regarding reproductive/developmental effects of Lewisite are inconclusive because of limited human exposures. Animal studies show no clear evidence of developmental effects.

Prehospital Management

Victims whose skin or clothing is contaminated with liquid Lewisite or Mustard-Lewisite Mixture can contaminate rescuers by direct contact or through off-gassing vapor.

Lewisite and Mustard-Lewisite Mixture cause immediate pain and irritation to the eyes, skin, and respiratory tract. Systemic effects include capillary leakage and subsequent shock.

Decontamination immediately after exposure decreases tissue damage.

Hot Zone

Responders should be trained and appropriately attired before entering the Hot Zone. If the proper personal protective equipment (PPE) is not available, or if the rescuers have not been trained in its use, call for assistance in accordance with local Emergency Operational Guides (EOG). Sources of such assistance include local HAZMAT teams, mutual aid partners, the closest metropolitan strike system (MMRS) and the U.S. Soldier and Biological Chemical Command (SBCCOM)-Edgewood Research Development and Engineering Center SBCCOM may be contacted (from 0700-1630 EST call 410-671-4411 and from 1630-0700 EST call 410-278-5201), ask for the Staff Duty Officer.

Rescuer Protection

Lewisite and Mustard-Lewisite Mixture are readily absorbed by inhalation and by ocular and dermal contact. Both Lewisite and Mustard-Lewisite Mixture are extremely irritating to the respiratory tract, skin, and eyes.

Respiratory protection: Pressure-demand, self-contained breathing apparatus (SCBA) is recommended in response situations that involve exposure to any level of Lewisite and Mustard-Lewisite Mixture vapor.

Skin/ocular protection: Personal protective equipment (PPE) and butyl rubber chemical protective gloves are recommended at all times when these chemicals are suspected to be involved.

Multi-Casualty Triage

Chemical casualty triage is based on walking feasibility, respiratory status, age, and additional conventional injuries. The triage officer must know the natural course of a given injury, the medical resources immediately available, the current and likely casualty flow, and the medical evacuation capabilities. General principles of triage for chemical exposures are presented in the box on the following page. There are four triage categories:

immediate (priority 1), delayed (priority 2), minimal (priority 3), and expectant (priority 4)**.** Clinical signs and effects of lewisite agents associated with each of these categories are presented in Table 2 (below).

Before transport, all casualties must be decontaminated. If needed, consult with the base station physician or the regional poison control center for advise concerning management of multiple casualties.

Patients who have sustained injury to the skin, eyes, or airways and patients who have ingested Lewisite or Mustard-Lewisite Mixture should be transported to a medical facility for evaluation and treatment.

Consult with the base station physician, closest Metropolitan Medical Response System, or the regional poison control center for advice regarding triage of multiple victims.

General principles of triage for chemical exposures are as follows:

- Check triage tag/card for any previous treatment or triage.
- Survey for evidence of associated traumatic/blast injuries.
- Observe for sweating, labored breathing, coughing/vomiting, secretions.
- Severe casualty triaged as immediate if assisted breathing is required.
- Blast injuries or other trauma, where there is question whether there is chemical exposure, victims must be tagged as immediate in most cases. Blast victims evidence delayed effects such as ARDS, etc.
- Mild/moderate casualty: self/buddy aid, triaged as delayed or minimal and release is based on strict follow up and instructions.
- If there are chemical exposure situations which may cause delayed but serious signs and symptoms, then overtriage is considered appropriate to the proper facilities that can observe and manage any delayed onset symptoms. *For Lewisite and Mustard-Lewisite mixture which do not have delayed effects overtriage would not be approprite.*
- Expectant categories in multi-casualty events are those victims who have experienced a cardiac arrest, respiratory arrest, or continued seizures immediately. Resources should not be expended on these casualties if there are large numbers of casualties requiring care and transport with minimal or scant resources available.

1. *Immediate:* casualties who require lifesaving care within a short time, when that care is available and of short duration. This care may be a procedure that can be done within minutes at an emergency treatment station (e.g., relief of an airway obstruction, administering antidotes) or may be acute lifesaving surgery.

2. *Delayed:* casualties with severe injuries who are in need of major or prolonged surgery or other care and who will require hospitalization, but delay of this care will not adversely affect the outcome of the injury (e.g., fixation of a stable fracture).

3. *Minimal:* casualties who have minor injuries, can be helped by nonphysician medical personnel, and will not require hospitalization.

4. *Expectant:* casualties with severe life-threatening injuries who would not survive with optimal medical care, or casualties whose injuries are so severe that their chance of survival does not justify expenditure of limited resources. As circumstances permit, casualties in this category may be reexamined and possibly be retriaged to a higher category.

Table 2. Triage for Lewisite Casualties

Category (Priority)	Clinical Signs and Symptoms
Immediate (1)	Lower respiratory signs (dyspnea, productive cough)
Delayed (2)	Eye lesions with impaired vision; moderate sized skin lesions for liquid exposure or any body surface burn for vapor exposure; lower respiratory symptoms (cough with sputum production)
Minimal (3)	Minor eye lesion with no vision impairment; small skin lesions in noncritical areas; minor upper respiratory symptoms (cough, sore throat).
Expectant (4)	Lower respiratory signs (dyspnea, necrosis); skin lesion covering more than half of body surface area from liquid exposure

ABC Reminders Quickly ensure that the victim has a patent airway. Maintain adequate circulation. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Apply direct pressure to stop arterial bleeding, if present.

Victim Removal If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be

removed on backboards or gurneys. If these are not available, carefully carry or drag victims to safety.

Decontamination Zone

All victims require decontamination (see *Basic Decontamination*, below). Rapid decontamination is critical to prevent further absorption by the patient and to prevent exposure to others. Decontaminable gurneys and back boards should be used if available when managing casualties in a contaminated area. Decontaminable gurneys are made of a monofilament polypropylene fabric that allows drainage of liquids, does not absorb chemical agents, and is easily decontaminated. Fiberglass back boards have been developed specifically for use in HAZMAT incidents. These are nonpermeable and readily decontaminated. The **Chemical Resuscitation Device** is a bag-valve mask equipped with a chemical agent cannister that can be used to ventilate casualties in a contaminated environment.

Rescuer Protection

Personnel should wear the same level of protection as required in the Hot Zone (see *Rescuer Protection* under *Hot Zone*, above).

ABC Reminders

Quickly ensure that the victim has a patent airway. Maintain adequate circulation. Stabilize the cervical spine with a decontaminable collar and a backboard if trauma is suspected. Administer supplemental oxygen if cardiopulmonary compromise is suspected. Assist ventilation with a bag-valve-mask device equipped with a cannister or air filter if necessary. Direct pressure should be applied to control bleeding, if present.

Basic Decontamination

To significantly reduce tissue damage, the eyes and skin must be decontaminated **within 1 or 2 minutes** after exposure. Flush the eyes immediately with water for about 5 to 10 minutes by tilting the head to the side, pulling eyelids apart with fingers, and pouring water slowly into eyes. Do not cover eyes with bandages.

If exposure to liquid agent is suspected, cut and remove all clothing and wash skin immediately with soap and water. If shower areas are available, showering with water alone will be adequate. However, in those cases where water is in short supply, and showers are not available, an alternative form of decontamination is to use 0.5% sodium hypochlorite solution or absorbent powders such as flour, talcum powder, or Fuller's earth. If exposure to vapor only is certain, remove outer clothing and wash exposed areas with soap and water or 0.5% solution

of sodium hypochlorite. Place contaminated clothes and personal belongings in a sealed double bag.

In cases of ingestion, **do not induce emesis**.

Transfer to Support Zone

As soon as basic decontamination is complete, move the victim to the Support Zone.

Support Zone

Be certain that victims have been decontaminated properly (see *Decontamination Zone* above). Victims who have undergone decontamination pose no serious risk of secondary contamination to rescuers. In such cases, Support Zone personnel require no specialized protective gear.

ABC Reminders

Quickly ensure that the victim has a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Ensure adequate respiration; administer supplemental oxygen if cardiopulmonary compromise is suspected. Maintain adequate circulation. Establish intravenous access if necessary. Attach a cardiac monitor, as needed. Direct pressure should be applied to stop bleeding, if present.

Additional Decontamination

In cases of ingestion, **do not induce emesis**.

Advanced Treatment

Intubate the trachea in cases of respiratory compromise. When the patient's condition precludes endotracheal intubation, perform cricothyrotomy if equipped and trained to do so.

Treat patients who have bronchospasm with bronchodilators.

Patients who are comatose, hypotensive, or have seizures or cardiac dysrhythmias should be treated according to advanced life support (ALS) protocols.

Transport to Medical Facility

Report to the base station and the receiving medical facility the condition of the patient, treatment given, and estimated time of arrival at the medical facility.

Emergency Department Management

Patients whose skin or clothing is contaminated with liquid Lewisite and Mustard-Lewisite Mixture can contaminate rescuers by direct contact or through off-gassing vapor.

Lewisite and Mustard-Lewisite Mixture cause immediate pain and irritation to the eyes, skin, and respiratory tract. Systemic effects include capillary leakage and subsequent shock. The Mustard-Lewisite Mixture may cause bone marrow suppression due to the mustard component.

British Anti-Lewisite (BAL) can be given by intramuscular injection as an antidote for systemic effects but has no effect on the local lesions of the skin, eyes, or airways. Treatment consists primarily of supportive care.

Decontamination Area

Previously decontaminated patients may be treated or held for observation. Others require decontamination as described below.

ABC Reminders

Evaluate and support the airway, breathing, and circulation. Intubate the trachea in cases of respiratory compromise. If the patient's condition precludes intubation, surgically create an airway.

Treat patients who have bronchospasm with bronchodilators.

Patients who are comatose or hypotensive, or have seizures or ventricular dysrhythmias due to other exposures or trauma should be treated in the conventional manner.

Personal Protection

If contaminated patients arrive at the Emergency Department, they must be decontaminated before being allowed to enter the facility. Decontamination can only take place inside the hospital if there is a decontamination facility with negative air pressure and floor drains to contain contamination. Personnel should wear the same level of protection required in the Hot Zone (see *Rescuer Protection* under Hot Zone, above).

Basic Decontamination

Flush the eyes with water for about 5-10 minutes by tilting the head to the side, pulling eyelids apart with fingers, and pouring water slowly into eyes. Do not cover eyes with bandages; if necessary, use dark or opaque goggles to relieve discomfort from photophobia.

If a liquid splash is suspected, clothing must be removed and the patient showered using soap and water. Showering should be accomplished using cool water and enough water pressure to quickly reduce the potential for agent penetration of the skin. If the patient was exposed to vapor only, remove outer clothing and wash exposed skin with soap and water. Place contaminated clothes and personal belongings in a sealed double bag.

In cases of ingestion, **do not induce emesis**. If the victim is alert and able to swallow, give 4 to 8 ounces of milk or water to drink if not already administered. There are no data regarding the efficacy of activated charcoal after exposure to Lewisite or Mustard-Lewisite Mixture.

Critical Care Area

Be certain that appropriate decontamination has been carried out (see *Decontamination Area*, above).

ABC Reminders

Evaluate and support the airway, breathing, and circulation (as in *ABC Reminders*, above). Establish intravenous access and continuously monitor cardiac rhythm in seriously ill patients.

Patients who are comatose or hypotensive, or have seizures or ventricular dysrhythmias due to other exposures or trauma should be treated in the conventional manner.

Triage

Patients arriving at the emergency department directly from the scene of potential exposure (within 30-60 minutes) will have pain or irritation if they were exposed. If they have no pain or irritation, they may be sent home and told to return with the onset of symptoms. Following decontamination, patients with signs of airway involvement should be admitted directly to the Critical Care Unit. Whether in the hospital or not, patients with no symptoms should be observed for 18 to 24 hours. Patients arriving later should be evaluated as described below. The sooner after exposure that symptoms occur, the more likely they are to progress and become severe.

Eye Exposure

Mild conjunctivitis beginning more than 12 hours after exposure is unlikely to progress to a severe lesion. The patient should have a thorough eye examination (including a test for visual acuity), treatment with a soothing eye solution such as Visine or Murine, and be advised to return if there is worsening. Conjunctivitis beginning earlier and other effects such as lid swelling and signs/symptoms of inflammation indicate a need for inpatient care and observation.

Lesions more severe than conjunctivitis should be treated with a topical mydriatic (e.g., atropine), topical antibiotics, and vaseline or similar substance applied to the lid edges several times a day. Consult an ophthalmologist for patients with severe corneal injuries. Topical analgesics should be used only for an initial examination (including slit lamp and a test of visual acuity), but not after. Pain should be controlled with systemic analgesics. Once the lid edema and blepharospasm subside and the eyes are open, dark glasses may reduce the discomfort of photophobia. Some authorities feel that topical steroids (used within the first 24 hours only) may reduce inflammation.

Skin Exposure

A small area of erythema beginning later than 12 hours after exposure is unlikely to progress to a significant lesion. The patient should be examined, treated with a soothing lotion and a systemic analgesic, sent home, and instructed to return if progression occurs. A patient with a significant area of erythema or one seen earlier with a significant area of erythema with or without blistering should be admitted for further evaluation.

Most burns are second degree although third degree burns may occur after liquid exposure. In general, small blisters (i.e., <1 cm) should remain roofed and larger ones (i.e., >1 cm) should be unroofed. This is a controversial issue, but many feel that the roof will eventually come off anyway. The denuded area should be irrigated two or three times a day using a whirlpool if the lesion is large (the patient should be given ample amounts of a systemic analgesic beforehand). This should be followed by liberal application of a topical antibiotic. Skin lesions may take many months to heal. Fluids are not lost as they are in thermal burns, and fluid replacement should be according to the general needs of the patient and not according to “burn therapy” formulas. Systemic antibiotics should be used when there are signs of infection and a culture indicates the responsible organism. Patients with a large area of second or third degree burns should be transferred to a Burn Unit for further care and reverse isolation.

Airway Exposure

A patient with a mild, non-productive cough, irritation of the nose and sinuses, and/or a sore throat that began later than 12 hours after exposure should be advised to use a cool steam vaporizer and lozenges or cough drops, and sent home with instructions to return if the symptoms worsen. Intubation should be done at the first sign of more severe effects. A patient with more severe effects (laryngitis, shortness of breath, a productive cough, pulmonary edema, pseudomembrane formation) should be provided with oxygen-assisted ventilation as necessary and

admitted directly to the Critical Care Unit once decontamination has been assured. Signs of damage to the larynx or lower airway indicate oxygen-assisted ventilation with PEEP. Patients with less severe effects should be admitted to a routine care ward.

Lewisite causes systemic capillary leakage, and hypovolemic shock may occur in severely exposed patients. Closely monitor blood pressure, blood volume, and hepatic and renal function.

Ingestion Exposure

Do not induce emesis. Treat nausea and vomiting with anti-emetics.

Antidotes

British Anti-Lewisite (BAL), also called Dimercaprol, is a chelating agent shown to reduce systemic effects from Lewisite exposure. Due to toxic side effects, **BAL should be administered only to patients who have signs of shock or significant pulmonary injury.**

Chelation therapy should be performed only by trained personnel. Consultation with the regional poison control center is recommended. The standard dosage regimen is 3 to 5 mg/kg IM every 4 hours for four doses. This regimen can be adjusted depending on the severity of the exposure and the symptoms. Contraindications to BAL include pre-existing renal disease, pregnancy (except in life threatening circumstances) and concurrent use of medicinal iron.

Alkalization of the urine stabilizes the Dimercaprol-metal complex and has been proposed to protect the kidneys during chelation therapy. If acute renal insufficiency develops, hemodialysis should be considered to remove the Dimercaprol-arsenic complex. Side effects of BAL administered at 3 mg/kg are mostly pain at the injection site. At 5 mg/kg, the effects may include nausea; vomiting; headache; burning sensation of the lips, mouth, throat, and eyes; lacrimation; rhinorrhea; salivation; muscle aches; burning and tingling in the extremities; tooth pain; diaphoresis; chest pain; anxiety; and agitation.

Laboratory Tests

Routine laboratory studies should be done for all patients requiring admission. These include CBC, glucose, serum electrolytes, and liver and kidney function tests. Consider monitoring hourly fluid intake and output. Chest X-ray and pulse oximetry (or ABG measurements) are recommended for all patients with inhalation exposures. Since Lewisite contains arsenic, urinary arsenic excretion may be helpful if the diagnosis is in doubt. A test for urine thiodiglycol, a metabolite of mustard,

can be performed at specialized laboratories, but is not a routine laboratory measure.

Disposition and Follow-up

Patients who have skin, eye, or airway signs and symptoms will require hospitalization, as discussed above.

Delayed Effects

Skin burns take up to 18 hours to fully develop. Chemical pneumonitis may begin within 24 hours or up to 3 days after inhalation exposure. Significant systemic absorption of Mustard-Lewisite Mixture may produce a fall in the leukocyte count beginning on days 3 through 5. Erythrocytes and thrombocytes may subsequently fall if bone marrow damage is severe and in this case the risk of life-threatening infection rises.

Patient Release

A patient who initially had mild symptoms should be observed for at least 18 to 24 hours after exposure. If no further symptoms develop and there is no significant progression, the patient may be discharged. Discharged patients should be advised to rest and to seek medical care promptly if symptoms develop (see below, *Follow-up Instructions*, included with the *Lewisite and Mustard-Lewisite Mixture Patient Information Sheet*).

Follow-up

Follow-up laboratory evaluation of bone marrow, hepatic, and renal function should be arranged for severely exposed patients until they are completely recovered. Patients who have mild skin burns or corneal lesions should be reexamined within 24 hours.

Reporting

Other persons may still be at risk in the setting where this incident occurred. If a public health risk exists, notify your state or local health department or other responsible public agency.

Lewisite and Mustard-Lewisite Mixture
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to Lewisite or Mustard-Lewisite Mixture.

What are Lewisite and Mustard-Lewisite Mixture?
Lewisite is a chemical warfare agent that was first produced in 1918. It has not been used in warfare, although it may be stockpiled by some countries. Mustard-Lewisite Mixture is a mixture of Lewisite and Mustard. It was developed to achieve a lower freezing point for ground dispersal and aerial spraying.

What immediate health effects can be caused by exposure to Lewisite and Mustard-Lewisite Mixture?
Lewisite and Mustard-Lewisite Mixture produce pain and skin irritation immediately after exposure. Both compounds cause skin blisters and damage to the airways and eyes. They are also extremely irritating to the eyes, skin, nose, and throat. Exposure to very high levels may result in kidney and liver damage. Mustard-Lewisite Mixture can also damage the immune system.

Can Lewisite and Mustard-Lewisite poisoning be treated?
Immediate decontamination reduces symptoms. Intramuscular injection of British Anti-Lewisite (BAL) may be used to treat severe conditions but will not prevent lesions on the skin, eye, or airways. Persons who have been exposed to large amounts of Lewisite and Mustard-Lewisite Mixture will need to be hospitalized.

Are any future health effects likely to occur?
Adverse health effects, such as chronic respiratory diseases, may occur from exposure to high levels of these agents. Severe damage to the eye may be present for a long time after the exposure.

What tests can be done if a person has been exposed to Lewisite or Mustard-Lewisite?
There is no specific test to confirm exposure to Lewisite or Mustard-Lewisite Mixture; however, measurement of arsenic in the urine may help to identify exposure.

Where can more information about Lewisite or Mustard-Lewisite be found?
More information about Lewisite and Mustard-Lewisite Mixture can be obtained from your regional poison control center; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in toxicology or occupational and environmental health. Ask the person who gave you this form for help locating these telephone numbers.

Lewisite and Mustard-Lewisite Mixture
Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow *only* the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:

- coughing, wheezing, shortness of breath, or discolored sputum
- increased pain or discharge from injured eyes
- increased redness, pain, or a pus-like discharge from injured skin; fever; or chills

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.
[ ] Call for an appointment with Dr. _____ in the practice of _____.
When you call for your appointment, please say that you were treated in the Emergency Department at _ _____ Hospital by _____ and were advised to be seen again in _____ days.
[ ] Return to the Emergency Department/ _____ Clinic on (date) _____at ___ _____ AM/PM for a follow-up examination.
[ ] Do not perform vigorous physical activities for 1 to 2 days.
[ ] You may resume everyday activities including driving and operating machinery.
[ ] Do not return to work for _____ days.
[ ] You may return to work on a limited basis. See instructions below.
[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.
[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.
[ ] Avoid taking the following medications: _____
[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: __
_____
_____
[ ] Other instructions: _____
_____
_____

- Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.

- You or your physician can get more information on the chemical by contacting: _____ _____ or _____, or by checking out the following Internet Web sites: _____; _____.

Signature of patient _____ Date _____

Signature of physician _____ Date_____

Blister Agents
Nitrogen Mustard (HN-1) ($C_6H_{13}Cl_2N$) CAS 538-07-8, UN 2810; Nitrogen Mustard (HN-2) ($C_5H_{11}Cl_2N$) CAS 51-75-2, UN 2927; and Nitrogen Mustard (HN-3) ($C_6H_{12}Cl_3N$) CAS 555-77-1, UN 2810

Synonyms:

HN-1: Bis(2-chloroethyl)ethylamine; 2-chloro-N-(2-chloroethyl)-N-ethylethanamine; 2,2'-dichlorotriethylamine; ethylbis(2-chloroethyl)amine; ethyl-S

HN-2: MBA; mechlorethamine; mustine; 2,2'-dichloro-N-methyldiethylamine; dichloren; caryolysin; mechlorethanamine; chlormethine; bis(2-chloroethyl)methylamine

HN-3: Tris(2-chloroethyl)amine; 2-chloro-N,N-bis(2-chloroethyl)ethanamine; 2,2',2''-trichlorotriethylamine

People whose skin or clothing is contaminated with nitrogen mustard can contaminate rescuers by direct contact or through off-gassing vapor.

- **Nitrogen mustards are colorless to yellow, oily liquids with variable odors.**
- **Nitrogen mustards are absorbed by the skin causing erythema and blisters. Ocular exposure to these agents may cause incapacitating injury to the cornea and conjunctiva. When inhaled, nitrogen mustard damages the respiratory tract epithelium and may cause death.**

Description

Nitrogen mustards are vesicants and alkylating agents. They are colorless to pale yellow, oily liquids that evaporate slowly. HN-1 has a faint, fishy or musty odor. It is sparingly soluble in water but miscible with acetone and other organic solvents. At temperatures greater than 194 °C, it decomposes.

HN-2 has a fruity odor at high concentrations and a soapy odor at low concentrations. Its solubility is similar to HN-1.

HN-3 is odorless when pure but has been reported to have a butter almond odor. It is the most stable of the nitrogen mustards but decomposes at temperatures greater than 256 °C. It has a much lower vapor pressure than HN-1 or HN-2 and is insoluble in water.

Routes of Exposure

Inhalation

Inhalation is an important route of exposure. Nitrogen mustard vapors are heavier than air. The LCt_{50} (the product of concentration times time that is lethal to 50% of the exposed

population by inhalation) is approximately 1,500 mg-min/m^3 for HN-1 and HN-3, and 3,000 mg-min/m^3 for HN-2.

Skin/Eye Contact

Exposure to nitrogen mustard vapor can cause injury to the eyes, skin, and mucous membranes at low concentrations. Direct contact with the liquid can cause skin and eye burns. The median incapacitating dose for the eyes is 100 mg-min/m^3 for HN-2 and 200 mg-min/m^3 for HN-1 and HN-3. Absorption may occur after skin or eye exposure to liquid or vapor nitrogen mustard and may cause systemic toxicity.

Ingestion

Ingestion is an uncommon route for exposure but can lead to local effects such as esophageal or gastrointestinal burns and systemic absorption.

Sources/Uses

Nitrogen mustards were first developed in the late 1920s and early 1930s. HN-1 was originally designed to remove warts but was later identified as a potential chemical warfare agent; HN-2 was designed as a military agent but was later used in chemotherapy; HN-3 was developed as a military agent. None of the nitrogen mustards have been used on the battlefield, and none are included in U.S. stockpiles.

Standards and Guidelines

HN-1: Airborne Exposure Limit (as recommended by the Surgeon General's Working Group, U.S. Department of Health and Human Services) = 0.003 mg/m^3 as a time-weighted average (TWA) for the workplace. No standards exist for HN-2 or HN-3.

Physical Properties

Table 1. Physical Properties of Nitrogen Mustards (Blister Agents)

Property	HN-1	HN-2	HN-3
Description	Colorless to pale yellow oily liquid	Pale amber to yellow oily liquid	Colorless to pale yellow oily liquid
Warning properties	Faint fishy or musty odor	Faint soapy odor at low concentrations; fruity odor at high concentrations	Faint butter almond odor
Molecular weight	170.08 daltons	156.07 daltons	204.54 daltons
Boiling point	(760 mm Hg) = 381 °F (194 °C)	(760 mm Hg) = 167 °F (75 °C)	(760 mm Hg) = 493 °F (256 °C) (decomposes)
Freezing point	29.2 °F (-34 °C)	-85 to -76 °F (-65 to -60 °C)	25.3 °F (-3.7 °C)
Specific gravity	No data (water = 1.0)	No data (water = 1.0)	No data (water = 1.0)
Vapor pressure	0.25 mm Hg at 77 °F (25 °C)	0.427 mm Hg at 77 °F (25 °C)	0.0109 mm Hg at 77 °F (25 °C)
Vapor density	5.9 (air = 1.0)	5.4 (air = 1.0)	7.1 (air = 1.0)
Liquid density	1.09 g/mL at 77 °F (25 °C)	1.15 g/mL at 68 °F (20 °C)	1.24 g/mL at 77 °F (25 °C)
Solubility in water	Sparingly soluble	Sparingly soluble	Practically insoluble
Volatility	No immediate danger of fire or explosion	No immediate danger of fire or explosion; however, polymerization results in components which present an explosion hazard in open air.	No immediate danger of fire or explosion; however, polymerization results in components which present an explosion hazard in open air
NAERG#	153	153	153

Incompatibilities

HN-1 is corrosive to ferrous alloys at temperatures of 149 °F (68 °C) and higher. HN-2 and HN-3 do not have any incompatible actions on metals or other materials.

Health Effects

Nitrogen mustards are vesicants causing skin, eye, and respiratory tract injury. Although these agents cause cellular changes within several minutes of contact, the onset of pain and other clinical effects is delayed for hours.

Nitrogen mustards are alkylating agents that may cause bone marrow suppression and neurologic toxicity.

Acute Exposure

Nitrogen mustards are vesicants and alkylating agents; however, the mechanisms of action are not clearly understood. They are highly reactive and combine rapidly with proteins, DNA, or other molecules. Therefore, within minutes following exposure intact mustard or its reactive metabolites are not found in tissue or biological fluids.

CNS

High doses of nitrogen mustards have caused tremors, seizures, incoordination, ataxia, and coma in laboratory animals.

Respiratory

Damage to the mucosa of the airways begins within hours and may progress over several days. Nasal and sinus pain or discomfort, pharyngitis, laryngitis, cough, and dyspnea may occur. Pulmonary edema is uncommon.

Gastrointestinal

Ingestion may cause chemical burns of the GI tract and hemorrhagic diarrhea. Nausea and vomiting may occur following ingestion, dermal, or inhalation exposure.

Ocular

Exposure to nitrogen mustard vapor or liquid may cause intense conjunctival and scleral inflammation, pain, swelling, lacrimation, photophobia, and corneal damage. High concentrations can cause burns and blindness.

Dermal

Direct skin exposure to nitrogen mustards causes erythema and blistering. Generally, a rash will develop within several hours, followed by blistering within 6 to 12 hours. Prolonged contact, or short contact with large amounts, may result in second- and third-degree chemical burns.

Hematopoietic

Systemic absorption of nitrogen mustard may induce bone marrow suppression and an increased risk for fatal complicating infections, hemorrhage, and anemia.

Delayed Effects

Chemotherapeutic doses of HN-2 have been associated with menstrual irregularities, alopecia, hearing loss, tinnitus, jaundice,

impaired spermatogenesis, generalized swelling, and hyperpigmentation.

Potential Sequelae

Chronic respiratory and eye conditions may persist following exposure to large amounts of nitrogen mustards. Narrowing of the esophagus and severe corrosive damage to the stomach lining can result from ingesting formalin.

Chronic Exposure

In laboratory animal studies, prolonged or repeated exposures to nitrogen mustards have caused cancer, developmental and reproductive effects, and hepatic toxicity. Repeated exposures result in cumulative effects because mustards are not naturally detoxified by the body.

Carcinogenicity

The International Agency for Research on Cancer (IARC) has classified nitrogen mustard as probably carcinogenic to humans (Group 2A). There is some evidence that it causes leukemia in humans, and it has been shown to cause leukemia and cancers of the lung, liver, uterus, and large intestine in animals.

Reproductive and Developmental Effects

Nitrogen mustards may decrease fertility. A few case reports have linked treatment with HN-2 to fetal abnormalities in humans. Nitrogen mustards have produced developmental effects in animals.

Prehospital Management

Victims whose skin or clothing is contaminated with liquid nitrogen mustard can contaminate rescuers by direct contact or through off-gassing vapor.

Nitrogen mustards are extremely toxic and may damage the eyes, skin, and respiratory tract and suppress the immune system. Although these agents cause cellular changes within minutes of contact, the onset of pain and other symptoms is delayed.

There is no antidote for nitrogen mustard toxicity. Decontamination of all potentially exposed areas within minutes after exposure is the only effective means of decreasing tissue damage.

Hot Zone

Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if the rescuers have not been trained in its use, call for assistance from the U.S. Soldier and Biological Chemical Command–Edgewood Research Development and Engineering Center (from 0700-1630 EST call 410-671-4411, and from 1630-0700 EST call 410-278-5201; ask for the Staff Duty Officer).

Rescuer Protection

Nitrogen mustard vapor and liquid are readily absorbed by inhalation and ocular and dermal contact.

Respiratory Protection: Pressure-demand, self-contained breathing apparatus (SCBA) is recommended in response situations that involve exposure to any amount of nitrogen mustard.

Skin/Ocular Protection: Personal protective equipment (PPE) and butyl rubber chemical protective gloves are recommended at all times when these chemicals are suspected to be involved.

Multi-Casualty Triage

Chemical casualty triage is based on walking feasibility, respiratory status, age, and additional conventional injuries. The triage officer must know the natural course of a given injury, the medical resources immediately available, the current and likely casualty flow, and the medical evacuation capabilities. General principles of triage for chemical exposures are presented in the box on the following page. There are four triage categories: immediate (priority 1), delayed (priority 2), minimal (priority 3), and expectant (priority 4).

Before transport, all casualties must be decontaminated. If needed, consult with the base station physician or the regional poison control center for advise concerning management of multiple casualties.

Because most signs and symptoms of nitrogen mustard exposure do not occur for several hours postexposure, patients should be observed for at least 6 hours or sent home with instructions to return immediately if symptoms develop. Patients who develop significant dermal, ocular, or airway injury and patients who have ingested nitrogen mustard should be transported to a medical facility for evaluation.

Symptoms may not develop for 24 hours. Patients with mild symptoms who are seen long enough after exposure to minimize the likelihood that the lesions will worsen may be sent home after their names, addresses, and telephone numbers have been recorded. They should be advised to rest and to seek medical care promptly if additional symptoms develop (see *Follow-up Instructions* included with the *Nitrogen Mustard Patient Information Sheet*).

Consult with the base station physician or closest Metropolitan Medical Response System, or the regional poison control center for advice regarding triage of multiple victims.

General principles of triage for chemical exposures are as follows:

(1) Check triage tag/card for any previous treatment or triage.
(2) Survey for evidence of associated traumatic/blast injuries.
(3) Observe for sweating, labored breathing, coughing/vomiting, secretions.
(4) Severe casualty triaged as immediate if assisted breathing is required.
(5) Blast injuries or other trauma, where there is question whether there is chemical exposure, victims must be tagged as immediate in most cases. Blast victims evidence delayed effects such as ARDS, etc.
(6) Mild/moderate casualty: self/buddy aid, triaged as delayed or minimal and release is based on strict follow up and instructions.
(7) If there are chemical exposure situations which may cause delayed but serious signs and symptoms, then overtriage is considered appropriate to the proper facilities that can observe and manage any delayed onset symptoms. *For nitrogen mustards, potentially exposed individuals should be observed for 6 - 8 hours and, if signs or symptoms appear, be sent to the hospital.*
(8) Expectant categories in multi-casualty events are those victims who have experienced a cardiac arrest, respiratory arrest, or continued seizures immediately. Resources should not be expended on these casualties if there are large numbers of casualties requiring care and transport with minimal or scant resources available.

1. *Immediate:* casualties who require lifesaving care within a short time, when that care is available and of short duration. This care may be a procedure that can be done within minutes at an emergency treatment station (e.g., relief of an airway obstruction, administering antidotes) or may be acute lifesaving surgery.

2. *Delayed:* casualties with severe injuries who are in need of major or prolonged surgery or other care and who will require hospitalization, but delay of this care will not adversely affect the outcome of the injury (e.g., fixation of a stable fracture).

3. *Minimal:* casualties who have minor injuries, can be helped by nonphysician medical personnel, and will not require hospitalization.

4. *Expectant:* casualties with severe life-threatening injuries who would not survive with optimal medical care, or casualties whose injuries are so severe that their chance of survival does not justify expenditure of limited resources. As circumstances permit, casualties in this category may be reexamined and possibly be retriaged to a higher

ABC Reminders

Quickly ensure that the victim has a patent airway. Maintain adequate circulation. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Apply direct pressure to stop arterial bleeding, if present.

Victim Removal

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be removed on backboards or gurneys. If these are not available, carefully carry or drag victims to safety.

Decontamination Zone

Decontamination within 1 or 2 minutes following exposure is the only effective means for decreasing tissue damage. Later decontamination is not likely to improve the victim's condition but will protect other personnel from exposure. Decontaminable gurneys and back boards should be used if available when managing casualties in a contaminated area. Decontaminable gurneys are made of a monofilament polypropylene fabric that allows drainage of liquids, does not absorb chemical agents, and is easily decontaminated. Fiberglass back boards have been developed specifically for use in HAZMAT incidents. These are nonpermeable and readily decontaminated. The **Chemical Resuscitation Device** is a bag-valve mask equipped with a chemical agent cannister that can be used to ventilate casualties in a contaminated environment.

Rescuer Protection

Personnel should continue to wear the same level of protection as required in the Hot Zone (see *Rescuer Protection* under *Hot Zone*, above).

ABC Reminders

Quickly ensure that the victim has a patent airway. Maintain adequate circulation. Stabilize the cervical spine with a decontaminable collar and a backboard if trauma is suspected. Administer supplemental oxygen if cardiopulmonary compromise is suspected. Assist ventilation with a bag-valve-mask device equipped with a cannister or air filter if necessary. Direct pressure should be applied to control heavy bleeding, if present.

Basic Decontamination

The eyes and skin must be decontaminated within 1 or 2 minutes after exposure to reduce tissue damage. Flush the eyes immediately with water for about 5 to 10 minutes by tilting the head to the side, pulling eyelids apart with fingers, and pouring water slowly into eyes. Do not cover eyes with bandages.

If exposure to liquid agent is suspected, cut and remove all clothing and wash skin immediately with soap and water. If shower areas are available, showering with water alone will be adequate. However, in those cases where water is in short supply, and showers are not available, an alternative form of decontamination is to use 0.5% sodium hypochlorite solution or absorbent powders such as flour, talcum powder, or Fuller's earth. If exposure to vapor only is certain, remove outer clothing and wash exposed areas with soap and water or 0.5% solution of sodium hypochlorite. Place contaminated clothes and personal belongings in a sealed double bag.

In cases of ingestion, **do not induce emesis**. There is no evidence that administration of activated charcoal is beneficial.

Transfer to Support Zone

As soon as basic decontamination is complete, move the victim to the Support Zone.

Support Zone

Be certain that victims have been decontaminated properly (see *Decontamination Zone*, above). Victims who have undergone decontamination pose no serious risk of secondary contamination to rescuers. In such cases, Support Zone personnel require no specialized protective gear.

ABC Reminders

Quickly ensure that the victim has a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Ensure adequate respiration; administer supplemental oxygen if cardiopulmonary compromise is suspected. Maintain adequate circulation. Establish intravenous access if necessary. Attach a cardiac monitor, as needed. Direct pressure should be applied to stop bleeding, if present.

Additional Decontamination

In cases of ingestion, **do not induce** emesis. If the victim is alert and able to swallow, give 4 to 8 ounces of milk or water to drink. There is no evidence that administration of activated charcoal is beneficial.

Advanced Treatment

Intubate the trachea in cases of respiratory compromise. When the patient's condition precludes endotracheal intubation, perform cricothyrotomy if equipped and trained to do so.

Treat patients who have bronchospasm with bronchodilators. Trauma patients who are comatose, hypotensive, or have seizures or cardiac dysrhythmias should be treated according to advanced life support (ALS) protocols.

Transport to Medical Facility

Report the condition of the patient, treatment given, and estimated time of arrival at the medical facility to the base station and the receiving medical facility.

Emergency Department Management

Patients whose skin or clothing is contaminated with liquid nitrogen mustard can contaminate rescuers by direct contact or through off-gassing vapor.

Nitrogen mustards are extremely toxic and may damage eyes, skin, and respiratory tract and suppress the immune system. Although these agents cause cellular changes within minutes of contact, the onset of pain and other symptoms is delayed. Thus, patients arriving immediately from the scene of exposure are not likely to have signs and symptoms.

There is no antidote for nitrogen mustard toxicity. Decontamination of all potentially exposed areas within minutes after exposure is the only effective means of decreasing tissue damage. Thus, by the time a patient arrives in the emergency department, decontamination can only prevent secondary exposure to medical staff; it does not limit the patient's injury. Medical treatment is supportive.

Decontamination Area

Previously decontaminated patients may be treated or held for observation. Others require decontamination as described below.

ABC Reminders

Evaluate and support the airway, breathing, and circulation. Intubate the trachea in cases of respiratory compromise. If the patient's condition precludes intubation, surgically create an airway.

Treat patients who have bronchospasm with bronchodilators. Patients who are comatose or hypotensive, or who have seizures or ventricular dysrhythmias due to other exposures or trauma, should be treated in the conventional manner.

Personal Protection

If contaminated patients are expected to arrive at the Emergency Department, they must be decontaminated before being allowed to enter the facility. Decontamination can take place inside the hospital only if there is a decontamination facility with negative air pressure and floor drains to contain contamination. Personnel should wear the same level of protection required in the Hot Zone (see *Rescuer Protection* under Hot Zone, above).

Basic Decontamination

Flush the eyes with water for about 5 to 10 minutes. Do not cover eyes with bandages; if necessary, use dark or opaque goggles to relieve discomfort from photophobia.

If a liquid splash is suspected, clothing must be removed and the patient showered using soap and water. Showering should be

accomplished using cool water and enough water pressure to quickly reduce the potential for agent penetration of the skin. If the patient was exposed to vapor only, remove outer clothing and wash exposed skin with soap and water. Place contaminated clothes and personal belongings in a sealed double bag.

In cases of ingestion, **do not induce emesis**. If the victim is alert and able to swallow, give 4 to 8 ounces of milk or water to drink if not already administered. There is no evidence that administration of activated charcoal is beneficial.

Critical Care Area

Be certain that appropriate decontamination has been carried out (see *Decontamination Area* above).

ABC Reminders

Evaluate and support the airway, breathing, and circulation (as in *ABC Reminders*, above). Establish intravenous access and continuously monitor cardiac rhythm in seriously ill patients.

Patients who are comatose, hypotensive, or who have seizures or ventricular dysrhythmias due to other exposures or trauma should be treated in the conventional manner.

Triage

Patients arriving at the emergency department directly from the scene of potential exposure (within 30-60 minutes) will rarely have symptoms. Following decontamination, patients with signs of airway involvement should be admitted directly to the Critical Care Unit. The others should be observed for at least 6 hours. Patients arriving later should be evaluated as described below. **The sooner after exposure that symptoms occur, the more likely they are to progress and become severe.**

Eye Exposure

Mild conjunctivitis beginning more than 12 hours after exposure is unlikely to progress to a severe lesion. The patient should have a thorough eye examination (including a test for visual acuity). The patient should be treated with a soothing eye solution, sent home, and told to return if there is worsening. Conjunctivitis beginning earlier and other effects such as lid swelling and signs/symptoms of inflammation indicate a need for inpatient care and observation.

Skin Exposure

A small area of erythema beginning later than 12 hours after exposure is unlikely to progress to a significant lesion. The patient should be examined, treated with a soothing lotion , sent home, and instructed to return if progression occurs. A patient with a significant area of erythema or one seen earlier with a

significant area of erythema with or without blistering should be admitted for further evaluation.

Airway Exposure

A patient with a mild, non-productive cough, irritation of the nose and sinuses, and/or a sore throat that began later than 12 hours after exposure should be told to use a cool steam vaporizer and lozenges or cough drops, and sent home with instructions to return if the symptoms worsen. Patients with more severe effects (laryngitis, shortness of breath, a productive cough) seen at any time postexposure should be admitted directly to the Critical Care Unit once decontamination has been assured. Those with less severe effects should be admitted to a routine care ward.

Ingestion Exposure

Do not induce emesis. If a large dose has been ingested and the patient's condition is evaluated within 30 minutes after ingestion, cautious orogastric lavage might remove ingested material. However, the risk of potential bleeding and perforation must be considered. There is no evidence that activated charcoal is beneficial.

Antidotes and Other Treatments

There is no antidote for nitrogen mustard. Treatment is supportive.

Laboratory Tests

Routine laboratory studies should be done for all patients requiring admission. These include CBC, glucose, and serum electrolytes. Chest x-ray and pulse oximetry (or ABG measurements) are recommended for inhalation exposures.

Disposition

As discussed above, consider hospitalizing patients who have had significant exposures.

Delayed Effects

Significant systemic absorption of nitrogen mustard may produce a fall in the leukocyte count beginning on days 3 to 5. Erythrocytes and thrombocytes may subsequently fall if bone marrow damage is severe and in this case the risk of life-threatening infection rises.

Patient Release

Patients who have sustained mild exposure may be discharged. Discharged patients should be advised to rest and to seek medical care promptly if symptoms develop (see page 22, *Follow-up Instructions*, included with the *Nitrogen Mustard Patient Information Sheet)*.

Reporting

Other people may still be at risk in the setting where this incident occurred or away from the setting due to secondary contamination. If a public health risk exists, notify your state or local health department or other responsible public agency.

General Medical Management

Since there are no immediate effects from mustard, most patients will go home or elsewhere from the incident and present to a medical facility hours later when effects occur. These patients must not be allowed to enter the facility until they have been decontaminated.

Patients whose skin or clothing is contaminated with liquid nitrogen mustard can contaminate medical personnel and others by direct contact or through off-gassing vapor.

Nitrogen mustards are extremely toxic and may damage the eyes, skin, and respiratory tract and suppress the immune system. Although these agents cause cellular changes within minutes of contact, the onset of pain and other symptoms is delayed.

There is no antidote for nitrogen mustard toxicity. Medical treatment is supportive.

Decontamination Area

A patient who arrives at a general medical facility (non-emergency) probably will not have undergone decontamination. Such a patient must be decontaminated as described below before being allowed to enter the facility.

ABC Reminders

Patients may have other injuries and must be evaluated using the concepts of BLS and ALS.

Personal Protection

Medical personnel or others (e.g., HAZMAT personnel) must meet incoming patients outside the facility or, if available, in the facility's decontamination area. Decontamination can take place inside the medical facility only if there is a decontamination area with negative air pressure and floor drains to contain contamination. Personnel must wear protection required in the Hot Zone (see *Rescuer Protection* under Hot Zone, above).

Basic Decontamination

A patient who has arrived directly from the scene must be decontaminated before being admitted to the facility. If a liquid splash is suspected, clothing must be removed and the patient showered using soap and water. If the patient was exposed to vapor only, removal of outer clothing and flushing of exposed skin (face, hair, and arms/hands) with soap and water or water alone is adequate. Place contaminated clothes and personal belongings in a sealed double bag.

A patient who has gone home and bathed and changed clothes may be considered decontaminated; however, the home will

require decontamination. Otherwise, patients should undergo the decontamination procedures described above.

Initial Evaluation

Patients arriving at the medical facility directly from the scene of potential exposure (within 30–60 minutes) will rarely have signs and symptoms. Patients with signs of airway involvement should be admitted directly to the Critical Care Unit once decontamination has been assured. The others should be observed for at least 6 hours.

Patients arriving later should be evaluated as described below. The sooner after exposure signs and symptoms occur, the more likely they are to progress and become severe.

Eye Exposure

Mild conjunctivitis beginning more than 12 hours after exposure is unlikely to progress to a severe lesion. The patient should have a thorough eye examination (including a test for visual acuity). The patient should be treated with a soothing eye solution, such as Visine or Murine, sent home, and told to return if there is worsening. Conjunctivitis beginning earlier and other effects such as lid swelling and signs/symptoms of inflammation indicate admission.

Skin Exposure

A small area of erythema beginning later than 12 hours after exposure is unlikely to progress to a significant lesion. The patient should be examined, treated with a soothing lotion , sent home, and instructed to return if progression occurs. A patient with a significant area of erythema or one seen earlier with a significant area of erythema with or without blistering should be admitted for further evaluation.

Airway Exposure

A patient with a mild, non-productive cough, irritation of the nose and sinuses, and/or a sore throat that began later than 12 hours after exposure should be told to use a cool steam vaporizer and lozenges or cough drops and sent home with instructions to return if the symptoms worsen. Patients with more severe effects (laryngitis, shortness of breath, a productive cough, pseudomembrane formation) seen at any time postexposure should be admitted directly to the Critical Care Unit once decontamination has been assured. Those with less severe effects should be admitted to a routine care ward.

Ingestion Exposure

Do not induce emesis. If a large dose has been ingested and the patient's condition is evaluated within 30 minutes after ingestion, cautious orogastric lavage might remove ingested material. However, the risk of potential bleeding and perforation must be

considered. There is no evidence that activated charcoal is beneficial.

Medical Management

General

There is no antidote for nitrogen mustard. Management is supportive.

A guideline is to keep the wounds (skin, eye, airway) free from infection. A patient with severe skin burns may require care in a burn unit.

Skin Exposure

Most burns are second degree although third degree burns may occur after liquid exposure. In general, small blisters (i.e., <1 cm) should remain roofed and larger ones (>1 cm) should be unroofed. This is a controversial issue, but many feel that the roof will eventually come off anyway. Blister fluid does not contain mustard or other toxic substances. The denuded area should be irrigated two or three times a day using a whirlpool if the lesion is large (the patient should be given ample amounts of a systemic analgesic beforehand). This should be followed by liberal application of a topical antibiotic. Skin lesions may take many months to heal. Fluids are not lost as they are in thermal burns, and fluid replacement should be according to the general needs of the patient and not according to "burn therapy" formulas. Systemic antibiotics should be used when there are signs of infection and a culture indicates the responsible organism. Patients with a large area of second or third degree burns should be transferred to a Burn Unit for further care and reverse isolation.

Eye Exposure

Eye lesions range from conjunctivitis to involvement of the entire eye including cornea and lids. Erosion of or perforation of the cornea may occur with very severe exposure to liquid, but this is rare. Readily available eye solutions may suffice for conjunctivitis. More severe lesions should be treated with a topical mydriatic (e.g., atropine), topical antibiotics, and vaseline or similar substance applied to the lid edges several times a day. Topical analgesics may be used only for an initial examination (including slit lamp and a test of visual acuity), but not after. Pain should be controlled with systemic analgesics. Once the lid edema and blepharospasm subside and the eyes are open, dark glasses may reduce the discomfort of photophobia. Some authorities feel that topical steroids (used within the first 24 hours only) may reduce inflammation.

Inhalation Exposure

Airway damage may range from irritation of the nose and sinuses, to pharyngitis, to destruction of the airway mucosa from the upper airways to the smallest bronchiole. Airway damage is a common cause of death. Upper airway irritation (nose, sinuses, pharynx) may benefit from cool steam inhalation and cough drops or throat lozenges. A patient with signs of airway damage below the pharynx should be provided with oxygen, assisted ventilation as necessary (with PEEP); at the first sign of damage of the larynx or below, the patient should be intubated and transferred to the Critical Care Unit. Bronchodilators should be used if there are signs of bronchoconstriction; steroids might be used if the usual bronchodilators are not effective, but otherwise steroids are not of proven value. Daily sputum cultures should be done and systemic antibiotics should be begun with signs of infection and an identified organism. A chemical pneumonitis may occur in the first several days with infiltrates on X-ray, an increase in WBC, and a fever, but this is generally sterile. Organisms generally are not the cause until the third or fourth day postexposure, and antibiotics should not be used prophylactically. Patients with airway damage below the pharynx should be managed on the Critical Care Unit by a physician experienced in the management of complicated pulmonary and airway injuries.

Bone Marrow

If the bone marrow has been damaged, the white blood cell count in the peripheral blood will start to decrease at about days 3 to 5 after exposure. This decrease may be followed by a decrease in red blood cells and platelets. Often, this decrease is not marked and the marrow recovers. Transfusions may be useful. Treatment with granulocyte colony-stimulating factor (GCSF) has been successful experimentally with nitrogen mustard. Marrow transplants have not been attempted, but might be useful. A patient with a marked decrease in white blood cell count should be transferred to an Oncology or Burn Unit for reverse isolation.

Laboratory Evaluation

Routine laboratory studies for admitted patients include glucose, serum electrolytes, and daily CBC. Chest X-ray and pulse oximetry (or ABG measurement) should be done frequently on all patients with inhalation exposure.

Disposition and Follow-up

Patients with moderate to severe exposures will require hospitalization, as described above.

Patient Release

Patients who have sustained mild exposure may be discharged. Discharged patients should be advised to rest and to seek medical

care promptly if symptoms develop (see below, *Follow-up Instructions*, included with the *Nitrogen Mustard Patient Information Sheet*).

Follow-up

Follow-up evaluation of respiratory, neurological, and bone marrow function should be arranged for severely exposed patients.

Reporting

Other people may still be at risk in the setting where this incident occurred or away from the setting due to secondary contamination. If a public health risk exists, notify your state or local health department or other responsible public agency.

Blister Agents
Nitrogen Mustard (HN-1, HN-2, and HN-3)
Patient Information Sheet

This handout provides information and follow-up instructions for people who have been exposed to nitrogen mustards.

What are nitrogen mustards?
Nitrogen mustards are compounds that were initially developed as chemical warfare agents or pharmaceuticals. They have never been used on the battlefield. HN-2 has been used in chemotherapy.

What immediate health effects can be caused by exposure to nitrogen mustards?
Nitrogen mustards cause injury to the skin, eyes, nose and throat. Eye damage may occur within minutes of exposure. Nausea and vomiting also may occur shortly after exposure. Skin rashes, blisters, and lung damage may develop within a few hours of exposure but may take 6 hours or more. Nitrogen mustards can also suppress the immune system.

Can nitrogen mustard poisoning be treated?
There is no antidote for nitrogen mustard, but its effects can be treated and most exposed people recover. Immediate decontamination reduces symptoms. People who have been exposed to large amounts of nitrogen mustard will need to be treated in a hospital.

Are any future health effects likely to occur?
Adverse health effects, such as chronic respiratory diseases, may occur from exposure to high levels of these agents. Severe damage to the eye may be present for a long time following the exposure.

What tests can be done if a person has been exposed to nitrogen mustard?
There are no routine tests to confirm exposure.

Where can more information about nitrogen mustard be found?
More information about nitrogen mustards can be obtained from your regional poison control center; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in toxicology or occupational and environmental health. Ask the person who gave you this form for help locating these telephone numbers.

Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow *only* the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:

- coughing, wheezing, shortness of breath, or discolored sputum
- increased pain or discharge from injured eyes
- increased redness, pain, or a pus-like discharge from injured skin
- fever or chills

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.
[ ] Call for an appointment with Dr. _____ in the practice of _____. When you call for your appointment, please say that you were treated in the Emergency Department at _ _____ Hospital by _____ and were advised to be seen again in _____ days.
[ ] Return to the Emergency Department/ _____ Clinic on (date) _____at ___ _____ AM/PM for a follow-up examination.
[ ] Do not perform vigorous physical activities for 1 to 2 days.
[ ] You may resume everyday activities including driving and operating machinery.
[ ] Do not return to work for _____ days.
[ ] You may return to work on a limited basis. See instructions below.
[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.
[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.
[ ] Avoid taking the following medications: _____
[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: __ _____
_____
[ ] Other instructions: _____
_____
_____

- Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.

- You or your physician can get more information on the chemical by contacting: _____ _____ or _____, or by checking out the following Internet Web sites: _____; _____.

Signature of patient _____ Date _____

Signature of physician _____ Date_____

Blister Agents
Sulfur Mustard Agent H or HD ($C_4H_8Cl_2S$)
CAS 505-60-2, UN 2927;
and Sulfur Mustard Agent HT CAS 6392-89-8

Synonyms:

H and HD: Bis(2-chloroethyl) sulfide; bis(beta-chloroethyl) sulfide; di-2-chloroethyl sulfide; 1-chloro-2(beta-chloroethylthio)ethane; 2,2'-dichloroethyl sulfide; sulfur mustard; Iprit; Kampstoff "Lost"; mustard gas; senfgas, S-yperite; yellow cross liquid; yperite

HT: Mixture of bis(2-chloroethyl) sulfide and bis[2-(2-chloroethylthio)-ethyl]ether

People whose skin or clothing is contaminated with sulfur mustard can contaminate rescuers by direct contact or through off-gassing vapor.

- **Sulfur mustards are yellow to brown oily liquids with a slight garlic or mustard odor. Although volatility is low, vapors can reach hazardous levels during warm weather.**
- **Sulfur mustards are absorbed by the skin, causing erythema and blisters. Ocular exposure to these agents may cause incapacitating damage to the cornea and conjunctiva. Inhalation damages the respiratory tract epithelium and may cause death.**

Description

Sulfur mustards are vesicants and alkylating agents. They are colorless when pure but are typically a yellow to brown oily substance with a slight garlic or mustard odor. H contains about 20 to 30% impurities (mostly sulfur); distilled mustard is known as HD and is nearly pure; HT is a mixture of 60% HD and 40% agent T (a closely related vesicant with a lower freezing point). Sulfur mustards evaporate slowly. They are very sparingly soluble in water but are soluble in oils, fats, and organic solvents. They are stable at ambient temperatures but decompose at temperatures greater than 149°C.

Routes of Exposure

Inhalation

Sulfur mustards are readily absorbed from the respiratory tract; injury develops slowly and intensifies over several days. The odor of sulfur mustards does not provide adequate warning of detection. The LCt_{50} (the product of concentration times time that is lethal to 50% of the exposed population by inhalation) is approximately 1,500 mg-min/m^3. The vapors are heavier than air. When inhaled, these agents may cause systemic effects. The estimated Ct for airway injury is 100 to 200 mg-min/m^3.

Skin/Eye Contact

Mustard vapor and liquid are absorbed through the eyes, skin, and mucous membranes. Clinical effects do not occur until hours after exposure. The median incapacitating dose for the vapor is 200 mg-min/m^3. A Ct of 12 to 70 mg-min/m ^{3}produces eye lesions. Direct contact with the liquid can cause skin and eye burns that develop an hour or more after exposure. A 10 µg droplet is capable of producing blisters. Skin, eye, and airway exposure to vapor sulfur mustard and skin and eye exposure to liquid mustard may cause systemic toxicity. The lethal dose is about 100 mg/kg or 1 to 1.5 teaspoons of liquid.

Ingestion

Ingestion may cause local effects and systemic absorption.

Sources/Uses

Sulfur mustards were first developed in the early-to-mid-1800s and were introduced as chemical warfare agents in 1917 during World War I. They have been used extensively in chemical warfare and remain a major threat. More than a dozen countries have sulfur mustard in their chemical arsenals. Destruction of U.S. stockpiles of chemical agents, including sulfur mustards, was mandated by the Chemical Weapons Convention to take place before April 2007..

Standards and Guidelines

Airborne Exposure Limit (as recommended by the Surgeon General's Working Group, U.S. Department of Health and Human Services) is 0.003 mg/m^3 as a time-weighted average (TWA) for the workplace.

Physical Properties

Table 1. Physical Properties of Sulfur Mustards

Property	Agent H and HD	Agent HT
Description	Colorless when pure but usually a pale yellow, dark brown or black oily liquid. The vapor is colorless	Clear yellowish liquid
Warning properties	Faint garlic or mustard odor (odor threshold 0.6 mg/m^3)	Slight garlic or mustard-like odor
Molecular weight	159.08 daltons	159.08 daltons (HD); 263.2 daltons (T)
Boiling point	(760 mm Hg) = 419 °F (217.5 °C)	(760 mm Hg) = >442 °F (>228 °C)
Freezing point	58.1 °F (14.5 °C)	32 to 34.3 °F (0 to 1.3 °C)
Specific gravity	1.27 g/mL (water = 1.0)	No data

Vapor pressure	0.072 mm Hg at 68°F (20 °C); 0.11 mm Hg at 77 °F (25 °C)	No data
Vapor density	5.4 to 5.5 (air = 1.0)	6.92 (air = 1.0)
Liquid density	1.24 to 1.27 g/mL at 68 °F (20 °C)	1.27 g/mL
Flash point	221 °F (105 °C)	212 °F (100 °C)
Solubility in water	0.8 g/L at 68 °F (20 °C)	Practically insoluble
Volatility	600 mg/m^3 (20 °C)	No data
NAERG#	153	153

Incompatibilities

Sulfur mustards are rapidly corrosive to brass and steel at 149 °F (65 °C); they are destroyed by strong oxidizing agents. These agents hydrolyze to form hydrochloric acid (HCl) and thiodiglycol.

Health Effects

Sulfur mustards are vesicants causing skin, eye, and respiratory tract injury. Although these agents cause cellular changes within minutes of contact, the onset of pain and other clinical effects are delayed for 1 to 24 hours.

- **Sulfur mustards are alkylating agents that may cause bone marrow suppression and neurologic and gastrointestinal toxicity.**

Acute Exposure

Sulfur mustards are vesicants and alkylating agents; however, the biochemical mechanisms of action are not clearly understood. They are highly reactive and combine rapidly with proteins, DNA, or other molecules. Therefore, within minutes following exposure intact mustard or its reactive metabolites are not found in tissue or biological fluids. Sulfur mustards also have cholinergic activity, stimulating both muscarinic and nicotinic receptors. The onset of clinical symptoms and their time of onset depend on the severity of exposure (Table 1). The death rate from exposure to sulfur mustard is low (2 to 3% during World War I). Death usually occurs between the 5th and 10th day due to pulmonary insufficiency complicated by infection due to immune system compromise.

Ocular

The eye is the most sensitive tissue to sulfur mustard effects. Sulfur mustard vapor or liquid may cause intense conjunctival and scleral pain, swelling, lacrimation, blepharospasm, and photophobia; however, these effects do not appear for an hour or more. Miosis due to cholinergic effects may occur. High concentrations of vapor or liquid can cause corneal edema, perforation, blindness, and later scarring.

Dermal

Direct skin exposure to sulfur mustards causes erythema and blistering. Generally, a pruritic rash will develop within 4 to 8 hours followed by blistering 2 to 18 hours later. Contact with the vapor may result in first and second degree burns, while contact with the liquid typically produces second and third degree chemical burns. An area of burn covering 25% or more of the body surface area may be fatal.

Respiratory

Dose-dependent inflammatory reactions in the upper and lower airway begin to develop several hours after exposure and progress over several days. Burning nasal pain, epistaxis, sinus pain, laryngitis, loss of taste and smell, cough, wheezing, and dyspnea may occur. Necrosis of respiratory epithelium can cause pseudomembrane formation and local airway obstruction.

Gastrointestinal

Ingestion may cause chemical burns of the GI tract and cholinergic stimulation. Nausea and vomiting may occur following ingestion or inhalation. Early nausea and vomiting is usually transient and not severe. Nausea, vomiting, and diarrhea occurring several days after exposure indicates damage to the GI tract and thus is a poor prognostic sign.

CNS

High doses of sulfur mustards can cause hyperexcitability, convulsions, and insomnia.

Hematopoietic

Systemic absorption of sulfur mustard may induce bone marrow suppression and an increased risk for fatal complicating infections, hemorrhage, and anemia.

Delayed Effects

Years after apparent healing of severe eye lesions, relapsing keratitis or keratopathy may develop.

Potential Sequelae

Persistent eye conditions, loss of taste and smell, and chronic respiratory illness including asthmatic bronchitis, recurrent respiratory infections, and lung fibrosis may persist following exposure to sulfur mustards.

Chronic Exposure

Prolonged or repeated acute exposure to sulfur mustards may cause cutaneous sensitization and chronic respiratory disease. Repeated exposures result in cumulative effects because mustards are not naturally detoxified by the body.

Carcinogenicity

The International Agency for Research on Cancer (IARC) has classified sulfur mustard as carcinogenic to humans (Group 1). Epidemiological evidence indicates that repeated exposures to sulfur mustard may lead to cancers of the upper airways.

Reproductive and Developmental Effects

There is limited evidence that repeated exposures to sulfur mustards may cause defective spermatogenesis years after exposure. Sulfur mustard has been implicated as a potential developmental toxicant because of its similarity to nitrogen mustard; however, data are inconclusive.

Table 1. Clinical Effects and Time of Onset by Severity of Exposure to Sulfur Mustard

Tissue	Severity of exposure	Clinical effects	Time to first effect
Eyes	Mild	Tearing, itching, burning, gritty feeling	4-12 hours
	Moderate	Above effects and reddening, lid edema, moderate pain	3-6 hours
	Severe	Marked lid edema, possible corneal damage, severe pain	1-2 hours
Airways	Mild	Rhinorrhea, sneezing, epistaxis, hoarseness, hacking cough	6-24 hours
	Severe	Above effects and productive cough, mild to severe dyspnea	2-6 hours
Skin	Mild	Erythema	2-24 hours
	Severe	Erythema and vesication	2-24 hours

Prehospital Management

Victims whose skin or clothing is contaminated with liquid sulfur mustard can contaminate rescuers by direct contact or through off-gassing vapor.

Sulfur mustards are extremely toxic and may damage the eyes, skin, and respiratory tract and suppress the immune system. Although these agents cause cellular changes within minutes of contact, the onset of pain and other symptoms is delayed.

There is no antidote for sulfur mustard toxicity. Decontamination within 1 or 2 minutes after exposure is the only effective means of decreasing tissue damage. Sodium thiosulfate given IV within minutes after exposure may prevent lethality.

Hot Zone

Responders should be trained and appropriately attired before entering the Hot Zone. If the proper personal protective equipment (PPE) is not available, or if the rescuers have not been trained in its use, call for assistance in accordance with local Emergency Operational Guides (EOG). Sources of such assistance include local Hazmat teams, mutual aid partners, the closest metropolitan strike system (MMRS) and the U.S. Soldier and Biological Chemical Command (SBCCOM)-Edgewood Research Development and Engineering Center SBCCOM may be contacted (from 0700-1630 EST call 410-671-4411 and from 1630-0700 EST call 410-278-5201), ask for the Staff Duty Officer.

Rescuer Protection

Sulfur mustard vapor and liquid are readily absorbed by inhalation and ocular and dermal contact.

Respiratory protection: Pressure-demand, self-contained breathing apparatus (SCBA) is recommended in response situations that involve exposure to any amount of sulfur mustard.

Skin/ocular protection: Personal protective equipment (PPE) and butyl rubber chemical-protective gloves are recommended at all times when these chemicals are suspected to be involved.

Multi-Casualty Triage

Chemical casualty triage is based on walking feasibility, respiratory status, age, and additional conventional injuries. The triage officer must know the natural course of a given injury, the medical resources immediately available, the current and likely casualty flow, and the medical evacuation capabilities. General principles of triage for chemical exposures are presented in the

box on the following page. There are four triage categories: immediate (priority 1), delayed (priority 2), minimal (priority 3), and expectant (priority 4). Clinical signs and effects of sulfur mustards associated with each of these categories are presented in Table 2.

Before transport, all casualties must be decontaminated. If needed, consult with the base station physician or the regional poison control center for advise concerning management of multiple casualties.

Because signs and symptoms of exposure do not occur for several hours postexposure, patients should be observed for at least 6 hours or sent home with instructions to return immediately if symptoms develop. Patients whose clinical effects and time of onset indicate moderate or severe exposure (see Table 1) and patients who have ingested sulfur mustard should be transported to a medical facility for evaluation.

Symptoms may not develop for 24 hours. Patients who are seen at least 24 hours after exposure and whose symptoms indicate mild exposure (see Table 1) may be sent home after treatment and once their names, addresses, and telephone numbers have been recorded. They should be advised to rest and to seek medical care promptly if additional symptoms develop (see *Follow-up Instructions*, included with the *Sulfur Mustard Patient Information Sheet* below).

Consult with the base station physician, closest Metropolitan Medical Response System, or the regional poison control center for advice regarding triage of multiple victims.

General principles of triage for chemical exposures are as follows:

(1) Check triage tag/card for any previous treatment or triage.
2. Survey for evidence of associated traumatic/blast injuries.
3. Observe for sweating, labored breathing, coughing/vomiting, secretions.
4. Severe casualty triaged as immediate if assisted breathing is required.
5. Blast injuries or other trauma, where there is question whether there is chemical exposure, victims must be tagged as immediate in most cases. Blast victims evidence delayed effects such as ARDS, etc.
6. Mild/moderate casualty: self/buddy aid, triaged as delayed or minimal and release is based on strict follow up and instructions.
7. If there are chemical exposure situations which may cause delayed but serious signs and symptoms, then overtriage is considered appropriate to the proper facilities that can observe and manage any delayed onset symptoms.
8. Expectant categories in multi-casualty events are those victims who have experienced a cardiac arrest, respiratory arrest, or continued seizures immediately. Resources should not be expended on these casualties if there are large numbers of casualties requiring care and transport with minimal or scant resources available.

1. *Immediate:* casualties who require lifesaving care within a short time, when that care is available and of short duration. This care may be a procedure that can be done within minutes at an emergency treatment station (e.g., relief of an airway obstruction, administering antidotes) or may be acute lifesaving surgery.

2. *Delayed:* casualties with severe injuries who are in need of major or prolonged surgery or other care and who will require hospitalization, but delay of this care will not adversely affect the outcome of the injury (e.g., fixation of a stable fracture).

3. *Minimal:* casualties who have minor injuries, can be helped by nonphysician medical personnel, and will not require hospitalization.

4. *Expectant:* casualties with severe life-threatening injuries who would not survive with optimal medical care, or casualties whose injuries are so severe that their chance of survival does not justify expenditure of limited resources. As circumstances permit, casualties in this category may be reexamined an possibly be retriaged to a higher category.

Table 2. Triage for Mustard Agent Casualties

Category (Priority)	Time of Onset	Clinical Signs and Symptoms
Immediate (1)	<4 up to 12 hours post exposure	Lower respiratory signs (dyspnea)
Delayed (2)	> 4 hours (eye and skin); or >12 hours (respiratory) post exposure	Eye lesions with impaired vision; skin lesion covering 2 to 50% of body surface area for liquid exposure or any body surface burn for vapor exposure; lower respiratory symptoms (cough with sputum production, dyspnea)
Minimal (3)	> 4 hours post exposure	Minor eye lesion with no vision impairment; skin lesion < 2% of body surface area in noncritical areas; minor upper respiratory symptoms (cough, sore throat).
Expectant (4)	< 4 hours post exposure	Lower respiratory signs (dyspnea); skin lesion covering 50% or more of body surface area from liquid exposure

ABC Reminders

Quickly ensure that the victim has a patent airway. Maintain adequate circulation. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Apply direct pressure to stop arterial bleeding, if present.

Victim Removal

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be removed on backboards or gurneys. If these are not available, carefully carry or drag victims to safety.

Decontamination Zone

Decontamination within 1 or 2 minutes following exposure is the only effective means for decreasing tissue damage. Later decontamination is not likely to improve the victim's condition but will protect other personnel from exposure. Decontaminable gurneys and back boards should be used if available when managing casualties in a contaminated area. Decontaminable gurneys are made of a monofilament polypropylene fabric that allows drainage of liquids, does not absorb chemical agents, and

is easily decontaminated. Fiberglass back boards have been developed specifically for use in HAZMAT incidents. These are nonpermeable and readily decontaminated. The **Chemical Resuscitation Device** is a bag-valve mask equipped with a chemical agent cannister that can be used to ventilate casualties in a contaminated environment.

Rescuer Protection

Personnel should continue to wear the same level of protection as required in the Hot Zone (see *Rescuer Protection* under *Hot Zone*, above).

ABC Reminders

Quickly ensure that the victim has a patent airway. Maintain adequate circulation. Stabilize the cervical spine with a decontaminable collar and a backboard if trauma is suspected. Administer supplemental oxygen if cardiopulmonary compromise is suspected. Assist ventilation with a bag-valve-mask device equipped with a cannister or air filter if necessary. Direct pressure should be applied to control bleeding, if present.

Basic Decontamination

Early decontamination, preferably within 1 or 2 minutes after exposure, is the only way to reduce tissue damage. Flush the eyes immediately with water for about 5 to 10 minutes by tilting the head to the side, pulling eyelids apart with fingers, and pouring water slowly into eyes. Do not cover eyes with bandages.

If exposure to liquid agent is suspected, victims should remove all clothing and wash skin with soap and water. If shower areas are available, showering with water alone will be adequate. However, in those cases where water is in short supply, and showers are not available, an alternative form of decontamination is to use 0.5% sodium hypochlorite solution or absorbent powders such as flour, talcum powder, or Fuller's earth. If exposure to vapor only is certain, remove outer clothing and wash with soap and water or 0.5% solution of sodium hypochlorite. Place contaminated clothes and personal belongings in a sealed double bag.

In cases of ingestion, **do not induce emesis**. There is no evidence that administration of activated charcoal is beneficial.

Transfer to Support Zone

As soon as basic decontamination is complete, move the victim to the Support Zone.

Support Zone

Be certain that victims have been decontaminated properly (see *Decontamination Zone*, above). Victims who have undergone decontamination pose no serious risk of secondary

contamination to rescuers. In such cases, Support Zone personnel require no specialized protective gear.

ABC Reminders

Quickly ensure that the victim has a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Ensure adequate respiration; administer supplemental oxygen if cardiopulmonary compromise is suspected. Maintain adequate circulation. Establish intravenous access if necessary. Attach a cardiac monitor. Direct pressure should be applied to stop bleeding, if present.

Additional Decontamination

In cases of ingestion, **do not induce emesis**. If the victim is alert and able to swallow, give 4 to 8 ounces of milk or water to drink. There is no evidence that administration of activated charcoal is beneficial.

Advanced Treatment

Intubate the trachea in cases of respiratory compromise. When the patient's condition precludes endotracheal intubation, perform cricothyrotomy if equipped and trained to do so.

Treat patients who have bronchospasm with bronchodilators.

Trauma patients who are comatose, hypotensive, or have seizures or cardiac dysrhythmias should be treated according to advanced life support (ALS) protocols.

Transport to Medical Facility

Report the condition of the patient, treatment given, and estimated time of arrival at the medical facility to the base station and the receiving medical facility.

Emergency Department Management

Patients whose skin or clothing is contaminated with liquid sulfur mustard can contaminate rescuers by direct contact or through off-gassing vapor.

Sulfur mustards are extremely toxic and may damage eyes, skin, and respiratory tract and suppress the immune system. Although these agents cause cellular changes within minutes of contact, the onset of pain and other symptoms is delayed. Thus, patients arriving immediately from the scene of exposure are not likely to have signs and symptoms.

There is no antidote for sulfur mustard toxicity. Decontamination of all potentially exposed areas within minutes after exposure is the only effective means of decreasing tissue damage. Thus, by the time a patient arrives in the emergency department, decontamination can only prevent secondary exposure to medical staff; it does not limit the patient's injury. Medical treatment is supportive.

Decontamination Area

Previously decontaminated patients may be treated or held for observation. Others require decontamination as described below.

ABC Reminders

Evaluate and support the airway, breathing, and circulation. Intubate the trachea in cases of respiratory compromise. If the patient's condition precludes intubation, surgically create an airway.

Treat patients who have bronchospasm with bronchodilators.

Patients who are comatose or hypotensive, or have seizures or ventricular dysrhythmias due to other exposures or trauma should be treated in the conventional manner.

Personal Protection

If contaminated patients are expected to arrive at the Emergency Department, they must be decontaminated before being allowed to enter the facility. Decontamination can take place inside the hospital only if there is a decontamination facility with negative air pressure and floor drains to contain contamination. Personnel should wear the same level of protection required in the Hot Zone (see *Rescuer Protection* under Hot Zone, above).

Basic Decontamination

Flush the eyes with water for about 5 to 10 minutes. Do not cover eyes with bandages; if necessary, use dark or opaque goggles to relieve discomfort from photophobia.

If a liquid splash is suspected, clothing must be removed and the patient showered using soap and water. Showering should be accomplished using warm water and low water pressure to reduce the potential for agent penetration of the skin. If the patient was exposed to vapor only, remove outer clothing and wash exposed skin with soap and water. Place contaminated clothes and personal belongings in a sealed double bag.

In cases of ingestion, **do not induce emesis**. If the victim is alert and able to swallow, give 4 to 8 ounces of milk or water to drink if not already administered. There is no evidence that administration of activated charcoal is beneficial.

Treatment Area

Be certain that appropriate decontamination has been carried out (see *Decontamination Area*, below).

ABC Reminders

Evaluate and support the airway, breathing, and circulation (as in *ABC Reminders*, above). Establish intravenous access and continuously monitor cardiac rhythm in seriously ill patients.

Patients who are comatose, hypotensive, or who have seizures or ventricular dysrhythmias due to other exposures or trauma should be treated in the conventional manner.

Triage

Patients arriving at the emergency department directly from the scene of potential exposure (within 30-60 minutes) will rarely have symptoms. Following decontamination, patients with signs of airway involvement should be admitted directly to the Critical Care Unit. The others should be observed for at least 6 hours. Patients arriving later should be evaluated as described below. **The sooner after exposure that symptoms occur, the more likely they are to progress and become severe.**

Eye Exposure

Mild conjunctivitis beginning more than 12 hours after exposure is unlikely to progress to a severe lesion. The patient should have a thorough eye examination (including a test for visual acuity). The patient should be treated with a soothing eye solution, such as Visine or Murine, sent home, and told to return if there is worsening. Conjunctivitis beginning earlier and other effects such as lid swelling and signs/symptoms of inflammation indicate a need for inpatient care and observation.

Skin Exposure

A small area of erythema beginning later than 12 hours after exposure is unlikely to progress to a significant lesion. The patient should be examined, treated with a soothing lotion, sent home, and instructed to return if progression occurs. A patient with a significant area of erythema or one seen earlier with a

significant area of erythema with or without blistering should be admitted for further evaluation.

Airway Exposure

A patient with a mild, non-productive cough, irritation of the nose and sinuses, and/or a sore throat that began later than 12 hours after exposure should be told to use a cool steam vaporizer and lozenges or cough drops and sent home with instructions to return if the symptoms worsen. Patients with more severe effects (laryngitis, shortness of breath, a productive cough) seen at any time postexposure should be admitted directly to the Critical Care Unit once decontamination has been assured. Those with less severe effects should be admitted to a routine care ward.

Ingestion Exposure

Do not induce emesis. If a large dose has been ingested and the patient's condition is evaluated within 30 minutes after ingestion, cautious orogastric lavage might remove ingested material. However, the risk of potential bleeding and perforation must be considered. There is no evidence that activated charcoal is beneficial.

Antidotes and Other Treatments

There is no antidote for sulfur mustard. Treatment is supportive.

Laboratory Tests

Routine laboratory studies should be done for all patients requiring admission. These include CBC, glucose, and serum electrolytes. Chest x-ray and pulse oximetry (or ABG measurements) are recommended for inhalation exposures. A test for urine thiodiglycol, a metabolite of mustard, can be performed at specialized laboratories, but is not a routine laboratory measure.

Disposition

As discussed above, consider hospitalizing patients who have had significant exposures.

Delayed Effects

Significant systemic absorption of sulfur mustard may produce a fall in the leukocyte count beginning on days 3 to 5. Erythrocytes and thrombocytes may subsequently fall if bone marrow damage is severe and in this case the risk of life-threatening infection rises.

Patient Release

Patients who have sustained mild exposure (see Table 1) may be discharged. Discharged patients should be advised to rest and to seek medical care promptly if symptoms progress (see, *Follow-up Instructions*, included with the *Sulfur Mustard Patient Information Sheet* below).

Reporting Other people may still be at risk in the setting where this incident occurred or away from the setting due to secondary contamination. If a public health risk exists, notify your state or local health department or other responsible public agency.

General Medical Management

Since there are no immediate effects from mustard, most patients will go home or elsewhere from the incident and present to a medical facility hours later when effects occur. These patients must not be allowed to enter the facility until they have been decontaminated.

Patients whose skin or clothing is contaminated with liquid sulfur mustard can contaminate medical personnel and others by direct contact or through off-gassing vapor.

Sulfur mustards are extremely toxic and may damage the eyes, skin, and respiratory tract and suppress the immune system. Although these agents cause cellular changes within minutes of contact, the onset of pain and other symptoms is delayed.

There is no antidote for sulfur mustard toxicity. Medical treatment is supportive.

Decontamination Area

A patient who arrives at a general medical facility (non-emergency) probably will not have undergone decontamination. Such a patient must be decontaminated as described below before being allowed to enter the facility.

ABC Reminders

Patients may have other injuries and must be evaluated using the concepts of BLS and ALS.

Personal Protection

Medical personnel or others (e.g., HAZMAT personnel) must meet incoming patients outside the facility or, if available, in the facility's decontamination area. Decontamination can take place inside the medical facility only if there is a decontamination area with negative air pressure and floor drains to contain contamination. Personnel must wear protection required in the Hot Zone (see *Rescuer Protection* under Hot Zone, above).

Basic Decontamination

A patient who has arrived directly from the scene must be decontaminated before being admitted to the facility. If a liquid splash is suspected, clothing must be removed and the patient showered using soap and water. Showering should be accomplished using cool water and enough water pressure to quickly reduce the potential for agent penetration of the skin. If the patient was exposed to vapor only, removal of outer clothing and flushing of exposed skin (face, hair, and arms/hands) with soap and water or water alone is adequate. Place contaminated clothes and personal belongings in a sealed double bag.

A patient who has gone home and bathed and changed clothes may be considered decontaminated; however, the home will require decontamination. Otherwise, patients should undergo the decontamination procedures described above.

Initial Evaluation

Patients arriving at the medical facility directly from the scene of potential exposure (within 30–60 minutes) will rarely have signs and symptoms. Patients with signs of airway involvement should be admitted directly to the Critical Care Unit once decontamination has been assured. The others should be observed for at least 6 hours.

Patients arriving later should be evaluated as described below. The sooner after exposure signs and symptoms occur, the more likely they are to progress and become severe (see Table 1).

Eye Exposure

Mild conjunctivitis beginning more than 12 hours after exposure is unlikely to progress to a severe lesion. The patient should have a thorough eye examination (including a test for visual acuity). The patient should be treated with a soothing eye solution such as Visine or Murine, sent home, and told to return if there is worsening. Conjunctivitis beginning earlier and other effects such as lid swelling and signs/symptoms of inflammation indicate admission.

Skin Exposure

A small area of erythema beginning later than 12 hours after exposure is unlikely to progress to a significant lesion. The patient should be examined, treated with a soothing lotion, sent home, and instructed to return if progression occurs. A patient with a significant area of erythema or one seen earlier with a significant area of erythema with or without blistering should be admitted for further evaluation.

Airway Exposure

A patient with a mild, non-productive cough, irritation of the nose and sinuses, and/or a sore throat that began later than 12 hours after exposure should be told to use a cool steam vaporizer and lozenges or cough drops and sent home with instructions to return if the symptoms worsen. Patients with more severe effects (laryngitis, shortness of breath, a productive cough) seen at any time postexposure should be admitted directly to the Critical Care Unit once decontamination has been assured. Those with less severe effects should be admitted to a routine care ward.

Ingestion Exposure

Do not induce emesis. If a large dose has been ingested and the patient's condition is evaluated within 30 minutes after ingestion, cautious orogastric lavage might remove ingested material.

However, the risk of potential bleeding and perforation must be considered. There is no evidence that activated charcoal is beneficial.

Medical Management

General

There is no antidote for sulfur mustard. Management is supportive.

A guideline is to keep the wounds (skin, eye, airway) free from infection. A patient with severe skin burns may require care in a burn unit.

Skin Exposure

Most burns are second degree although third degree burns may occur after liquid exposure. In general, small blisters (i.e., <1cm) remain roofed and larger ones (i.e., >1cm) should be unroofed. This is a controversial issue, but many feel that the roof will eventually come off anyway. Blister fluid does not contain mustard or other toxic substances. The denuded area should be irrigated two or three times a day using a whirlpool if the lesion is large (the patient should be given ample amounts of a systemic analgesic beforehand). This should be followed by liberal application of a topical antibiotic. Skin lesions may take many months to heal. Fluids are not lost as they are in thermal burns, and fluid replacement should be according to the general needs of the patient and not according to "burn therapy" formulas. Systemic antibiotics should be used when there are signs of infection and a culture indicates the responsible organism. Patients with a large area of second or third degree burns should be transferred to a Burn Unit for further care and reverse isolation.

Eye Exposure

Eye lesions range from conjunctivitis to involvement of the entire eye including cornea and lids. Erosion of or perforation of the cornea may occur with very severe exposure to liquid, but this is rare. Readily available eye solutions may suffice for conjunctivitis. More severe lesions should be treated with a topical mydriatic (e.g., atropine), topical antibiotics, and vaseline or similar substance applied to the lid edges several times a day. Topical analgesics should be used only for an initial examination (including slit lamp and a test of visual acuity), but not after. Pain should be controlled with systemic analgesics. Once the lid edema and blepharospasm subside and the eyes are open, dark glasses may reduce the discomfort of photophobia. Some authorities feel that topical steroids (used within the first 24 hours only) may reduce inflammation.

Inhalation Exposure

Airway damage may range from irritation of the nose and sinuses, to pharyngitis, to destruction of the airway mucosa from the upper airways to the smallest bronchiole. Airway damage is a common cause of death. Upper airway irritation (nose, sinuses, pharynx) may benefit from cool steam inhalation and cough drops or lozenges. A patient with signs of airway damage below the pharynx should be provided with oxygen- assisted ventilation as necessary (with PEEP); at the first sign of damage of the larynx or below, the patient should be intubated and transferred to the Critical Care Unit. Bronchodilators should be used if there are signs of bronchoconstriction; steroids might be used if the usual bronchodilators are not effective, but otherwise steroids are not of proven value. Daily sputum cultures should be done and systemic antibiotics should be begun with signs of infection and an identified organism. A chemical pneumonitis may occur in the first several days with infiltrates on X-ray, an increase in WBC, and a fever, but this is generally sterile. Organisms generally are not the cause until the third or fourth day postexposure, and antibiotics should not be used prophylactically. Patients with airway damage below the pharynx should be managed on the Critical Care Unit by a physician experienced in the management of complicated pulmonary and airway injuries.

Bone Marrow

If the bone marrow has been damaged, the white blood cell count in the peripheral blood will start to decrease at about days 3 to 5 after exposure. This decrease may be followed by a decrease in red blood cells and platelets. Often, this decrease is not marked and the marrow recovers. Transfusions may be useful. Treatment with granulocyte colony-stimulating factor (GCSF) has been successful experimentally with nitrogen mustard. Marrow transplants have not been attempted, but might be useful. A patient with a marked decrease in white blood cell count should be transferred to an Oncology or Burn Unit for reverse isolation.

Laboratory Evaluation

Routine laboratory studies for admitted patients include glucose, serum electrolytes, and daily CBC. Chest x-ray and pulse oximetry (or ABG measurement) should be done frequently on all patients with inhalation effects. A test for urinary thioglycol (a metabolite of mustard) can be performed at specialized laboratories, but is not a routine laboratory measure.

Disposition and Follow-up

Patients with moderate to severe exposures will require hospitalization, as described above.

Patient Release

Patients who have sustained mild exposure (see Table 1), may be discharged. Discharged patients should be advised to rest and to seek medical care promptly if symptoms progress (see below, *Follow-up Instructions*, included with the *Sulfur Mustard Patient Information Sheet*).

Follow-up

Follow-up evaluation of respiratory, neurological, and bone marrow function should be arranged for severely exposed patients.

Reporting

Other people may still be at risk in the setting where this incident occurred or away from the setting due to secondary contamination. If a public health risk exists, notify your state or local health department or other responsible public agency.

Blister Agents
Sulfur Mustard (H, HD, and HT)
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to sulfur mustard.

What are sulfur mustards?
Sulfur mustards are yellowish to brown liquids that have been used as chemical warfare agents since 1917.

What immediate health effects can result from exposure to sulfur mustards?
Sulfur mustards produce blistering and cell damage, but symptoms are delayed for hours. They cause damage to the skin, eyes, and respiratory tract. The eyes are the most sensitive. Nausea and vomiting may occur within the first few hours after exposure. Skin rashes, blisters, and lung damage may develop within a few hours of exposure but may take 12 to 24 hours to develop. Sulfur mustard can also suppress the immune system.

Can sulfur mustard poisoning be treated?
There is no antidote for sulfur mustard, but its effects can be treated and most exposed people recover. Immediate decontamination reduces symptoms. People who have been exposed to large amounts of sulfur mustard will need to be treated in a hospital.

Are any future health effects likely to occur?
Adverse health effects, such as chronic respiratory diseases, may occur from exposure to high levels of these agents. Severe damage to the eyes and skin may be present for a long time following the exposure.

What tests can be done if a person has been exposed to sulfur mustards?
There are no routine tests to determine if someone has been exposed to sulfur mustard. Thiodiglycol (a break-down product of mustard) may be detected in the urine up to 2 weeks following exposure; however, this test is available only in several specialized laboratories.

Where can more information about sulfur mustards be found?
More information about sulfur mustard can be obtained from your regional poison control center; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in toxicology or occupational and environmental health. Ask the person who gave you this form for help locating these telephone numbers.

Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow *only* the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:

- coughing, wheezing, shortness of breath, or discolored sputum
- increased pain or discharge from injured eyes
- increased redness, pain, or a pus-like discharge from injured skin
- fever or chills

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.
[ ] Call for an appointment with Dr. _____ in the practice of _____.
When you call for your appointment, please say that you were treated in the Emergency Department at _ _____ Hospital by _____ and were advised to be seen again in _____ days.
[ ] Return to the Emergency Department/ _____ Clinic on (date) _____at ___ _____ AM/PM for a follow-up examination.
[ ] Do not perform vigorous physical activities for 1 to 2 days.
[ ] You may resume everyday activities including driving and operating machinery.
[ ] Do not return to work for _____ days.
[ ] You may return to work on a limited basis. See instructions below.
[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.
[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.
[ ] Avoid taking the following medications: _____
[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: __
_____
_____
[ ] Other instructions: _____
_____
_____

- Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.

- You or your physician can get more information on the chemical by contacting: _____ _____ or _____, or by checking out the following Internet Web sites: _____; _____.

Signature of patient _____ Date _____

Signature of physician _____ Date_____

1,3-Butadiene (C_4H_6)
CAS 106-99-0; UN 1010

Synonyms include butadiene, buta-1,3-diene, biethylene, bivinyl, vinylethylene, erythrene, α,γ-butadiene, divinyl, and pyrrolylene.

- **Persons exposed to 1,3-butadiene gas do not pose a significant risk of secondary contamination to response personnel outside the Hot Zone. Persons whose skin or clothing has been contaminated with liquid 1,3-butadiene can secondarily contaminate response personnel by direct contact or through off-gassing vapor.**
- **1,3-Butadiene is a colorless, highly flammable gas at room temperature. The gas is heavier than air and potentially explosive. It has a mild, aromatic, gasoline-like odor that is often an adequate warning to protect against acute overexposure.**
- **The major route of exposure to 1,3-butadiene is inhalation. 1,3-Butadiene escaping its container in liquid or gas form can produce irritation or frostbite injury. Significant dermal absorption is unlikely.**
- **1,3-Butadiene's extreme flammability and potential for explosion is probably of greater health concern than its toxic effects.**

Description

1,3-Butadiene is a colorless gas with a mild, aromatic, gasoline-like odor. It is non-corrosive but highly flammable. The vapor is heavier than air. 1,3- Butadiene is commercially available as a liquefied gas (under pressure) with a stabilizer added for shipment. Liquid 1,3-butadiene floats and boils on water. Because of 1,3-butadiene's physical properties (e.g., low flashpoint and tendency to polymerize), its fire and explosion potential might be greater concerns (more likely to occur and more dangerous) than its health effects.

Routes of Exposure

Inhalation

1,3-Butadiene is a gas at all ambient temperatures; therefore, the most common exposure route for humans is inhalation. 1,3-Butadiene is heavier than air and can collect in poorly ventilated or enclosed spaces and low-lying areas, posing a risk of asphyxiation. Short-term exposure to concentrations of 2,000 to 8,000 ppm has been reported to cause irritation of the mucous membranes of the nose, mouth, and throat. The odor of 1,3-butadiene is discernable at 1 to 1.6 ppm which is slightly lower than the OSHA PEL (1 ppm) and therefore is a generally sufficient warning of acute exposure.

Children exposed to the same levels of 1,3-butadiene vapor as adults may receive larger dose because they have greater lung surface area:body weight ratios and increased minute volumes:weight ratios. In addition, they may be exposed to higher levels than adults in the same location because of their short stature and the higher levels of 1,3-butadiene vapor found nearer to the ground.

Skin/Eye Contact

Exposure to concentrated vapors of liquid 1,3-butadiene can cause mild to moderate irritation of the eyes and upper respiratory tract, and mild irritation of the skin. Direct contact with escaping compressed gas or liquid can cause frostbite injury.

Ingestion

Ingestion is unlikely because 1,3-butadiene is a gas at room temperature. No human or animal toxicity information was available for ingested 1,3-butadiene at the time of this review.

Sources/Uses

Large amounts (about 3 billion pounds) of 1,3-butadiene are produced each year from petroleum gases. Over 60% of this is used to make styrene/butadiene and polybutadiene rubber, primarily for automotive tires. Smaller percentages are used to produce a component of nylon (12%), styrene-butadiene co-polymer latexes (8%), neoprene rubber (2-chloro-1,3-butadiene) (7%), and acrylonitrile/butadiene/styrene (ABS) resins (6%). Most of the remaining 7% is used in the production of rocket propellants and specialty copolymer resins and latexes for paints, coatings, and adhesives; and as an additive to oil lubricants. Nonpolymer applications include the manufacture of agricultural fungicides (Captan and Captofol), sulfolane (an industrial solvent), and anthraquinone dyes.

Small amounts of 1,3-butadiene are found in gasoline, automobile exhaust, cigarette smoke, and wood-fire smoke.

Standards and Guidelines

OSHA PEL (permissible exposure limit) = 1 ppm (averaged over an 8-hour workshift).

OSHA STEL (short-term exposure limit) = 5 ppm (15-minute exposure).

NIOSH IDLH (immediately dangerous to life or health) = 2,000 ppm.

AIHA ERPG-2 (maximum airborne concentration below which it is believed that nearly all persons could be exposed for up to 1 hour without experiencing or developing irreversible or other

serious health effects or symptoms that could impair their abilities to take protective action) = 200 ppm.

Physical Properties

Description: colorless gas; colorless liquid when pressurized

Warning properties: odor often provides an adequate warning for acute but not chronic exposures. The gas has a mild, aromatic, gasoline-like odor detectable at concentrations ranging from 1 to 1.6 ppm.

Molecular weight: 54.09 daltons

Boiling point (760 mm Hg): 24.08 °F (-4.4 °C)

Freezing point: -164 °F (-108.9 °C)

Specific gravity: 0.62 (liquid) at 68 °F (20 °C) (water = 1.00)

Vapor pressure: 910 mm Hg at 68 °F (20 °C)

Gas density: 1.9 (air = 1 at boiling point of 1,3-butadiene)

Water solubility: Negligible solubility in water (735 mg/L at 77 °F [25 °C])

Flammability: Flammable at temperatures > -105 °F (-76 °C)

Flammable range: 2.0 to 12.0%

Incompatibilities

1,3-Butadiene is highly reactive and polymerizes easily, especially in the presence of oxygen. Inhibitors (such as tributylcatechol) are normally added to prevent self-polymerization and formation of peroxides. It reacts violently with strong oxidizing agents and can cause fires and explosions. Crude 1,3-butadiene (the dimer, not the monomer) can react with copper and copper alloys to form explosive copper compounds. It breaks down some types of plastics, rubber, and coatings. It polymerizes at elevated temperatures; if polymerization occurs in a container, the process can violently rupture the container. Toxic gases such as carbon monoxide can be released when 1,3-butadiene burns.

Health Effects

- **Acute, high-level exposure to 1,3-butadiene gas initially can cause eye, nose, throat, and skin irritation. Exposures to very high concentrations of 1,3-butadiene can cause central nervous system (CNS) depression. Signs and symptoms can include blurred vision, nausea, fatigue, headache, vertigo, decreased blood pressure and pulse rate, unconsciousness, and respiratory paralysis.**

- **Acute toxicity of 1,3-butadiene is due to its narcotic effects. 1,3-Butadiene is metabolized to produce two DNA reactive metabolites; butadiene monoepoxide and butadiene diepoxide.**

Acute Exposure

Acute toxicity of 1,3-butadiene is due to its narcotic effects. 1,3-Butadiene is metabolized to two DNA reactive metabolites: butadiene monoepoxide and butadiene diepoxide. Acute exposure to 1,3-butadiene can cause irritation and (at high concentrations) narcosis. At air concentrations of 1,000 ppm or greater, 1,3-butadiene can cause irritation of the skin, eyes, nose, and throat. Eye irritation, blurred vision, coughing, and drowsiness have been reported after 8-hour exposures to 8,000 ppm.

Children do not always respond to chemicals in the same way that adults do. Different protocols for managing their care may be needed.

CNS

In humans, inhalation of very high concentrations of 1,3-butadiene can result in CNS effects including lethargy, headache, drowsiness, fatigue, vertigo, ataxia, unconsciousness, coma, and respiratory depression and death. Humans exposed to 2,000 ppm in air for 7 hours reported hallucinations and distortions in perception. In experimental animal studies, concentrations of 150,000 to 200,000 ppm have produced mild anesthesia. At concentrations of 200,000 to 250,000 ppm, respiratory depression leading to death has been reported within 35 minutes. As air levels approach those high enough to seriously threaten CNS function, however, the far greater danger is from explosion.

Respiratory

Acute inhalation of 2,000 to 8,000 ppm 1,3-butadiene can cause irritation of the upper respiratory tract. Coughing and bronchospasm can occur, especially in susceptible individuals, such as persons with asthma.

Dermal

Skin contact with escaping compressed gas or liquid 1,3-butadiene can cause mild to moderate irritation and frostbite. Mixtures of 1,3-butadiene and clay minerals have been reported to cause dermatitis.

Ocular

Exposure to 2,000 to 8,000 ppm 1,3-butadiene gas can cause eye irritation, chemical conjunctivitis, and corneal irritation.

Cardiovascular

Bradycardia and hypotension secondary to CNS depression is possible with exposure to very high concentrations (150,000–250,000 ppm) of 1,3-butadiene.

Gastrointestinal

Nausea and dryness of the mouth can occur.

Potential Sequelae

In survivors, dermal, ocular, and systemic effects of 1,3-butadiene exposure rapidly subside. However, victims who suffer prolonged hypoxia from coma or respiratory arrest can develop multiple organ damage.

Chronic Exposure

Cancer is suspected to be the primary adverse effect of chronic exposure to 1,3-butadiene. 1,3-Butadiene metabolites are mutagenic in both germ and somatic cells. The rates of epoxide metabolite formation in different species are thought to be an important factor in the species' responses to 1,3-butadiene. There is some evidence for bone marrow depression and DNA repair deficiencies after long-term exposure of experimental animals to 1,3-butadiene.

Chronic exposure may be more serious for children because of their potential longer latency period.

Carcinogenicity

1,3-Butadiene has caused multi-site tumors in laboratory mice and rats. The U.S. Department of Health and Human Services (DHHS) has determined that 1,3-butadiene can reasonably be anticipated to be a human carcinogen. In a recent re-evaluation, the International Agency for Research on Cancer (IARC) viewed the human epidemiological evidence for carcinogenicity as limited and retained the Group 2A classification, "probably carcinogenic to humans." The carcinogenic effect if it were to occur would most likely occur following long-term exposure.

Reproductive and Developmental Effects

No adverse reproductive effects form 1,3-butadiene exposure have been reported for humans. Experimental animal studies have yielded evidence for damage to the testes and ovaries, and for direct toxic effects on the developing young from exposures during gestation. No information was located on whether 1,3-butadiene can cross the placenta or on levels of

1,3-butadiene in breast milk. 1,3-Butadiene is not included in *Reproductive and Developmental Toxicants*, a 1991 report published by the General Accounting Office (GAO) that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences.

Special consideration regarding the exposure of pregnant women is warranted, since metabolites of 1,3-butadiene have been shown to be genotoxicants; thus, medical counseling may be warranted for the acutely exposed pregnant woman.

Prehospital Management

- **Persons exposed only to 1,3-butadiene gas pose no risk of secondary contamination to rescuers. Those whose skin or clothing is heavily contaminated with liquid 1,3-butadiene can secondarily contaminate response personnel by direct contact or through rapidly evaporating gas.**

- **1,3-Butadiene is a gas at all ambient temperatures; therefore, the most common exposure route for humans is inhalation. Very high concentrations (150,000 to 250,000 ppm) of 1,3-butadiene have the potential to cause CNS and respiratory depression. Lower concentrations can cause headache, nausea, coughing, blurred vison, and irritation of the eyes and upper respiratory tract.**

- **There is no specific antidote for 1,3-butadiene poisoning. Treatment is supportive.**

Hot Zone

Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if the rescuers have not been trained in its use, call for assistance from a local or regional HAZMAT team or other properly equipped response organization.

1,3-Butadiene is very flammable and has a high fire and explosion potential. Responders should eliminate all sources of ignition, including grounding of electrical equipment.

Rescuer Protection

1,3-Butadiene gas is readily absorbed by inhalation and is a respiratory tract irritant. Contact of skin or eyes with escaping compressed gas or liquid can cause irritation or frostbite injury.

Respiratory protection: Positive-pressure, self-contained breathing apparatus (SCBA) is recommended in response situations that involve exposure to potentially hazardous levels of 1,3-butadiene gas.

Skin protection: When skin contact with the liquid or escaping compressed gas is expected, wearing chemical-protective clothing is recommended to avoid skin irritation and frostbite. Chemical-protective clothing is not generally required with gas-only exposure because dermal irritation and absorption of 1,3-butadiene gas is minimal.

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible.

Victim Removal

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk should be removed on backboards or gurneys. If these are not available, carefully carry or drag victims to safety.

Consider appropriate management of chemically contaminated children, such as measures to reduce separation anxiety if a child is separated from a parent or other adult.

Decontamination Zone

Victims exposed only to 1,3-butadiene gas who have no skin or eye irritation do not need decontamination. They may be transferred immediately to the Support Zone. Other patients will require decontamination as described below.

Rescuer Protection

If exposure levels are determined to be safe, decontamination may be conducted by personnel wearing a lower level of protection than that required in the Hot Zone (described above).

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. Stabilize the cervical spine with a collar and a backboard if trauma is suspected. Administer supplemental oxygen as required. Assist ventilation with a bag-valve-mask if necessary.

Basic Decontamination

Victims who are able may assist with their own decontamination. If the patient's clothing is wet with 1,3-butadiene, remove and double bag the contaminated clothing and all personal belongings.

Handle frostbitten skin and eyes with caution. Place frostbitten skin in warm water, about 108 °F (42 °C). If warm water is not available, wrap the affected part gently in blankets. Let the circulation reestablish itself naturally. Encourage the victim to exercise the affected part while it is being warmed.

Flush exposed skin and hair with plain water for 2 to 3 minutes, then wash with mild soap. Rinse thoroughly with water.

Do not irrigate frostbitten eyes. Otherwise, irrigate exposed eyes with plain water or saline for at least 15 minutes. Remove contact lenses if easily removable without additional trauma to the eye. If pain or injury is evident, continue irrigation while transferring the victim to the Support Zone.

Transfer to Support Zone

As soon as basic decontamination is complete, move the victim to the Support Zone.

Support Zone

Be certain that victims have been decontaminated properly (see *Decontamination Zone* above). Victims who have undergone decontamination or have been exposed only to 1,3-butadiene gas pose no serious risk of secondary contamination to rescuers. In such cases, Support Zone personnel require no specialized protective gear.

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Ensure adequate respiration and pulse; administer supplemental oxygen as required and establish intravenous access if necessary. Place on a cardiac monitor.

Additional Decontamination

Continue irrigating exposed skin and eyes, as appropriate.

Advanced Treatment

In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, perform cricothyroidotomy if equipped and trained to do so.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Also consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). 1,3-Butadiene poisoning is not known to pose additional risk during the use of bronchial or cardiac sensitizing agents.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed cautioning for myocardial variability.

Patients who are comatose, hypotensive, or have seizures or cardiac dysrhythmias should be treated according to advanced life support (ALS) protocols.

If frostbite injury is present, treat by rewarming in a water bath at a temperature of 102 to 108 °F (40 to 42 °C) for 20 to

30 minutes and continue until a flush has returned to the affected area.

Transport to Medical Facility

Only decontaminated patients or patients not requiring decontamination should be transported to a medical facility. "Body bags" are not recommended.

Report the condition of the patient, treatment given, and estimated time of arrival at the medical facility to the base station and the receiving medical facility.

Multi-Casualty Triage

Consult with the base station physician or the regional poison control center for advice regarding triage of multiple victims.

Patients with evidence of significant exposure, such as respiratory difficulties or symptoms of CNS depression, should be transported to a medical facility for evaluation. Others may be discharged at the scene after their names, addresses, and telephone numbers are recorded. Those discharged should be advised to seek medical care promptly if symptoms develop (see *Patient Information Sheet* below).

Emergency Department Management

- **Patients exposed only to 1,3-butadiene gas pose no risk of secondary contamination to rescuers. Patients whose skin or clothing is contaminated with liquid 1,3-butadiene could potentially contaminate hospital personnel by contact with rapidly evaporating gas. The gas is highly flammable; therefore, decontamination should be conducted in a well-ventilated area and all sources of ignition should be eliminated.**
- **1,3-Butadiene is a gas at all ambient temperatures and is not absorbed well through the skin; therefore, the most common exposure route for humans is inhalation. Very high concentrations of 1,3-butadiene have the potential to cause CNS and respiratory depression. Lower concentrations can cause irritation of the eyes and upper respiratory tract, coughing, blurred vision, nausea, and headache.**
- **There is no specific antidote for 1,3-butadiene. Treatment is supportive.**

Decontamination Area

Previously decontaminated patients and those exposed only to 1,3-butadiene gas who have no skin or eye irritation may be transferred immediately to the Critical Care Area. Others require decontamination as described below.

Be aware that use of protective equipment by the provider may cause fear in children, resulting in decreased compliance with further management efforts.

ABC Reminders

Evaluate and support airway, breathing, and circulation. In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, surgically create an airway.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Also consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). 1,3-Butadiene poisoning is not known to pose additional risk during the use of bronchial or cardiac sensitizing agents.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine

solution in 2.5 cc water, repeat every 20 minutes as needed cautioning for myocardial variability.

Patients who are comatose, hypotensive, or are having seizures or ventricular arrhythmias should be treated in the conventional manner.

Basic Decontamination

1,3-Butadiene gas or liquid should no longer be present on the patient. Nevertheless, if further decontamination is needed, patients who are able and cooperative may assist with their own decontamination. Remove contaminated clothing and all personal belongings and place them outside in a well ventilated area (due to a potential fire or explosion hazard).

Handle frostbitten skin and eyes with caution. Place frostbitten skin in warm water, about 108 °F (42 °C). If warm water is not available, wrap the affected part gently in blankets. Let the circulation reestablish itself naturally. Encourage the victim to exercise the affected part while it is being warmed.

Flush exposed skin and hair with plain water for 2 to 3 minutes, then wash with mild soap. Rinse thoroughly with water. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Do not irrigate frostbitten eyes. Otherwise, flush exposed or irritated eyes with plain water or saline for at least 15 minutes. Remove contact lenses if easily removable. If pain or injury is evident, continue irrigation while transferring the victim to the Critical Care Area.

Critical Care Area

Be certain that appropriate decontamination has been carried out (see *Decontamination Area* above).

ABC Reminders

Evaluate and support airway, breathing, and circulation as in ABC Reminders above. Establish intravenous access in seriously patients if this has not been done previously. Continuously monitor cardiac rhythm.

Patients who are comatose, hypotensive, or have seizures or cardiac arrhythmias should be treated in the conventional manner.

Inhalation Exposure

Administer supplemental oxygen by mask to patients who have respiratory complaints or CNS depression. Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical

exposures may pose additional risks. Also consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). 1,3-Butadiene poisoning is not known to pose additional risk during the use of bronchial or cardiac sensitizing agents.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed cautioning for myocardial variability.

Skin Exposure

Escaping compressed gas or liquid 1,3-butadiene can cause frostbite injury. If a victim has frost bite, treat by rewarming affected areas in a water bath at a temperature of 102 to 108 °F (40 to 42 °C) for 20 to 30 minutes and continue until a flush has returned to the affected area.

Eye Exposure

Ensure that adequate eye irrigation has been completed. Test visual acuity. Examine the eyes for conjucorneal damage and treat appropriately. Immediately consult an ophthalmologist for patients who have a suspected corneal injury.

Ingestion Exposure

Ingestion of 1,3-butadiene is highly unlikely because it is gaseous at room temperatures and a liquid only when kept under pressure.

Antidotes and Other Treatments

There is no specific antidote for 1,3-butadiene poisoning. Treatment is supportive.

Laboratory Tests

The diagnosis of acute 1,3-butadiene toxicity is primarily clinical based on respiratory distress or symptoms of CNS depression. Routine laboratory studies for symptomatic patients should include CBC, glucose, electrolytes, liver enzymes, and kidney function tests. Chest radiography and pulse oximetry (or ABG measurements) are recommended in cases of severe inhalation exposure.

1,3-Butadiene and its major metabolites, the epoxides (mono- and di-) and the mercapturic acid derivatives of the epoxides, are rapidly eliminated from the body through the lungs and kidney, respectively. Any testing should be performed shortly after exposure. Breath levels of the epoxides and urine levels of mercapturic acids are not clinically useful, but they can be used to document an exposure.

Disposition and Follow-up

Consider hospitalizing patients who have persistent or progressive symptoms, ventricular ectopy, or who might have been exposed to extremely high levels of 1,3-butadiene.

Delayed Effects

Patients who experience significant CNS depression should be observed until complete recovery is evident, preferably for 24 hours or longer.

Patient Release

Patients who have not experienced alterations in mental status or respiratory difficulty may be discharged. Patients who initially exhibited mild symptoms, but who become asymptomatic during 6 to 8 hours of observation, may also be discharged. These patients should be advised to rest and to seek medical care promptly if symptoms develop or recur (see the *1,3-Butadiene—Patient Information Sheet* below).

Follow-up

Obtain the name of the patient's primary care physician so that the hospital can send a copy of the ED visit to the patient's doctor.

After significant exposures, CBC, liver enzymes, and kidney function tests are recommended in cases of severe cardiopulmonary compromise. Patients who have skin or corneal injury should be re-examined within 24 hours.

Reporting

If a work-related incident has occurred, you might be legally required to file a report. Contact your state or local health department.

Other persons might still be at risk in the setting where this incident occurred. If the incident occurred in the workplace, discussing it with company personnel might prevent future incidents. If a public health risk exists, notify your state or local health department or other responsible public agency. When appropriate, inform patients that they may request an evaluation of their workplace from OSHA or NIOSH. See Appendices III and IV for a list of agencies that may be of assistance.

1,3-Butadiene
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to 1,3-butadiene.

What is 1,3-butadiene?
1,3-Butadiene is shipped and handled as a liquefied compressed gas in a special container. At room temperatures, it is a gas with a mild, gasoline-like odor. It is used to make synthetic rubber, tires, and plastics.

What immediate health effects can be caused by exposure to 1,3-butadiene?
Inhaling 1,3-butadiene can cause irritation of the nose, eyes, mouth, and throat. Typical symptoms include sore throat, runny nose, burning eyes, and cough. Exposure to very high concentrations can cause headache, nausea, blurred vision, drowsiness, fatigue, vertigo, coma, and death. If the skin or eyes come in contact with liquid 1,3-butadiene, frostbite can occur.

Can 1,3-butadiene poisoning be treated?
There is no specific antidote for 1,3-butadiene, but its effects can be treated and most exposed persons recover well. Persons who have inhaled large amounts of 1,3-butadiene might need to be hospitalized.

Are any future health effects likely to occur?
A small single exposure from which a person quickly recovers is not likely to cause any delayed or long-term effects. There are no reported human reproductive health effects, but some animal studies have shown developmental defects after long-term exposure. Medical evaluation is recommended for such patients. Chronic, long-term exposure might also cause cancer; 1,3-butadiene is considered a probable human carcinogen.

What tests can be done if a person has been exposed to 1,3-butadiene?
Specific tests for the presence of 1,3-butadiene and its breakdown products in the breath and urine are not widely available and must be performed shortly after exposure. These tests are not generally useful to your doctor.

Where can more information about 1,3-butadiene be found?
More information about 1,3-butadiene can be obtained from your regional poison control center; your state, county, or local health department; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in occupational and environmental health If the exposure happened at work, you may wish to discuss it with your employer, the Occupational Safety and Health Administration (OSHA), or the National Institute for Occupational Safety and Health (NIOSH). Ask the person who gave you this form for help locating these telephone numbers.

Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow *only* the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:

- shortness of breath
- coughing, wheezing, or chest tightness
- increased pain or discharge from injured eyes
- signs of skin infection, increased redness, pain, or pus-like discharge from injured skin

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.
[ ] Call for an appointment with Dr. _____ in the practice of _____. When you call for your appointment, please say that you were treated in the Emergency Department at _ _____ Hospital by _____ and were advised to be seen again in _____ days.
[ ] Return to the Emergency Department/ _____ Clinic on (date) _____ at _____ AM/PM for a follow-up examination.
[ ] Do not perform vigorous physical activities for 1 to 2 days.
[ ] You may resume everyday activities including driving and operating machinery.
[ ] Do not return to work for _____ days.
[ ] You may return to work on a limited basis. See instructions below.
[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.
[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.
[ ] Avoid taking the following medications: _____
[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: _____
_____
_____
[ ] Other instructions: _____
_____
_____

- Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.

- You or your physician can get more information on the chemical by contacting: _____ _____ or _____, or by checking out the following Internet Web sites: _____; _____.

Signature of patient _____ Date _____

Signature of physician _____ Date _____

Carbon Disulfide (CS_2)
CAS 75-15-0; UN 1131

Synonyms include carbon bisulfide, carbon sulfide, and dithiocarbonic anhydride.

- **Persons exposed only to carbon disulfide vapor pose no risk of secondary contamination. Persons whose skin or clothing is contaminated with liquid carbon disulfide can secondarily contaminate rescuers by direct contact or through off-gassing of vapor.**
- **At room temperature, carbon disulfide is a very flammable liquid that readily evaporates when exposed to air. Gaseous carbon disulfide is more than twice as heavy as air. Pure carbon disulfide liquid is colorless with a pleasant odor. Most industrially-used carbon disulfide is yellowish in color and has an unpleasant sulfurous odor imparted by impurities. Odors of carbon disulfide usually provide adequate warning of its presence.**
- **Carbon disulfide is readily absorbed through the upper respiratory tract. Carbon disulfide can also be readily absorbed through the digestive tract or skin.**

Description

At room temperature, carbon disulfide is a very flammable liquid that readily evaporates when exposed to air. Gaseous carbon disulfide is more than twice as heavy as air. Pure carbon disulfide liquid is colorless with a pleasant odor. Most industrially-used carbon disulfide liquid is yellowish in color and has an unpleasant foul-smelling odor, characteristic of hydrogen sulfide (a contaminant of technical grade carbon disulfide). Most people can smell carbon disulfide vapors at levels as low as 0.02 to 0.1 ppm. Carbon disulfide is handled and transported as a very flammable and explosive liquid.

Routes of Exposure

Inhalation

Inhalation is the major route of exposure to carbon disulfide. The vapors are readily absorbed by the lungs. The odor threshold is approximately 200 to 1,000 times lower than the OSHA PEL-TWA (20 ppm). Odors of pure or commercial grades of carbon disulfide usually provide adequate warning of hazardous concentrations. Significant exposures to carbon disulfide occur primarily in occupational settings. Acute exposure to carbon disulfide vapors can be irritating to the eye, mucous membranes, and respiratory epithelium. Acute exposure to concentrations that are orders of magnitude higher than the OSHA exposure limit may cause severe neurological effects such as headache, confusion, psychosis, coma,

and even death. Being more than twice as heavy as air, carbon disulfide vapors may be more concentrated in low-lying areas.

Children exposed to the same levels of carbon disulfide as adults may receive larger doses because they have relatively greater lung surface area:body weight ratios and higher minute volume:weight ratios. In addition, they may be exposed to higher levels than adults in the same location because of their short stature and the higher levels of carbon disulfide found nearer to the ground.

Skin/Eye Contact

Contact with liquid or concentrated vapors of carbon disulfide may cause irritation of the skin, eyes, and mucous membranes. In extreme exposure cases, direct contact may cause chemical burning of skin, eyes, or mucous membranes. Direct contact may result in significant dermal absorption. Significant inhalation or dermal exposure to carbon disulfide would most likely be encountered in an industrial environment, particularly during rayon production.

Because of their relatively larger surface area:weight ratio, children are more vulnerable to toxicants absorbed through the skin.

Ingestion

Ingestion of carbon disulfide in amounts as small as 15 mL may result in the death of an adult. Premortem symptoms include respiratory difficulty, tremors, convulsions, and coma. Humans are unlikely to be exposed to significant quantities of carbon disulfide in food or water.

Sources/Uses

Carbon disulfide is a natural product of anaerobic biodegradation. It is also synthesized via the catalyzed reaction between sulfur and methane at 600 °C. Carbon disulfide is used in the manufacture of viscose rayon, cellophane, carbon tetrachloride, dyes, and rubber. Some solvents, waxes, and cleaners contain carbon disulfide. It is also used as an insecticide.

Standards and Guidelines

OSHA PEL (permissible exposure limit) = 20 ppm (averaged over an 8-hour workshift); 30 ppm (acceptable ceiling concentration; 100 ppm (30-minute maximum peak)

NIOSH IDLH (immediately dangerous to life or health) = 500 ppm

AIHA ERPG-2 (maximum airborne concentration below which it is believed that nearly all persons could be exposed for up to 1 hour without experiencing or developing irreversible or other serious

health effects or symptoms that could impair their abilities to take protective action) = 50 ppm

Physical Properties

Description: Colorless to slightly yellowish liquid at room temperature; volatile, flammable, explosive in air

Warning properties: Sweet odor of pure carbon disulfide and foul odor of commercial and technical grade carbon disulfide are usually adequate to warn of acute. Most people can detect carbon disulfide at levels of 0.02 to 0.1 ppm (1 ppm is equivalent to 3.1 mg/m^3).

Molecular weight: 76.14 daltons

Boiling point (760 mm Hg): 115.3 °F (46.3 °C)

Freezing point: -168.9 °F (-111.6 °C)

Vapor pressure: 352.6 mm Hg at 77 °F (25 °C)

Vapor density: 2.67 g/mL (air = 1.00)

Water solubility: soluble in ethanol, methanol, benzene, and ether; only slightly soluble in water (0.23 g/100 mL at 71.6 °F [22 °C])

Flammability: LEL 1.3%; Flashpoint -22 °F (-30 °C)

Incompatibilities

Carbon disulfide is incompatible with air, alkali metals, aluminum, azides, many oxidants, and phenyl copper-triphenylphosphine complexes. Such incompatible mixtures may result in violent, and possibly explosive, reactions.

Health Effects

- **Carbon disulfide is irritating to the eyes, mucous membranes, and skin. Acute neurological effects may result from all routes of exposure and may include headache, confusion, psychosis, and coma. Acute exposure to extremely high levels of carbon disulfide may result in death.**

- **The neurotoxic effects caused by carbon disulfide may be due, in part, to its metabolic conversion to dithiocarbamates. Individuals especially susceptible to the toxic effects of carbon disulfide include those with existing disorders of the nervous system, respiratory system, cardiovascular system, or eyes.**

Acute Exposure

Mechanisms of toxicity have not been clearly elucidated for carbon disulfide, but are thought to be the result of the formation of carbon disulfide metabolites such as dithiocarbamates and/or derivatives. Most absorbed carbon disulfide is rapidly metabolized; there appears to be no substantial delay in the onset of adverse effects following acute exposure to high levels of carbon disulfide. Direct contact with carbon disulfide results in local irritation, which may be severe in cases of high-level exposure. Acute exposure to high concentrations of carbon disulfide may result in rapid onset of both local irritation and concentration-dependent increased severity of neurological symptoms such as nausea, dizziness, headache, delusions, hallucinations, delerium, mania, psychosis, blurred vision, convulsions, and coma.

Children do not always respond to chemicals in the same way that adults do. Different protocols for managing their care may be needed.

CNS

Absorption of large amounts of carbon disulfide results in rapid onset of severe neurological symptoms such as nausea, dizziness, headache, delusions, hallucinations, delerium, mania, psychosis, blurred vision, convulsions, and coma. These symptoms are dependent upon both exposure concentration and duration and may occur following inhalation, oral, or dermal exposure. Death has been reported from exposure to a vapor concentration of 4,815 ppm for 30 minutes. An exposure of 500 ppm for 30 minutes may cause a situation immediately dangerous to life and health. Death due to carbon disulfide poisoning may occur, in part, as a result of respiratory paralysis.

Respiratory

Acute exposure to carbon disulfide vapor concentrations of several hundred parts per million may result in irritation of the upper respiratory tract.

Children may be more vulnerable to gas exposure because of higher minute ventilation per kg and failure to evacuate an area promptly when exposed.

Ocular/Ophthalmic

Conjunctivitis and corneal burns can result from the irritant effect of carbon disulfide vapor and from direct exposure to the liquid. Degenerative changes of the retina and optic nerve may also result from acute exposure.

Dermal

Carbon disulfide is a skin irritant that causes pain, redness, and blisters, especially on mucous membranes. Carbon disulfide dissolves fatty layers of the epidermis. Therefore, second and third degree chemical burns may result from direct contact during high-level exposure.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants that affect the skin.

Gastrointestinal

Nausea, vomiting, and abdominal pain have been reported after acute exposure to carbon disulfide.

Chronic Exposure

Chronic exposure to carbon disulfide can result in neurological effects similar to those experienced during acute exposure, but at much lower exposure levels. In addition, chronic exposure may cause effects such as permanent central and peripheral nervous system damage, atherosclerotic tendencies, ECG abnormalities, gastrointestinal disturbances, fatty degeneration of the liver, kidney damage, sexual dysfunction, hearing loss, visual disturbances, retinal microaneurism, and blood dyscrasia. Chronic exposure may be more serious for children because of their potential for a longer latency period.

Carcinogenicity

A carcinogenicity classification for carbon disulfide has not been established by the Department of Health and Human Services, the International Association for Research on Cancer, or the U.S. EPA.

Reproductive and Developmental Effects

Carbon disulfide is included in the list of *Reproductive and Developmental Toxicants*, a 1991 report published by the U.S. General Accounting Office that lists 30 chemicals of concern

because of widely acknowledged reproductive and developmental consequences. Carbon disulfide-induced reproductive effects include alterations of the menstrual cycle in women and altered libido and abnormalities in spermatogenesis in men. There is no conclusive evidence that carbon disulfide is a genotoxin in humans.

Prehospital Management

- **Persons exposed only to carbon disulfide vapor pose no risk of secondary contamination to rescuers. Persons whose skin or clothing is contaminated with liquid carbon disulfide can secondarily contaminate response personnel by direct contact or through off-gassing of vapor.**
- **Carbon disulfide is severely irritating to the eyes, mucous membranes, and skin. Acute neurological effects may result from all routes of exposure and may include headache, confusion, psychosis, and coma. Acute exposure to extremely high levels of carbon disulfide may result in respiratory failure and death.**
- **There is no antidote for carbon disulfide. Treatment consists of removal of the victim from the contaminated area, support of respiratory and cardiovascular functions, and irrigation of contaminated eyes or skin.**

Hot Zone

Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if the rescuers have not been trained in its use, call for assistance from a local or regional hazardous materials (HAZMAT) team or other properly equipped response organization.

Rescuer Protection

Inhaled carbon disulfide is readily absorbed and is a respiratory tract irritant. Contamination of the skin or eyes can cause chemical burns. Carbon disulfide is readily absorbed through the skin.

Respiratory protection: Positive-pressure, self-contained breathing apparatus (SCBA) is recommended in response to situations that involve exposure to potentially unsafe levels of carbon disulfide gas.

Skin protection: Fully encapsulated chemical-protective clothing is recommended because carbon disulfide can cause skin irritation and burns.

ABC Reminders

Quickly establish a patent airway, ensure adequate respiration and pulse. Maintain adequate circulation. Provide supplemental oxygen if cardiopulmonary compromise is suspected. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Apply direct pressure to stop bleeding.

Victim Removal

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk should be

removed on backboards or gurneys. If these are not available, carefully carry or drag victims to safety.

Consider appropriate management of anxiety in victims with chemically-induced acute disorders, especially children who may suffer separation anxiety if separated from a parent or other adult.

Decontamination Zone

Patients exposed only to carbon disulfide gas who have no eye or skin irritation do not need decontamination. They may be transferred immediately to the Support Zone. Other patients will require decontamination as described below.

Rescuer Protection

If exposure levels are determined to be safe, decontamination may be conducted by personnel wearing a lower level of protection than that required in the Hot Zone (described above).

ABC Reminders

Quickly establish a patent airway, ensure adequate respiration and pulse. Maintain adequate circulation. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Administer supplemental oxygen as required or if cardiopulmonary compromise is suspected. Assist ventilation with a bag-valve-mask device if necessary. Apply direct pressure to control bleeding.

Basic Decontamination

Rapid skin decontamination is critical. Victims who are able may assist with their own decontamination. Remove contaminated clothing and personal belongings and place them in double plastic bags.

Gently wash exposed skin and hair with copious amounts of water (preferably under a cool shower). Use caution to avoid hypothermia when decontaminating victims, particularly children or the elderly. Use blankets or warmers after decontamination as needed.

Irrigate exposed eyes with copious amounts of tepid tap water for at least **15 minutes**. Remove contact lenses if they are easily removable without additional trauma to the eye. If pain or injury is evident, continue irrigation while transferring the victim to the Support Zone.

In cases of ingestion, **do not induce emesis**. Rinse the mouth and administer water for dilution if the patient can swallow, has a strong gag reflex, and does not drool. If the victim is not symptomatic, administer activated charcoal at a dose of 1 g/kg (infant, child, and

adult dose). A soda can and straw may be of assistance when offering charcoal to a child.

Consider appropriate management of chemically contaminated children at the exposure site. Also, provide reassurance to the child during decontamination, especially if separation from a parent occurs.

Transfer to Support Zone

As soon as basic decontamination is complete, move the victim to the Support Zone.

Support Zone

Be certain that victims have been decontaminated properly (see *Decontamination Zone*, above). Victims who have undergone decontamination or have been exposed only to carbon disulfide vapors pose no serious risk of secondary contamination to rescuers. In such cases, Support Zone personnel require no specialized protective gear. The Support Zone team should wear disposable aprons or gowns and latex gloves.

ABC Reminders

Quickly establish a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Ensure adequate respiration and pulse. Administer supplemental oxygen as required and establish intravenous access if necessary. Place on a cardiac monitor.

Additional Decontamination

Continue irrigating exposed skin and eyes, as appropriate.

In cases of ingestion, **do not induce emesis**. Rinse the mouth and administer water for dilution if the patient can swallow, has a strong gag reflex, and does not drool. If the victim is not symptomatic, administer activated charcoal at a dose of 1 g/kg (infant, child, and adult dose). A soda can and straw may be of assistance when offering charcoal to a child.

Advanced Treatment

In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, perform cricothyrotomy if equipped and trained to do so.

Treat patients who have bronchospasm with an aerosolized bronchodilator such as albuterol.

Patients who are comatose, hypotensive, or having seizures or cardiac arrhythmias should be treated according to advanced life support (ALS) protocols when clinically indicated. Avoid

epinephrine and related beta agonists (unless patient is in cardiac arrest or has reactive airways disease refractory to other treatment) because of the possible irritable condition of the myocardium, which may lead to ventricular fibrillation.

If evidence of shock or hypotension is observed, begin fluid administration. For adults with systolic pressure less than 80 mm Hg, bolus perfusion of 1,000 mL/hour intravenous saline or lactated Ringer's solution may be appropriate. Higher adult systolic pressures may necessitate lower perfusion rates. For children with compromised perfusion, administer a 20 mL/kg bolus of normal saline over 10 to 20 minutes, then infuse at 2 to 3 mL/kg/hour.

Transport to Medical Facility

Only decontaminated patients or patients not requiring decontamination should be transported to a medical facility. "Body bags" are not recommended.

Report the condition of the patient, treatment given, and estimated time of arrival at the medical facility to the base station and the receiving medical facility.

If carbon disulfide has been ingested, prepare the ambulance in case the victim vomits toxic material. Have ready several towels and open plastic bags to quickly clean up and isolate vomitus.

Multi-Casualty Triage

Consult with the base station physician or the regional poison control center for advice regarding triage of multiple victims.

Patients who have histories or evidence suggesting significant exposure (e.g., altered behavior, respiratory distress, or chemical burns) should be transported to a medical facility for evaluation. Patients who have a history of chronic pulmonary disease should be clinically evaluated for airflow obstruction.

Patients who have symptoms of mild or transient skin, nose, or eye irritation may be discharged from the scene after their names, addresses, and telephone numbers are recorded. They should be advised to rest and to seek medical care promptly if symptoms develop or recur (see *Patient Information Sheet* below).

Emergency Department Management

- **Persons exposed only to carbon disulfide vapor pose no risk of secondary contamination to rescuers. Persons whose skin or clothing is contaminated with liquid carbon disulfide can secondarily contaminate response personnel by direct contact or through off-gassing of vapor.**
- **Carbon disulfide is severely irritating to the eyes, mucous membranes, and skin. Acute neurological effects may result from all routes of exposure and may include headache, confusion, psychosis, and coma. Acute exposure to extremely high levels of carbon disulfide may result in respiratory failure and death.**
- **There is no antidote for carbon disulfide. Treatment consists of removal of the victim from the contaminated area, support of respiratory and cardiovascular functions, and irrigation of contaminated eyes or skin.**

Decontamination Area

Previously decontaminated patients and those exposed only to carbon disulfide vapor who have no skin or eye irritation may be transferred immediately to the Critical Care Area. Others require decontamination as described below.

Be aware that use of protective equipment by the provider may cause anxiety, particularly in children, resulting in decreased compliance with further management efforts.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxins absorbed through the skin. Also emergency department personnel should examine children's mouths because of the frequency of hand-to-mouth activity among children.

ABC Reminders

Evaluate and support the airways, breathing, and circulation. Provide supplemental oxygen if cardiopulmonary compromise is suspected. In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, perform cricothyrotomy if equipped and trained to do so.

Treat patients who have bronchospasm with an aerosolized bronchodilator such as albuterol.

Patients who are comatose, hypotensive, or are having cardiac arrhythmias should be treated according to established emergency department protocols. Treat seizures with diazepam.

Basic Decontamination

Patients who are able may assist with their own decontamination.

Because carbon disulfide can cause burns, ED staff should don chemical-resistant jumpsuits (e.g., of Tyvek or Saranex) or butyl rubber aprons, rubber gloves, and eye protection if the patient's clothing or skin is wet. After the patient has been decontaminated, no special protective clothing or equipment is required for ED personnel.

Quickly remove contaminated clothing while gently washing the skin with water (preferably under a cool shower). Double-bag the contaminated clothing and personal belongings. Carbon disulfide dissolves fatty layers of the epidermis; therefore, chemical burns are likely. Handle burned skin with caution.

Wash exposed skin and hair thoroughly with soap and cool water. If pain or injury is evident, continue irrigation while transferring the victim to the Critical Care Area. Use caution to avoid hypothermia when decontaminating victims, particularly children or the elderly. Use blankets or warmers after decontamination as needed.

Flush exposed or irritated eyes with copious amounts of tepid water for at least **15 minutes**. Remove contact lenses if easily removable without additional trauma to the eye. If pain or injury is evident, continue irrigation while transferring the victim to the Critical Care Area.

In cases of ingestion, **do not induce emesis**. Rinse the mouth and administer water for dilution if the patient can swallow, has a strong gag reflex, and does not drool. If the victim is not symptomatic, administer activated charcoal at a dose of 1 g/kg (infant, child, and adult dose). A soda can and straw may be of assistance when offering charcoal to a child.

Critical Care Area

Be certain that appropriate decontamination has been carried out.

ABC Reminders

Evaluate and support the airways, breathing, and circulation as in *ABC Reminders* above. Establish intravenous access in seriously ill patients. Continuously monitor cardiac rhythm.

Patients who are comatose, hypotensive, or are having seizures or cardiac arrhythmias should be treated in the conventional manner.

Inhalation Exposure

Administer supplemental oxygen by mask to patients who have respiratory complaints. Treat patients who have bronchospasm with an aerosolized bronchodilator such as albuterol.

Skin Exposure

If concentrated carbon disulfide is in contact with the skin, chemical burns may result; treat as thermal burns.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants that affect the skin.

Eye Exposure

Continue irrigation for at least **15 minutes**. Test visual acuity. Examine the eyes for corneal injury (burn) and treat appropriately. Immediately consult an ophthalmologist for patients who have suspected severe corneal injuries.

Ingestion

Do not induce emesis. Consider endoscopy to evaluate the extent of gastrointestinal-tract injury. Extreme throat swelling may require endotracheal intubation or cricothyrotomy. Gastric lavage is useful in certain circumstances to remove caustic material and prepare for endoscopic examination. Consider gastric lavage with a small nasogastric (NG) tube if: (1) a large dose has been ingested; (2) the patient is evaluated within 30 minutes; (3) the patient has oral lesions or persistent esophageal discomfort; and (4) the lavage can be administered within 1 hour of ingestion. Care must be taken when placing the gastric tube because blind gastric-tube placement may further injure the chemically damaged esophagus or stomach.

If the victim is not symptomatic, administer activated charcoal at a dose of 1 g/kg (infant, child, and adult dose). A soda can and straw may be of assistance when offering charcoal to a child.

Antidotes and Other Treatments

There is no antidote for carbon disulfide. Treatment is supportive of respiratory and cardiac function.

Laboratory Tests

Routine laboratory studies include chest radiography, electrocardiogram, blood chemistry, and arterial blood gases.

Disposition and Follow-up

Consider hospitalizing symptomatic patients who have evidence of respiratory or cardiac distress, seizures, changes in mental status, or significant chemical burns.

Delayed Effects

Acute exposure to high concentrations of carbon disulfide result in immediate adverse effects. However, some of the common manifestations of acute high-level exposure may be delayed.

Patient Release

Patients who become totally asymptomatic in terms of pulmonary complaints in a 6- to 8-hour observation period are not likely to develop complications. They may be released and advised to rest and to seek medical care promptly if symptoms develop (see the *Carbon Disulfide—Patient Information Sheet* below). Cigarette smoking can exacerbate pulmonary injury and should be discouraged for 72 hours after exposure.

Follow-up

Obtain the name of the patient's primary care physician so that the hospital can send a copy of the record of the ED visit to the patient's doctor.

Follow-up evaluation of respiratory function should be arranged for severely exposed patients. Patients who have skin or corneal injuries should be reexamined within 24 hours.

Reporting

If a work-related incident has occurred, you might be legally required to file a report; contact your state or local health department.

Other persons might still be at risk in the setting where this incident occurred. If the incident occurred in the workplace, discussing it with company personnel might prevent future incidents. If a public health risk exists, notify your state or local health department or other responsible public agency. When appropriate, inform patients that they may request an evaluation of their workplace from the Occupational Safety and Health Administration (OSHA) or the National Institute for Occupational Safety and Health (NIOSH).

Carbon Disulfide (CS_2)
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to carbon disulfide.

What is carbon disulfide?
Carbon disulfide is a very flammable liquid that readily evaporates when exposed to air. Pure carbon disulfide liquid is colorless with a pleasant odor. Most industrially-used carbon disulfide liquid is yellowish in color and has an unpleasant foul-smelling odor. Carbon disulfide has many industrial and agricultural uses. Most potential for exposure comes from its use in the rayon-producing industry. It is shipped and handled as a flammable and explosive liquid in a special container.

What immediate health effects can be caused by exposure to carbon disulfide?
Inhaling carbon disulfide causes irritation to the nose, eyes, throat, and lungs. Typical symptoms include sore throat, runny nose, burning eyes, and cough. Inhaling high levels can cause difficulty breathing. Skin contact with carbon disulfide vapor or liquid can cause irritation or burns. Acute neurological effects may result from inhalation, ingestion, or skin contact and may include headache, confusion, psychosis, and coma. Acute exposure to extremely high levels of carbon disulfide may result in death.

Can carbon disulfide poisoning be treated?
There is no antidote for carbon disulfide, but its effects can be treated and most acutely-exposed persons recover completely. Persons who have inhaled large amounts of carbon disulfide might need to be hospitalized. Persons who have come into direct skin or eye contact with carbon disulfide liquid or vapors may need to be treated for skin or eye chemical burns.

Are any future health effects likely to occur?
A single exposure from which a person recovers quickly is not likely to cause delayed or long-term effects.

What tests can be done if a person has been exposed to carbon disulfide?
Specific tests for the presence of carbon disulfide in blood or urine are not generally useful. If a severe exposure has occurred, blood analyses, x-rays, and breathing tests might show whether the lungs have been injured. The level of a metabolite of carbon disulfide (2-thiazolidine-4-carboxylic acid) can be measured in the urine, but can not be used to determine the degree of exposure to carbon disulfide.

Where can more information about carbon disulfide be found?
More information about carbon disulfide can be obtained from your regional poison control center; your state, county, or local health department; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in occupational and environmental health. If the exposure happened at work, you may wish to discuss it with your employer, the Occupational Safety and Health Administration (OSHA), or the National Institute for Occupational Safety and Health (NIOSH). Ask the person who gave you this form for help in locating these telephone numbers.

Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow *only* the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:

- eye, nose, throat irritation
- coughing or wheezing
- difficulty breathing or shortness of breath
- chest pain or tightness
- nausea, vomiting, diarrhea, or stomach pain
- dizziness, incoordination, blurred vision
- mood or behavioral changes
- headache

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.

[ ] Call for an appointment with Dr. _____ in the practice of _____. When you call for your appointment, please say that you were treated in the Emergency Department at _____ Hospital by _____ and were advised to be seen again in _____ days.

[ ] Return to the Emergency Department/ _____ Clinic on (date) _____at _ _____ AM/PM for a follow-up examination.

[ ] Do not perform vigorous physical activities for 1 to 2 days.

[ ] You may resume everyday activities including driving and operating machinery.

[ ] Do not return to work for _____ days.

[ ] You may return to work on a limited basis. See instructions below.

[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.

[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.

[ ] Avoid taking the following medications: _____

[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: __ _____

_____

[ ] Other instructions: _____

_____

_____

- Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.

- You or your physician can get more information on the chemical by contacting: _____ _____ or _____, or by checking out the following Internet Web sites: _____; _____.

Signature of patient _____ Date _____

Signature of physician _____ Date _____

Calcium Hypochlorite ($CaCl_2O_2$)/Sodium Hypochlorite (NaOCl)
CAS 7778-54-3/7681-52-9; UN 1748/1791

Synonyms of calcium hypochlorite include Losantin, hypochlorous acid, calcium salt, BK powder, Hy-Chlor, chlorinated lime, lime chloride, chloride of lime, calcium oxychloride, HTH, mildew remover X-14, perchloron, and pittchlor.

Synonyms of sodium hypochlorite include Clorox, bleach, liquid bleach, sodium oxychloride, Javex, antiformin, showchlon, chlorox, B-K, Carrel-dakin solution, Chloros, Dakin's solution, hychlorite, Javelle water, Mera Industries 2MOM3B, Milton, modified dakin's solution, Piochlor, and 13% active chlorine.

- **Persons contaminated with calcium hypochlorite dust, or whose clothing or skin is soaked with industrial-strength hypochlorite solutions may be corrosive to rescuers and may release harmful vapor. Individuals exposed only to gases released by hypochlorite pose little risk of secondary contamination to others.**

- **Calcium hypochlorite is generally available as a white powder, pellets, or flat plates; sodium hypochlorite is usually a greenish yellow, aqueous solution. Although not flammable, they may react explosively. Calcium hypochlorite decomposes in water to release chlorine and oxygen; sodium hypochlorite solutions can react with acids or ammonia to release chlorine or chloramine. Odor may not provide an adequate warning of hazardous concentrations.**

- **Both hypochlorites are toxic by the oral and dermal routes and can react to release chlorine or chloramine which can be inhaled. The toxic effects of sodium and calcium hypochlorite are primarily due to the corrosive properties of the hypochlorite moiety. Systemic toxicity is rare, but metabolic acidosis may occur after ingestion.**

Description

Calcium hypochlorite is generally available as a white powder, pellets, or flat plates. It decomposes readily in water or when heated, releasing oxygen and chlorine. It has a strong chlorine odor, but **odor may not provide an adequate warning of hazardous concentrations**. Calcium hypochlorite is not flammable, but it acts as an oxidizer with combustible material and may react explosively with ammonia, amines, or organic sulfides. Calcium hypochlorite should be stored in a dry, well ventilated area at a temperature below 120 °F (50 °C) separated from acids, ammonia, amines, and other chlorinating or oxidizing agents.

Sodium hypochlorite is generally sold in aqueous solutions containing 5 to 15% sodium hypochlorite, with 0.25 to 0.35% free alkali (usually NaOH) and 0.5 to 1.5% NaCl. Solutions of up to 40%

sodium hypochlorite are available, but solid sodium hypochlorite is not commercially used. Sodium hypochlorite solutions are a clear, greenish yellow liquid with an odor of chlorine. **Odor may not provide an adequate warning of hazardous concentrations**. Sodium hypochlorite solutions can liberate dangerous amounts of chlorine or chloramine if mixed with acids or ammonia. Anhydrous sodium hypochlorite is very explosive. Hypochlorite solutions should be stored at a temperature not exceeding 20 °C away from acids in well-fitted air-tight bottles away from sunlight.

Routes of Exposure

Inhalation

Hypochlorite solutions can liberate toxic gases such as chlorine. Chlorine's odor or irritant properties generally provide adequate warning of hazardous concentrations. However, prolonged, low-level exposures, such as those that occur in the workplace, can lead to olfactory fatigue and tolerance of chlorine's irritant effects. Chlorine is heavier than air and may cause asphyxiation in poorly ventilated, enclosed, or low-lying areas.

Children exposed to the same levels of gases as adults may receive a larger dose because they have greater lung surface area:body weight ratios and higher minute volumes:weight ratios. Children may be more vulnerable to corrosive agents than adults because of the smaller diameter of their airways. In addition, they may be exposed to higher levels than adults in the same location because of their short stature and the higher levels of chlorine found nearer to the ground.

Skin/Eye Contact

Direct contact with hypochlorite solutions, powder, or concentrated vapor causes severe chemical burns, leading to cell death and ulceration.

Because of their relatively larger surface area:weight ratio, children are more vulnerable to toxicants affecting the skin.

Ingestion

Ingestion of hypochlorite solutions causes vomiting and corrosive injury to the gastrointestinal tract. Household bleaches (3 to 6% sodium hypochlorite) usually cause esophageal irritation, but rarely cause strictures or serious injury such as perforation. Commercial bleaches may contain higher concentrations of sodium hypochlorite and are more likely to cause serious injury. Metabolic acidosis is rare, but has been reported following the ingestion of household bleach. Pulmonary complications resulting from aspiration may also be seen after ingestion.

Sources/Uses

Sodium and calcium hypochlorite are manufactured by the chlorination of sodium hydroxide or lime. Sodium and calcium hypochlorite are used primarily as oxidizing and bleaching agents or disinfectants. They are components of commercial bleaches, cleaning solutions, and disinfectants for drinking water and waste water purification systems and swimming pools (Teitelbaum 2001).

Standards and Guidelines

AIHA WEEL:
STEL (15-min) = 2 mg/m^3

Physical Properties	Calcium Hypochlorite	Sodium Hypochlorite
Description:	White powder, pellets or flat plates	Clear greenish yellow liquid
Warning properties:	Chlorine odor; inadequate warning of hazardous concentrations	Chlorine odor; inadequate warning of hazardous concentrations
Molecular weight:	142.98 daltons	74.44 daltons
Boiling point (760 mm Hg):	Decomposes at 100 °C (HSDB 2001)	Decomposes above 40 °C (HSDB 2001)
Freezing point:	Not applicable	6 °C (21 °F)
Specific gravity:	2.35 (water = 1)	1.21 (14% NAOCl solution) (water = 1)
Water solubility:	21.4% at 76 °F (25 °C)	29.3 g/100 g at 32 °F (0 °C)
Flammability:	Not flammable	Not flammable

Incompatibilities

Calcium or sodium hypochlorite react explosively or form explosive compounds with many common substances such as ammonia, amines, charcoal, or organic sulfides.

Health Effects

- **Hypochlorite powder, solutions, and vapor are irritating and corrosive to the eyes, skin, and respiratory tract. Ingestion and skin contact produces injury to any exposed tissues. Exposure to gases released from hypochlorite may cause burning of the eyes, nose, and throat; cough as well as constriction and edema of the airway and lungs can occur.**

- **Hypochlorite produces tissue injury by liquefaction necrosis. Systemic toxicity is rare, but metabolic acidosis may occur after ingestion.**

Acute Exposure

The toxic effects of sodium and calcium hypochlorite are primarily due to the corrosive properties of the hypochlorite moiety. Hypochlorite causes tissue damage by liquefaction necrosis. Fats and proteins are saponified, resulting in deep tissue destruction. Further injury is caused by thrombosis of blood vessels. Injury increases with hypochlorite concentration and pH. Symptoms may be apparent immediately or delayed for a few hours. Calcium hypochlorite decomposes in water releasing chlorine gas. Sodium hypochlorite solutions liberate the toxic gases chlorine or chloramine if mixed with acid or ammonia (this can occur when bleach is mixed with another cleaning product). Thus, exposure to hypochlorite may involve exposure to these gases.

Children do not always respond to chemicals in the same way that adults do. Different protocols for managing their care may be needed.

Gastrointestinal

Pharyngeal pain is the most common symptom after ingestion of hypochlorite, but in some cases (particularly in children), significant esophagogastric injury may not have oral involvement. Additional symptoms include dysphagia, stridor, drooling, odynophagia, and vomiting. Pain in the chest or abdomen generally indicates more severe tissue damage. Respiratory distress and shock may be present if severe tissue damage has already occurred. In children, refusal to take food or drink liquid may represent odynophagia.

Ingestion of hypochlorite solutions or powder can also cause severe corrosive injury to the mouth, throat, esophagus, and stomach, with bleeding, perforation, scarring, or stricture formation as potential sequelae.

Dermal

Hypochlorite irritates the skin and can cause burning pain, inflammation, and blisters. Damage may be more severe than is apparent on initial observation and can continue to develop over time.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxins affecting the skin.

Ocular

Contact with low concentrations of household bleach causes mild and transitory irritation if the eyes are rinsed, but effects are more severe and recovery is delayed if the eyes are not rinsed. Exposure to solid hypochlorite or concentrated solutions can produce severe eye injuries with necrosis and chemosis of the cornea, clouding of the cornea, iritis, cataract formation, or severe retinitis.

Respiratory

Ingestion of hypochlorite solutions may lead to pulmonary complications when the liquid is aspirated. Inhalation of gases released from hypochlorite solutions may cause eye and nasal irritation, sore throat, and coughing at low concentrations. Inhalation of higher concentrations can lead to respiratory distress with airway constriction and accumulation of fluid in the lungs (pulmonary edema). Patients may exhibit immediate onset of rapid breathing, cyanosis, wheezing, rales, or hemoptysis. Pulmonary injury may occur after a latent period of 5 minutes to 15 hours and can lead to reactive airways dysfunction syndrome (RADS), a chemical irritant-induced type of asthma.

Children may be more vulnerable to corrosive agents than adults because of the smaller diameter of their airways. Children may also be more vulnerable to gas exposure because of increased minute ventilation per kg and failure to evacuate an area promptly when exposed.

Metabolic

Metabolic acidosis has been reported in some cases after ingestion of household bleach.

Potential Sequelae

Exposure to toxic gases generated from hypochlorite solutions can lead to reactive airways dysfunction syndrome (RADS), a chemical irritant-induced type of asthma. Chronic complications following ingestion of hypochlorite include esophageal obstruction, pyloric stenosis, squamous cell carcinoma of the esophagus, and vocal cord paralysis with consequent airway obstruction.

Chronic Exposure

Chronic dermal exposure to hypochlorite can cause dermal irritation.

Carcinogenicity

The International Agency for Research on Cancer has determined that hypochlorite salts are not classifiable as to their carcinogenicity to humans.

Reproductive and Developmental Effects

No information was located regarding reproductive or developmental effects of calcium or sodium hypochlorite in experimental animals or humans. Calcium and sodium hypochlorite are not included in *Reproductive and Developmental Toxicants*, a 1991 report published by the U.S. General Accounting Office (GAO) that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences.

Prehospital Management

- **Rescue personnel are at low risk of secondary contamination from victims who have been exposed only to gases released from hypochlorite solutions. However, clothing or skin soaked with industrial-strength bleach or similar solutions may be corrosive to rescuers and may release harmful gases.**
- **Ingestion of hypochlorite solutions may cause pain in the mouth or throat, dysphagia, stridor, drooling, odynophagia, and vomiting. Hypochlorite irritates the skin and can cause burning pain, inflammation, and blisters. Acute exposure to gases released from hypochlorite solutions can cause coughing, eye and nose irritation, lacrimation, and a burning sensation in the chest. Airway constriction and noncardiogenic pulmonary edema may also occur.**
- **There is no specific antidote for hypochlorite poisoning. Treatment is supportive.**

Hot Zone

Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if rescuers have not been trained in its use, assistance should be obtained from a local or regional HAZMAT team or other properly equipped response organization.

Rescuer Protection

Hypochlorite is irritating to the skin and eyes and in some cases may release toxic gases.

Respiratory Protection: Positive-pressure, self-contained breathing apparatus (SCBA) is recommended in response to situations that involve exposure to potentially unsafe levels of chlorine gas.

Skin Protection: Chemical-protective clothing should be worn due to the risk of skin irritation and burns from direct contact with solid hypochlorite or concentrated solutions.

ABC Reminders

Quickly establish a patent airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible.

Victim Removal

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be removed on backboards or gurneys; if these are not available, carefully carry or drag victims to safety.

Consider appropriate management in victims with chemically-induced acute disorders, especially children who may suffer separation anxiety if separated from a parent or other adult.

Decontamination Zone

Victims exposed only to chlorine gas released by hypochlorite who have no skin or eye irritation do not need decontamination. They may be transferred immediately to the Support Zone. All others require decontamination as described below.

Rescuer Protection

If exposure levels are determined to be safe, decontamination may be conducted by personnel wearing a lower level of protection than that worn in the Hot Zone (described above).

ABC Reminders

Quickly establish a patent airway, ensure adequate respiration and pulse. Stabilize the cervical spine with a collar and a backboard if trauma is suspected. Administer supplemental oxygen as required. Assist ventilation with a bag-valve-mask device if necessary.

Basic Decontamination

Rapid decontamination is critical. Victims who are able may assist with their own decontamination. Remove and double-bag contaminated clothing and personal belongings.

Flush exposed skin and hair with copious amounts of plain tepid water. Use caution to avoid hypothermia when decontaminating victims, particularly children or the elderly. Use blankets or warmers after decontamination as needed.

Irrigate exposed or irritated eyes with saline, Ringer's lactate, or D_5W for at least 20 minutes. Eye irrigation may be carried out simultaneously with other basic care and transport. Remove contact lenses if it can be done without additional trauma to the eye. If a corrosive material is suspected or if pain or injury is evident, continue irrigation while transferring the victim to the support zone.

In cases of ingestion, **do not induce emesis or offer activated charcoal.**

Victims who are conscious and able to swallow should be given 4 to 8 ounces of water or milk; if the victim is symptomatic, delay decontamination until other emergency measures have been instituted. Dilutants are contraindicated in the presence of shock, upper airway obstruction, or in the presence of perforation.

Consider appropriate management of chemically contaminated children at the exposure site. Provide reassurance to the child during decontamination, especially if separation from a parent occurs.

Transfer to Support Zone

As soon as basic decontamination is complete, move the victim to the Support Zone.

Support Zone

Be certain that victims have been decontaminated properly (see *Decontamination Zone* above). Victims who have undergone decontamination or have been exposed only to vapor pose no serious risks of secondary contamination to rescuers. In such cases, Support Zone personnel require no specialized protective gear.

ABC Reminders

Quickly establish a patent airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Administer supplemental oxygen as required and establish intravenous access if necessary. Place on a cardiac monitor, if available.

Additional Decontamination

Continue irrigating exposed skin and eyes, as appropriate.

In cases of ingestion, **do not induce emesis or offer activated charcoal.**

Victims who are conscious and able to swallow should be given 4 to 8 ounces of water or milk; if the victim is symptomatic, delay decontamination until other emergency measures have been instituted. Dilutants are contraindicated in the presence of shock, upper airway obstruction, or in the presence of perforation.

Advanced Treatment

In cases of respiratory compromise secure airway and respiration via endotracheal intubation. Avoid blind nasotracheal intubation or use of an esophageal obturator: only use direct visualization to intubate. When the patient's condition precludes endotracheal intubation, perform cricothyrotomy if equipped and trained to do so.

Treat patients who have bronchospasm with an aerosolized bronchodilator such as albuterol.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in water, repeat every 20 minutes as needed cautioning for myocardial variability.

Patients who are comatose, hypotensive, or having seizures or who have cardiac arrhythmias should be treated according to advanced life support (ALS) protocols.

Transport to Medical Facility

Only decontaminated patients or those not requiring decontamination should be transported to a medical facility. "Body bags" are not recommended.

Report to the base station and the receiving medical facility the condition of the patient, treatment given, and estimated time of arrival at the medical facility.

If a chemical has been ingested, prepare the ambulance in case the victim vomits toxic material. Have ready several towels and open plastic bags to quickly clean up and isolate vomitus.

Multi-Casualty Triage

Consult with the base station physician or the regional poison control center for advice regarding triage of multiple victims.

Patients who have ingested hypochlorite, or who show evidence of significant exposure to hypochlorite or chlorine (e.g., severe or persistent cough, dyspnea or chemical burns) should be transported to a medical facility for evaluation. Patients who have minor or transient irritation of the eyes or throat may be discharged from the scene after their names, addresses, and telephone numbers are recorded. They should be advised to seek medical care promptly if symptoms develop or recur (see *Patient Information Sheet* below).

Emergency Department Management

- **Hospital personnel are at low risk of secondary contamination from victims who have been exposed only to gases released from hypochlorite solutions. However, clothing or skin soaked with industrial-strength bleach or similar solutions may be corrosive to rescuers and may release harmful gases.**
- **Ingestion of hypochlorite solutions may cause pain in the mouth or throat, dysphagia, stridor, drooling, odynophagia, and vomiting. Hypochlorite irritates the skin and can cause burning pain, inflammation, and blisters. Acute exposure to gases released from hypochlorite solutions can cause coughing, eye and nose irritation, lacrimation, and a burning sensation in the chest. Airway constriction and noncardiogenic pulmonary edema may also occur.**
- **There is no specific antidote for hypochlorite poisoning. Treatment requires supportive care.**

Decontamination Area

Unless previously decontaminated, all patients suspected of contact with hypochlorite and all victims with skin or eye irritation require decontamination as described below. Patients exposed only to chlorine gas who have no skin or eye irritation may be transferred immediately to the Critical Care Area. Because hypochlorite is an irritant, don butyl rubber gloves and apron before treating patients.

Be aware that use of protective equipment by the provider may cause anxiety, particularly in children, resulting in decreased compliance with further management efforts.

Because of their relatively larger surface area:weight ratio, children are more vulnerable to toxicants affecting the skin. Also, emergency department personnel should examine children's mouths because of the frequency of hand-to-mouth activity among children.

ABC Reminders

Evaluate and support airway, breathing, and circulation. Children may be more vulnerable to corrosive agents than adults because of the smaller diameter of their airways. In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, surgically secure an airway.

Treat patients who have bronchospasm with an aerosolized bronchodilator such as albuterol.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in water, repeat every 20 minutes as needed cautioning for myocardial variability.

Patients who are comatose, hypotensive, or having seizures or cardiac arrhythmias should be treated in the conventional manner.

Metabolic acidosis can be managed with intravenous sodium bicarbonate and buffer solutions.

Basic Decontamination

Patients who are able may assist with their own decontamination. Remove and double bag contaminated clothing and personal belongings.

Flush exposed skin and hair with copious amounts of plain water. Use caution to avoid hypothermia when decontaminating victims, particularly children or the elderly. Use blankets or warmers after decontamination as needed.

Irrigate exposed or irritated eyes with saline, Ringer's lactate, or D_5W for at least 20 minutes. Remove contact lenses if it can be done without additional trauma to the eye. Continue irrigation while transporting the patient to the Critical Care Area.

In cases of ingestion, **do not induce emesis or offer activated charcoal**.

Victims who are conscious and able to swallow should be given 4 to 8 ounces of water or milk. Dilutants are contraindicated in the presence of shock, upper airway obstruction, or in the presence of perforation.

Critical Care Area

Be certain that appropriate decontamination has been carried out (see *Decontamination Area* above).

ABC Reminders

Evaluate and support airway, breathing, and circulation as in ABC Reminders above. Children may be more vulnerable to corrosive agents than adults because of the smaller diameter of their airways. Establish intravenous access in seriously ill patients if this has not been done previously. Continuously monitor cardiac rhythm.

Patients who are comatose, hypotensive, or having seizures or cardiac arrhythmias should be treated in the conventional manner.

Metabolic acidosis can be managed with intravenous sodium bicarbonate and buffer solutions.

Inhalation Exposure

Administer supplemental oxygen by mask to patients who have respiratory symptoms. Treat patients who have bronchospasm with an aerosolized bronchodilator such as albuterol.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in water, repeat every 20 minutes as needed cautioning for myocardial variability.

Skin Exposure

If concentrated hypochlorite solutions contact the skin, chemical burns may occur; treat as thermal burns. Patients developing dermal hypersensitivity reactions may require treatment with systemic or topical corticosteroids or antihistamines.

Because of their relatively larger surface area:body weight ratio children are more vulnerable to toxicants that affect the skin.

Eye Exposure

Irrigate exposed or irritated eyes with saline, Ringer's lactate, or D_5W for at least 20 minutes. Check the pH of the conjunctiva every 30 minutes for 2 hours after irrigation is stopped. If the pH is not neutral an irrigating contact lens should be used to apply continuous irrigation for several hours until the pH of the tissue normalizes. Test visual acuity and examine the eyes for corneal damage and treat appropriately. Immediately consult an ophthalmologist for patients who have corneal injuries.

Ingestion

In cases of ingestion, **do not induce emesis or offer activated charcoal**.

Give 4 to 8 ounces of water or milk to alert patients who can swallow if not done previously. Dilutants are contraindicated in the presence of shock, upper airway obstruction, or in the presence of perforation.

Direct visualization of the esophagus is of primary importance for determining the extent of injury. All patients who are suspected of having significant ingestion, or those (such as children) for whom there is an unreliable history, must have early endoscopy within 36 to 48 hours of ingestion. Use of a flexible endoscope is associated with a lower risk of perforation. The esophagus, stomach and duodenum should be endoscopically evaluated because burns of the

esophagus do not correlate with the presence of burns in the stomach.

Contraindications for endoscopy include: unstable patient, evidence of perforation, upper airway compromise, or more than 48 hours after ingestion.

Gastric lavage is not generally recommended for hypochlorite ingestion.

Antidotes and Other Treatments

There is no specific antidote for hypochlorite. Treatment is supportive.

Laboratory Tests

The diagnosis of acute hypochlorite toxicity is primarily clinical. However, laboratory testing is useful for monitoring the patient and evaluating complications. Routine laboratory studies for all exposed patients include CBC, glucose, and electrolyte determinations. Patients who have respiratory complaints may require pulse oximetry (or ABG measurements) and chest radiography. Chlorine inhalation may be complicated by hyperchloremic metabolic acidosis; in addition to electrolytes, monitor blood pH.

Disposition and Follow-up

Consider hospitalizing patients who have a suspected significant exposure or have eye burns or serious skin burns. Patients with perforation should be prepared for emergency surgery.

Delayed Effects

Patients who ingested large volumes of hypochlorite, who have unreliable histories, or are symptomatic complaining of pain in swallowing, persistent shortness of breath, severe cough, or chest tightness should be admitted to the hospital and observed until symptom-free. Injury may progress for several hours.

Patient Release

Asymptomatic patients and those who experienced only minor irritation of the nose, throat, eyes, or respiratory tract may be released. In most cases, these patients will be free of symptoms in an hour or less. They should be advised to seek medical care promptly if symptoms develop or recur (see the *Hypochlorite—Patient Information Sheet* below).

Follow-up

Obtain the name of the patient's primary care physician so that the hospital can send a copy of the ED visit to the patient's doctor.

Follow up is recommended for all hospitalized patients because long-term gastrointestinal or respiratory problems can result. Respiratory monitoring is recommended until the patient is symptom-free. Chlorine-induced reactive airways dysfunction syndrome (RADS) has been reported to persist from 2 to 12 years.

Patients who have skin or corneal injury should be re-examined within 24 hours.

Reporting

If a work-related incident has occurred, you may be legally required to file a report; contact your state or local health department.

Other persons may still be at risk in the setting where this incident occurred. If the incident occurred in the workplace, discussing it with company personnel may prevent future incidents. If a public health risk exists, notify your state or local health department or other responsible public agency. When appropriate, inform patients that they may request an evaluation of their workplace from OSHA or NIOSH. See Appendix III for a list of agencies that may be of assistance.

Calcium/Sodium Hypochlorite
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to calcium or sodium hypochlorite.

What is hypochlorite?
Calcium hypochlorite is generally available as a white powder, pellets, or flat plates, while sodium hypochlorite is usually a greenish yellow, aqueous solution. Hypochlorite is used widely in cleaning agents, and in bleaching, drinking-water and swimming-pool disinfecting. Calcium hypochlorite decomposes in water to release chlorine and sodium hypochlorite solutions and can release chlorine gas if mixed with other cleaning agents.

What immediate health effects can be caused by exposure to hypochlorite?
Hypochlorite powder, solutions, and vapor are irritating and corrosive. Swallowing hypochlorite or contact with the skin or eyes produces injury to any exposed tissues. Exposure to gases released from hypochlorite may cause burning of the eyes, nose, and throat; cough; and damage to the airway and lungs. Generally, the more serious the exposure, the more severe the symptoms.

Can hypochlorite poisoning be treated?
There is no antidote for hypochlorite, but its effects can be treated and most exposed persons get well. Persons who have experienced serious symptoms may need to be hospitalized.

Are any future health effects likely to occur?
A single small exposure from which a person recovers quickly is not likely to cause delayed or long-term effects. After a serious exposure, symptoms may worsen for several hours.

What tests can be done if a person has been exposed to hypochlorite?
Specific tests for the presence of hypochlorite in blood or urine generally are not useful to the doctor. If a severe exposure has occurred, blood and urine analyses and other tests may show whether the lungs, heart, or brain have been injured. Testing is not needed in every case.

Where can more information about hypochlorite be found?
More information about hypochlorite can be obtained from your regional poison control center, your state, county, or local health department; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in occupational and environmental health. If the exposure happened at work, you may wish to discuss it with your employer, the Occupational Safety and Health Administration (OSHA), or the National Institute for Occupational Safety and Health (NIOSH). Ask the person who gave you this form for help in locating these telephone numbers.

Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow *only* the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:

- difficulty swallowing, or pain in the abdomen or chest
- coughing or wheezing, difficulty breathing, shortness of breath, or chest pain
- increased ocular pain or discharge, change in vision
- increased redness or pain or a pus-like discharge in the area of a skin burn

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.
[ ] Call for an appointment with Dr. _____ in the practice of _____. When you call for your appointment, please say that you were treated in the Emergency Department at _____ Hospital by _____ and were advised to be seen again in _____ days.
[ ] Return to the Emergency Department/ _____ Clinic on (date) _____ at _____ AM/PM for a follow-up examination.
[ ] Do not perform vigorous physical activities for 1 to 2 days.
[ ] You may resume everyday activities including driving and operating machinery.
[ ] Do not return to work for _____ days.
[ ] You may return to work on a limited basis. See instructions below.
[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.
[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.
[ ] Avoid taking the following medications: _____
[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: _____
_____
_____
[ ] Other instructions: _____
_____
_____

- Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.

- You or your physician can get more information on the chemical by contacting: _____ _____ or _____, or by checking out the following Internet Web sites: _____; _____.

Signature of patient _____ Date _____

Signature of physician _____ Date _____

Chlordane ($C_{10}H_6Cl_8$)
CAS 57-74-9; UN 2996

Synonyms include a wide variety of trade names: Chlordan, Chlor-Kil, CD-68, Octachlor, Termi-Ded, Toxichlor, Topichlor, and Velsicol 1068.

- **Persons exposed only to chlordane vapor do not pose risks of secondary contamination to others. Persons whose skin or clothing is contaminated with liquid or powdered chlordane can cause secondary contamination by direct contact.**
- **Chlordane is a white powder or a colorless to amber/brown viscous liquid. Chlordane itself is not combustible, but it is often dissolved in solvents that are flammable. Chlordane has low volatility; however, solid residues can result in contaminated air and inhalation exposure. Odor generally provides inadequate warning of hazardous concentrations.**
- **Chlordane is absorbed well by the lungs and gastrointestinal tract and through intact skin. Exposure by any route can cause systemic effects.**

Description

Technical-grade chlordane is a mixture of chlordane isomers and more than 140 related reaction products. Depending on the composition, the mixture may be an amber-to-brown, viscous liquid or a white powder. At room temperature, chlordane is almost odorless or may have a slight chlorine-like odor, but the odor is inadequate as a warning of exposure. It is semi-volatile, volatilizing in hot environments but not under cooler conditions. Chlordane is insoluble in water and soluble in hydrocarbon solvents. It is not combustible, but will decompose when heated or reacted with strong oxidizers or alkaline agents to produce corrosive and/or toxic gases: carbon monoxide, hydrogen chloride gas, chlorine, and phosgene. As a commercial pesticide, chlordane is usually dissolved in hydrocarbons and used as a spray. Chlordane will attack some forms of plastics and rubber and is corrosive to iron and zinc; it can be stored in a cool, dry, well-ventilated area in aluminum, aluminum-clad or high-baked phenolic enamel-lined metal containers.

Routes of Exposure

Inhalation

Acute inhalation of chlordane vapor is unlikely because of chlordane's low vapor pressure at ordinary temperatures; however, chlordane is semi-volatile and may volatilize in hot environments. **The odor threshold for chlordane is about 10 times lower than the OSHA permissible exposure limit (PEL); however, odor may not provide an adequate warning for prolonged exposures because olfactory fatigue may**

occur. Toxic effects can occur after acute inhalation of a spray or mist containing chlordane and after chronic inhalation, usually by occupants of contaminated houses. With pesticide formulations, toxicity may also occur from inhalation of the solvents used to dissolve chlordane.

Children exposed to the same levels of chlordane as adults may receive larger dose because they have greater lung surface area:body weight ratios and increased minute volumes:weight ratios. In addition, they may be exposed to higher levels than adults in the same location because of their short stature and the higher levels of chlordane found nearer to the ground.

Skin/Eye Contact

Chlordane is rapidly absorbed through the skin, which can lead to systemic toxicity. Oils applied to the skin increase the absorption of chlordane. Early formulations of chlordane were irritating to the skin and mucous membranes.

Children are more vulnerable to toxicants absorbed through the skin because of their larger surface area:weight ratio.

Ingestion

Acute toxic effects, including death, can result from ingestion of chlordane.

Sources/Uses

Chlordane is a synthetic compound. It was used widely as an insecticide on food crops and as a termiticide in buildings and homes. Since 1988, the use and commercial production of chlordane (except for export) has been prohibited in the United States and many other countries. However, chlordane residue is still present from prior use in many homes and other structures, as well as the surrounding soil. Old supplies of chlordane may still exist in locations such as warehouses, garages, and landfills.

Standards and Guidelines

OSHA PEL (permissible exposure limit) = 0.5 mg/m^3 (skin) (averaged over an 8-hour work shift)

NIOSH IDLH (immediately dangerous to life or health) = 100 mg/m^3

Physical Properties

Description: Amber, viscous liquid

Warning properties: Nearly odorless; inadequate warning for acute or chronic exposure.

Molecular weight: 409.8 daltons

Boiling point (2 mm Hg): 347 °F (175° C)

Melting point (*cis* isomer): 225–228 °F (107–109 °C)

Melting point (*trans* isomer): 217–221 °F (103–105 °C)

Vapor pressure: 0.00001 (1 x 10^{-5}) mm Hg at 77 °F (25 °C)

Specific gravity: 1.59–1.63 at 77 °F (water = 1)

Water solubility: Water insoluble

Flammability: Noncombustible liquid (but the commercial product may be dissolved in various flammable solvents).

Incompatibilities

Chlordane reacts with strong oxidizers and alkaline reagents; decomposition produces corrosive/toxic fumes of carbon monoxide, hydrogen chloride gas, chlorine, and phosgene. Chlordane will attack some forms of plastic, rubber, and coatings. It is corrosive to iron and zinc.

Health Effects

- **Significant chlordane exposure by any route disrupts the transmission of nerve impulses, resulting in CNS excitation, convulsions, and respiratory depression.**
- **Chlordane is absorbed well through intact skin. Early formulations contained impurities that were skin and mucous-membrane irritants.**
- **Common symptoms of chlordane poisoning include headache, nausea, excitability, confusion, and muscle tremors that may precede convulsions.**

Acute Exposure

Adverse health effects of chlordane are due both to the parent compound and its metabolites. The mechanism of neurotoxic effects may involve competitive inhibition of gamma aminobutyric acid (GABA), reducing GABA-mediated inhibition of post-synaptic neuronal excitability.

Children do not always respond to chemicals in the same way that adults do. Different protocols for managing their care may be needed.

CNS

Chlordane poisoning by any exposure route can cause blurred vision, sensory disturbances, headache, refractory convulsions, muscle tremors, excitability, confusion, loss of consciousness, coma, and death. Serious poisonings are characterized by onset of violent convulsions within 0.5 to 3 hours, with death or remission of convulsions following shortly thereafter.

Gastrointestinal

Nausea, vomiting, and diarrhea can occur, especially after ingestion.

Dermal

Extensive skin contact may result in dermal irritation. Chlordane produced prior to 1951 had a high percentage of irritant impurities; chlordane produced after that date is generally nonirritating. Chlordane is absorbed well even through intact skin, and dermal absorption can lead to systemic toxicity and death.

Because of their larger surface area:body weight ratio, children are more vulnerable to toxicants absorbed through the skin

Ocular

When splashed in the eye, chlordane may produce redness and pain.

Respiratory

Respiratory depression, irritation, reduced gas exchange, and chemical pneumonitis may occur.

Musculoskeletal

In serious acute exposures, myoclonic jerking may be so intense as to cause compression fractures of the vertebrae.

Metabolic

Severe metabolic acidosis may be a consequence of convulsions and an immediate cause of death.

Hepatic

Chlordane induces liver microsomal enzymes, thereby enhancing the metabolism of and reducing the efficacy of therapeutic drugs such as phenobarbital, which may be administered as an anticonvulsant.

Potential Sequelae

Chlordane poisoning by any exposure route can cause permanent alterations of nervous system function, including problems with memory, learning, thinking, sleeping, personality changes, depression, numbness in the extremities, headache, and sensory and perceptual changes. Inflammation of the lungs due to pulmonary aspiration of vomitus, accumulation of fluid in the lungs, and acute kidney failure may occur after acute poisoning. If a toxic or lethal dose has been absorbed, anorexia and loss of body weight may be marked if death is delayed.

Chronic Exposure

Chronic chlordane exposure can cause permanent alterations of nervous system function, including problems with memory, learning, thinking, sleeping, personality changes, depression, numbness in the extremities, headache, and sensory and perceptual changes. It has been suggested that chronic exposure can cause blood disorders, but these disorders were not shown to have an increased incidence in heavily exposed groups of workers. Besides blood disorders, jaundice has been reported in persons living in homes treated with chlordane for termite control, but liver-function tests were normal in workers who manufactured chlordane. Chronic exposures may be more serious for children because of their potential longer latency period.

Carcinogenicity

IARC has determined that chlordane is possibly carcinogenic to humans (group 2B). The EPA has determined that technical grade chlordane is a likely human carcinogen. Chlordane is structurally similar to rodent carcinogens and chronic chlordane exposure can cause hepatocellular carcinoma in several strains of mice. The evidence for carcinogenicity in humans is weak: a few case reports and mixed or equivocal case-control study results associating exposure to chlordane with leukemia and non-Hodgkin's lymphoma. Epidemiological evidence for an

association is supported by limited evidence of mutagenicity in human and rodent lymphocytes tested *in vitro*.

Reproductive and Developmental Effects

The TERIS database states that no epidemiologic studies have reported birth defects among infants born to mothers exposed to chlordane during pregnancy. Chlordane is excreted in breast milk. Chlordane is not included in *Reproductive and Developmental Toxicants*, a 1991 report published by the U.S. General Accounting Office (GAO) that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences. No teratogenic effects from acute exposure have been reported. Prenatal exposure to chlordane has been reported for a few cases of neuroblastoma, blood dyscrasias, and depressed cell-mediated immunity, but no direct link with the chemical was established.

Chlordane induces liver enzymes and enhances metabolism of steroid hormones, including oral contraceptives; sterility has been reported in animals.

Prehospital Management

- **Chlordane is absorbed well through intact skin. Victims whose skin or clothing is contaminated with liquid or powdered chlordane can secondarily contaminate response personnel by direct contact and in very severe contamination by off-gassing of carrier solvents. In rare instances, toxic vomitus can also secondarily contaminate rescuers by the same routes.**

- **Chlordane can cause CNS excitation, blurred vision, confusion, and intractable seizures. Victims should be protected from loud noises or other stimuli that might trigger seizures. Do not administer epinephrine (or other adrenergic drug) or atropine, since ventricular fibrillation may ensue.**

- **There is no specific antidote for chlordane poisoning. Treatment consists of supportive measures.**

Hot Zone

Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if rescuers have not been trained in its use, assistance should be obtained from a local or regional HAZMAT team or other properly equipped response organization.

Rescuer Protection

Chlordane is a moderately toxic systemic poison that is absorbed well by inhalation, and through the skin. It is also irritating to the skin and eyes on direct contact. Rescuers should wear chlordane-resistant gear.

Respiratory Protection: Positive-pressure, self-contained breathing apparatus (SCBA) is recommended in response situations that involve exposure to potentially unsafe levels of chlordane.

Skin Protection: Chemical-protective clothing is recommended because skin irritation and dermal absorption may occur and may contribute to systemic toxicity. For chlordane hazards, NIOSH recommends suits made of CPF3™ (Kappler Company), and Trellchem HPS™ (Trelleborg Company) and gloves or boots made of Teflon™ (DuPont Company). NTP recommends Tyvek-type clothing or sleeves and gloves made of Viton (North F-091), Nitrile (Edmont 37-155), PVA (Edmont 15-554), or Neoprene (Pioneer N-44).

ABC Reminders

Quickly access a patent airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization

manually and apply a cervical collar and a backboard when feasible.

Victim Removal

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be removed on backboards or gurneys; if these are not available, carefully carry or drag victims to safety.

Consider appropriate management of chemically contaminated children, such as measures to reduce anxiety if a child is separated from a parent or other adult.

Decontamination Zone

All victims who have contacted chlordane liquid or powder require decontamination as described in this section (see *Basic Decontamination*). Victims exposed only to chlordane vapor who have no skin or eye irritation do not need decontamination and may be transferred to the Support Zone

Rescuer Protection

If exposure levels are determined to be safe, decontamination may be conducted by personnel wearing a lower level of protection than that worn in the Hot Zone (see *Rescuer Protection* above).

ABC Reminders

Quickly access a patent airway, ensure adequate respiration and palpable pulse. Stabilize the cervical spine with a collar and a backboard if trauma is suspected. Apply artificial respiration if the victim is not breathing. Assist ventilation with a bag-valve-mask device if necessary. Do not use mouth-to-mouth resuscitation if the victim inhaled or ingested chlordane. Administer supplemental oxygen as required.

For inhalation exposures, monitor for respiratory distress. If cough or breathing difficulty develops, evaluate for respiratory tract irritation, bronchitis, or pneumonitis. Administer 100% humidified supplemental oxygen if breathing is difficult.

Basic Decontamination

Victims who are able and cooperative may assist with their own decontamination. Remove and double-bag contaminated clothing and personal belongings. Leather absorbs chlordane; therefore, items such as leather shoes, gloves, and belts should be discarded.

If there has been direct contact with liquid or powdered chlordane, flush exposed skin, hair, and under nails with plain, running, tepid water for 20 minutes, then wash twice with mild soap. **Do not scrub**, since this can increase absorption through the skin. Rinse thoroughly with water.

If eyes have been exposed directly, irrigate with large amounts of plain, tepid water or saline for 20 minutes, occasionally lifting the lower and upper lids. During this time, remove contact lenses, if easily removable without additional trauma to the eye.

Keep victims (adults or children) warm and quiet to avoid triggering seizures and the complication of hypothermia.

In cases of chlordane ingestion, **do not induce emesis**. If the victim is conscious and able to swallow, administer an aqueous slurry of activated charcoal at 1 gm/kg (usual adult dose 60–90 g, child dose 25–50 g). A soda can and straw may be of assistance when offering charcoal to a child. (The efficacy of activated charcoal for chlordane poisoning is uncertain).

Transfer to Support Zone

As soon as basic decontamination is complete, move the victim to the Support Zone.

Support Zone

Be certain that victims have been decontaminated properly (see *Basic Decontamination* above). Persons who have undergone decontamination or who have been exposed only to vapor pose no serious risks of secondary contamination to rescuers. In such cases, Support Zone personnel require no special protective gear.

ABC Reminders

Quickly access a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Ensure adequate respiration and pulse. Administer supplemental oxygen as required and establish intravenous access if necessary. Place on a cardiac monitor.

Additional Decontamination

Continue irrigating exposed skin and eyes, as appropriate.

In cases of chlordane ingestion, **do not induce emesis**. If the exposure is recent (within 1–2 hours) and the patient is conscious and able to swallow, administer a slurry of activated charcoal (at 1 gm/kg, usual adult dose 60–90 g, child dose 25–50 g) if it has not been given previously. A soda can and straw may be of assistance when offering charcoal to a child. (The efficacy of activated charcoal for chlordane poisoning is uncertain.)

Advanced Treatment

In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, perform cricothyroidotomy if equipped and trained to do so.

To control metabolic acidosis, treat with sodium bicarbonate under medical base control (adult dose = 1 ampule; pediatric dose = 1 mEq/kg).

Patients who are comatose, hypotensive, or have seizures or cardiac dysrhythmias should be treated according to advanced life support (ALS) protocols.

High concentrations of chlordane can increase cardiac irritability, use caution with cardiac or bronchial sensitizing agents.

Transport to Medical Facility

Only decontaminated patients or patients not requiring decontamination should be transported to a medical facility. "Body bags" can cause added danger and are not recommended.

Report to the base station and the receiving medical facility the condition of the patient, treatment given, and estimated time of arrival at the medical facility.

If a chlordane-containing mixture has been ingested, prepare the ambulance in case the victim vomits toxic material. Have ready several towels and open plastic bags to quickly clean up and isolate vomitus.

Because of the rapidity of the onset of intractable seizures in patients who have chlordane toxicity and the potential for vomiting during seizures, suction should be readily available. Be prepared to protect the airway by positioning or intubation.

Multi-Casualty Triage

Consult with the base station physician or the regional poison control center for advice regarding triage of multiple victims.

Patients who have histories or symptoms suggesting substantial exposure (CNS effects, eye irritation, respiratory distress, or cardiac dysrhythmias) and all persons who have ingested chlordane should be transported to a medical facility for evaluation.

Asymptomatic patients exposed only by inhalation may be released from the scene after their names, addresses, and telephone numbers are recorded. Be certain that no significant dermal exposure has occurred before releasing a patient from the scene. Those released should be advised to seek medical care

promptly if symptoms develop (see the *Patient Information Sheet* below).

Emergency Department Management

- **Chlordane is absorbed well through intact skin. Patients whose skin or clothing is contaminated with liquid or powdered chlordane can secondarily contaminate response personnel by direct contact and, in cases of severe contamination, by off-gassing of carrier solvents. Rarely, toxic vomitus can also secondarily contaminate rescuers by the same routes. Patients do not pose serious contamination risks after contaminated clothing is removed and the skin is thoroughly washed.**

- **Chlordane is irritating to the skin, eyes, and respiratory tract. Systemic effects can occur from all routes of exposure and may include CNS excitation, intractable seizures, respiratory depression, and ventricular dysrhythmia. Sensory and motor abnormalities may be early signs of convulsions.**

- **There is no specific antidote for chlordane poisoning. Treatment consists of management of seizures and other measures to support respiratory and cardiovascular function.**

Decontamination Area

Unless previously decontaminated, all patients suspected of direct contact with chlordane liquid or solid and all patients with skin or eye irritation require decontamination as described below. Because chlordane is absorbed through the skin and can attack rubber and several kinds of plastics, don Teflon™ gloves and suits before treating patients. Patients exposed only to vapor who have no skin or eye irritation do not need decontamination and may be transferred to the Critical Care area.

Be aware that use of protective equipment by the provider may cause fear in children, resulting in decreased compliance with further management efforts.

Because of their larger surface area:weight ratio, children are more vulnerable to toxicants absorbed through the skin. Also, emergency room personnel should examine children's mouths because of the frequency of hand-to-mouth activity among children.

ABC Reminders

Evaluate and support airway, breathing, and circulation. Children may be more vulnerable to corrosive or irritating agents than adults because of the smaller diameter of their airways. Intubate the trachea in cases of respiratory compromise. If the patient's condition precludes intubation, surgically create an airway.

Chlordane exposure may cause cardiac arrhythmias. Therefore, administration of epinephrine or other adrenergics or atropine is **not recommended** unless absolutely necessary.

Patients who have seizures or ventricular dysrhythmias or who are comatose or hypotensive should be treated in the conventional manner.

For seizures, administer a benzodiazepine: Diazepam: *adults*, 5 to 10 mg i.v., repeated every 10 to 15 minutes as needed to a maximum of 30 mg; *children*, 0.2 to 0.5 mg/kg i.v., repeated every 5 minutes as needed to a maximum of 10 mg in children over 5 years or to a maximum of 5 mg in children under 5 years; or Lorazepam: *adults*, 4 to 8 mg i.v.; *children*, 0.05 to 0.1 mg/kg i.v.. Consider phenobarbital and/or phenytoin or fosphenytoin if seizures are uncontrollable or recur after diazepam.

Correct acidosis in the patient who has coma, seizures, or cardiac dysrhythmias by administering intravenously sodium bicarbonate (adult dose = 1 ampule; pediatric dose = 1 Eq/kg). Further bicarbonate therapy should be guided by arterial blood gas (ABG) measurements.

Basic Decontamination

Patients who are able may assist with their own decontamination. If the patient's clothing is contaminated with chlordane, remove and double-bag the contaminated clothing and all personal belongings. Since leather absorbs chlordane, items such as leather belts, shoes, and gloves should be discarded and destroyed by incineration.

Flush exposed skin, hair, and under nails with plain water for 20 minutes (preferably under a shower), then wash twice with mild soap and shampoo. Rinse thoroughly with water.

Exposed adults or children should be kept warm and quiet to avoid seizures or the complications of hypothermia.

Flush exposed eyes with plain water or saline for at least 20 minutes, occasionally lifting the lower and upper lids. During this time, remove contact lenses if easily removable without additional trauma to the eye. Continue irrigation while transporting the patient to the Critical Care Area.

In cases of ingestion, **do not induce emesis**. (More information is provided in *Ingestion Exposure* under **Critical Care Area** below).

Critical Care Area

Be certain that appropriate decontamination has been carried out (see *Decontamination Area* above).

ABC Reminders

Evaluate and support airway, breathing, and circulation as in *ABC Reminders* above under **Decontamination Zone**. Children may be more vulnerable to corrosive agents than adults because of the smaller diameter of their airways. Establish intravenous access in symptomatic patients if this has not been done previously. Continuously monitor cardiac rhythm.

Patients exposed to high levels of chlordane should be carefully observed for sensory or motor abnormalities that might signal the onset of seizures.

Patients who are comatose or have seizures should be treated in the conventional manner. Refractory seizures may require more aggressive measures such as mechanical ventilation or inducing muscle paralysis or barbiturate coma. Use continuous EEG monitoring.

Control metabolic acidosis with sodium bicarbonate (*adult dose* = 1 ampule; *initial pediatric dose* = 1 mEq/kg).

Inhalation Exposure

Administer supplemental oxygen by mask to patients who have respiratory symptoms (difficulty in breathing, pneumonitis).

Do not administer epinephrine, other adrenergic amines, or atropine, since enhanced chlordane-induced myocardial irritability may predispose to ventricular fibrillation.

Skin Exposure

Washing the skin and hair with mild soap and rinsing thoroughly with water is usually sufficient treatment for skin exposure.

Because of their larger surface area:weight ratio, children are more vulnerable to toxicants absorbed through the skin.

Eye Exposure

Continue irrigation for at least 15 minutes. Test visual acuity. Examine the eyes for corneal damage and treat appropriately. Immediately consult an ophthalmologist for patients who have severe corneal injuries.

Ingestion Exposure

Do not induce emesis because the patient is at risk of CNS depression or seizures, which may lead to pulmonary aspiration during vomiting. Control any seizures first.

Consider cautious gastric lavage with a small nasogastric tube if: (1) a large dose has been ingested; (2) the patient's condition is

evaluated within 30 minutes; (3) the patient has oral lesions or persistent esophageal discomfort; and (4) the lavage can be administered within 1 hour of ingestion. Care must be taken when placing the gastric tube because blind gastric-tube placement may further injure the chemically damaged esophagus or stomach.

If the patient is alert and charcoal has not been given previously, administer a slurry of activated charcoal at 1 gm/kg (usual adult dose 60–90 g, child dose 25–50 g). A soda can and straw may be of assistance when offering charcoal to a child. (The efficacy of charcoal for chlordane poisoning is uncertain.)

Because of the risk of perforation from NG intubation, lavage is discouraged in children unless intubation is performed under endoscopic guidance.

Antidotes and Other Treatments

There is no specific antidote for chlordane. Repeated doses of cholestyramine (3 to 8 g four times a day for several days) mixed with pulpy fruit or liquid, or activated charcoal have been suggested to enhance the elimination of chlordane in cases of severe poisoning. During convalescence, enhance carbohydrate, protein, and vitamin intake by diet or parenteral therapy.

The following treatments are NOT effective: forced diuresis, hemodialysis, and hemoperfusion. Oil-based cathartics should NEVER be used, as they may facilitate absorption.

Laboratory Tests

Routine laboratory studies for all exposed patients include CBC, glucose, and electrolyte determinations. Additional studies for patients exposed to chlordane include liver and renal-function tests.

Determining chlordane or chlordane-metabolite levels in blood after acute exposure is not clinically useful. However, these tests may be useful in documenting massive acute exposure.

If problems with memory, concentration, and personality changes are present, or seizures or convulsions have occurred, then neurobehavioral toxicity testing is indicated. If numbness of the hands or feet is present, then nerve conduction studies are indicated.

Disposition and Follow-up

Consider hospitalizing patients who have a suspected serious exposure and are symptomatic.

Delayed Effects

Patients exposed by inhalation should be observed for signs of pulmonary edema and those who have ingested chlordane should be watched for signs of aspiration pneumonitis.

Patient Release

Patients who are initially asymptomatic and who remain so 2 to 3 hours after exposure may be discharged with instructions to seek medical care promptly if symptoms develop (see the *Follow-up Instructions* on the *Chlordane – Patient Information Sheet* below).

Follow-up

Obtain the name of the patient's primary care physician so that the hospital can send a copy of the ED visit to the patient's doctor.

Patients who have shown symptoms of seizures, convulsions, headache or confusion, need to be followed for permanent central nervous system dysfunction with neurobehavioral toxicity testing, with particular attention to problems with memory, personality changes, and perceptual dysfunction. If peripheral numbness is present, then nerve conduction studies are indicated.

Chlordane has been inconclusively implicated in rare cases of megaloblastic anemia and a variety of other blood dyscrasias. Patients should be evaluated for blood dyscrasias after substantial exposure. Since kidney damage has been observed in humans exposed to chlordane, a urinalysis should be repeated on an annual basis. In addition, the condition of eyes, skin, liver, and lungs should be evaluated following exposure to chlordane.

Patients who have corneal injuries should be reexamined within 24 hours.

Reporting

If a pesticide or work-related incident has occurred, you may be legally required to file a report; contact your state or local health department.

Other persons may still be at risk in the setting where this incident occurred. If the incident occurred in the workplace, discussing it with company personnel may prevent future incidents. If a public health risk exists, notify your state or local health department or other responsible public agency. When appropriate, inform patients that they may request an evaluation of their workplace from OSHA or NIOSH. See Appendices III and IV for a list of agencies that may be of assistance.

Chlordane
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to chlordane.

What is chlordane?

Chlordane was produced as a thick, amber liquid or white powder. It was used as an insecticide in the form of a spray or powder on food crops and to rid homes and buildings of termites. It has been banned in the United States since 1988; however, many buildings and the soils around them have residue from previous chlordane use. Old bottles of chlordane may still be found in garages, warehouses, and landfills. Chlordane is not flammable, but may be dissolved in flammable solvents. On burning, or upon reaction with strong oxidizers or alkalis, chlordane decomposes to produce toxic fumes that include chlorine, phosgene (mustard gas), and hydrogen chloride.

What immediate health effects can be caused by exposure to chlordane?

Chlordane may cause effects when it is breathed or swallowed or when it touches the skin. Common effects of poisoning are nausea, irritability, headaches, stomach pain, and vomiting. Loss of coordination, tremors, convulsions, and death can occur with severe exposures. Generally, the higher the exposure, the more severe the symptoms. If lactating mothers are exposed, chlordane will contaminate the breast milk and may cause adverse effects in nursing infants.

Can chlordane poisoning be treated?

There is no antidote for chlordane, but its effects can be treated, and most exposed persons get well. Persons with serious symptoms may need to be hospitalized.

Are any future health effects likely to occur?

A single small exposure from which a person recovers quickly is not likely to cause delayed or long-term effects. However, a single large exposure can result in the same neurological effects seen with chronic exposure. Exposure to chlordane over many years may cause blood disorders, and neurological effects, such as memory loss, irritability, numbness, loss of coordination, and seizures.

What tests can be done if a person has been exposed to chlordane?

Specific tests for the presence of chlordane in blood or urine generally are not useful to the doctor. If a severe exposure has occurred, blood and urine analyses and other tests may show whether the blood, brain or kidneys have been injured. An electroencephalogram (EEG) may be used for evaluation if seizures have occurred. Testing is not needed in every case.

Where can more information about chlordane be found?

More information about chlordane can be obtained from your regional poison control center, your state, county, or local health department; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in occupational and environmental health. If the exposure happened at work, you may wish to discuss it with your employer, the Occupational Safety and Health Administration (OSHA), or the National Institute for Occupational Safety and Health (NIOSH). Ask the person who gave you this form for help in locating these telephone numbers.

Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow *only* the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:

- blurred vision
- coughing, difficulty breathing, or shortness of breath
- seizures or convulsions
- fever

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.
[ ] Call for an appointment with Dr. _____ in the practice of _____. When you call for your appointment, please say that you were treated in the Emergency Department at _ _____ Hospital by _____ and were advised to be seen again in _____ days.
[ ] Return to the Emergency Department/ _____ Clinic on (date) _____ at _____ AM/PM for a follow-up examination.
[ ] Do not perform vigorous physical activities for 1 to 2 days.
[ ] You may resume everyday activities including driving and operating machinery.
[ ] Do not return to work for _____ days.
[ ] You may return to work on a limited basis. See instructions below.
[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.
[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.
[ ] Avoid taking the following medications: _____
[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: _____
_____
_____
[ ] Other instructions: _____
_____
_____

- Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.

- You or your physician can get more information on the chemical by contacting: _____ _____ or _____, or by checking out the following Internet Web sites: _____; _____.

Signature of patient _____ Date _____

Signature of physician _____ Date _____

Chlorine (Cl_2)
CAS 7782-50-5; UN 1017

Synonyms include molecular chlorine.

- **Persons exposed only to chlorine gas pose little risk of secondary contamination to others. However, clothing or skin soaked with industrial-strength chlorine bleach or similar solutions may be corrosive to rescuers and may release harmful chlorine gas.**
- **Chlorine is a yellow-green, noncombustible gas with a pungent, irritating odor. It is a strong oxidizing agent and can react explosively or form explosive compounds with many common substances. Chlorine is heavier than air and may collect in low-lying areas.**
- **Chlorine gas is highly corrosive when it contacts moist tissues such as the eyes, skin, and upper respiratory tract. Significant dermal absorption or ingestion is unlikely.**

Description

At room temperature, chlorine is a yellow-green gas with a pungent irritating odor. Under increased pressure or at temperatures below -30 °F, it is a clear, amber-colored liquid. It is generally shipped in steel cylinders as a compressed liquid. Chlorine is only slightly soluble in water, but on contact with moisture it forms hypochlorous acid (HClO) and hydrochloric acid (HCl); the unstable HClO readily decomposes, forming oxygen free radicals. Because of these reactions, water substantially enhances chlorine's oxidizing and corrosive effects.

Routes of Exposure

Inhalation

Most exposures to chlorine occur by inhalation. Chlorine's odor or irritant properties are discernible by most individuals at 0.32 ppm which is less than the OSHA permissible exposure limit (PEL) of 1 ppm. Chlorine's odor or irritant properties generally provide adequate warning of hazardous concentrations. However, prolonged, low-level exposures, such as those that occur in the workplace, can lead to olfactory fatigue and tolerance of chlorine's irritant effects. Chlorine is heavier than air and may cause asphyxiation in poorly ventilated, enclosed, or low-lying areas.

Children are at increased risk for exposure to inhaled toxicants because they have a greater lung surface area:body weight ratio and an increased minute volume:weight ratio. Children may be more vulnerable to corrosive agents than adults because of the smaller diameter of their airways. Children also may be at

increased risk because of their short stature, when higher concentrations of the chemical are found at low-lying areas.

Skin/Eye Contact

Direct contact with liquid chlorine or concentrated vapor causes severe chemical burns, leading to cell death and ulceration.

Ingestion

Ingestion is unlikely to occur because chlorine is a gas at room temperature. Solutions that are able to generate chlorine (e.g., sodium hypochlorite solutions) may cause corrosive injury if ingested.

Sources/Uses

Chlorine is produced commercially by electrolysis of sodium chloride brine. It is among the ten highest volume chemicals manufactured in the United States, with 1998 production in excess of 14 million tons.

Chlorine's most important use is as a bleach in the manufacture of paper and cloth. Chlorine is also used widely as a chemical reagent in the synthesis and manufacture of metallic chlorides, chlorinated solvents, pesticides, polymers, synthetic rubbers, and refrigerants.

Sodium hypochlorite, which is a component of commercial bleaches, cleaning solutions, and disinfectants for drinking water and waste water purification systems and swimming pools, releases chlorine gas when it comes in contact with acids.

Standards and Guidelines

OSHA ceiling = 1 ppm

NIOSH IDLH (immediately dangerous to life or health) = 10 ppm

AIHA ERPG-2 (maximum airborne concentration below which it is believed that nearly all persons could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action) = 3 ppm.

Physical Properties

Description: Yellow-green gas at room temperature

Warning properties: odor and irritation are generally adequate, but olfactory fatigue can occur; pungent odor at about 0.31 ppm

Molecular weight: 70.9 daltons

Boiling point: (760 mm Hg) = -29 °F (-34 °C)

Freezing point: -150 °F (-101 °C)

Specific gravity: 1.56 at boiling point (water = 1)

Vapor pressure: 5,168 mm Hg at 68 °F (20 C)

Gas density: 2.5 (air = 1)

Water solubility: (0.7% at 68 °F) (20 °C)

Flammability: Not flammable, but reacts explosively or forms explosive compounds with many common substances

Incompatibilities

Chlorine reacts explosively or forms explosive compounds with many common substances such as acetylene, ether, turpentine, ammonia, fuel gas, hydrogen, and finely divided metals.

Health Effects

- **Chlorine gas is irritating and corrosive to the eyes, skin, and respiratory tract.**
- **Exposure to chlorine may cause burning of the eyes, nose, and throat; cough as well as constriction and edema of the airway and lungs can occur.**

Acute Exposure

The toxic effects of chlorine are primarily due to its corrosive properties. The action of chlorine is due to its strong oxidizing capability, in which chlorine splits hydrogen from water in moist tissue, causing the release of nascent oxygen and hydrogen chloride which produce major tissue damage. Alternatively, chlorine may be converted to hypochlorous acid which can penetrate cells and react with cytoplasmic proteins to form N-chloro derivatives that destroy cell structure. Symptoms may be apparent immediately or delayed for a few hours.

Respiratory

Chlorine is water soluble and therefore, primarily removed by the upper airways. Exposure to low concentrations of chlorine (1 to 10 ppm) may cause eye and nasal irritation, sore throat, and coughing. Inhalation of higher concentrations of chlorine gas (>15 ppm) can rapidly lead to respiratory distress with airway constriction and accumulation of fluid in the lungs (pulmonary edema). Patients may have immediate onset of rapid breathing, blue discoloration of the skin, wheezing, rales or hemoptysis. In symptomatic patients, pulmonary injury may progress over several hours. Lung collapse may occur. The lowest lethal concentration for a 30-minute exposure has been estimated as 430 ppm. Exposure to chlorine can lead to reactive airways dysfunction syndrome (RADS), a chemical irritant-induced type of asthma.

Children may be more vulnerable to corrosive agents than adults because of the smaller diameter of their airways. Children may also be more vulnerable to gas exposure because of increased minute ventilation per kg and failure to evacuate an area promptly when exposed.

Cardiovascular

Tachycardia and initial hypertension followed by hypotension may occur. After severe exposure, cardiovascular collapse may occur from lack of oxygen.

Metabolic

Acidosis may result from insufficient oxygenation of tissues. An unusual complication of massive chlorine inhalation is an excess of chloride ions in the blood, causing an acid-base imbalance.

Because of their higher metabolic rates, children may be more vulnerable to toxicants interfering with basic metabolism.

Dermal

Chlorine irritates the skin and can cause burning pain, inflammation, and blisters. Exposure to liquefied chlorine can result in frostbite injury.

Ocular

Low concentrations in air can cause burning discomfort, spasmodic blinking or involuntary closing of the eyelids, redness, conjunctivitis, and tearing. Corneal burns may occur at high concentrations.

Potential Sequelae

After acute exposure, pulmonary function usually returns toward baseline within 7 to 14 days. Although complete recovery generally occurs, symptoms and prolonged pulmonary impairment may persist. Exposure to chlorine can lead to reactive airways dysfunction syndrome (RADS), a chemical irritant-induced type of asthma.

Chronic Exposure

Chronic exposure to chlorine, usually in the workplace, may cause corrosion of the teeth. Multiple exposures to chlorine have produced flu-like symptoms and a high risk of developing reactive airways dysfunction syndrome (RADS).

Carcinogenicity

Chlorine has not been classified for carcinogenic effects. However, the association of cigarette smoking and chlorine fumes may increase the risk of cancer.

Reproductive and Developmental Effects

No information is available regarding reproductive or developmental effects of chlorine in experimental animals or humans. Chlorine gas has been used as a chemical warfare agent, but no retrospective reproductive studies of survivors have been published. Chlorine is not included in *Reproductive and Developmental Toxicants*, a 1991 report published by the U.S. General Accounting Office (GAO) that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences.

Prehospital Management

- **Rescue personnel are at low risk of secondary contamination from victims who have been exposed only to chlorine gas. However, clothing or skin soaked with industrial-strength bleach or similar solutions may be corrosive to rescuers and may release harmful chlorine gas.**
- **Acute exposure to chlorine gas initially causes coughing, eye and nose irritation, lacrimation, and a burning sensation in the chest. Airway constriction and noncardiogenic pulmonary edema may occur. Chlorine irritates the skin and can cause burning pain, inflammation, and blisters. Exposure to liquefied chlorine can result in frostbite.**
- **There is no specific antidote for chlorine poisoning. Treatment is supportive.**

Hot Zone

Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if rescuers have not been trained in its use, assistance should be obtained from a local or regional HAZMAT team or other properly equipped response organization.

Rescuer Protection

Chlorine is a severe respiratory-tract and skin irritant.

Respiratory Protection: Positive-pressure, self-contained breathing apparatus (SCBA) is recommended in response situations that involve exposure to potentially unsafe levels of chlorine.

Skin Protection: Chemical-protective clothing should be worn because chlorine gas can condense on the skin and cause irritation and burns.

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible.

Victim Removal

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be removed on backboards or gurneys; if these are not available, carefully carry or drag victims to safety.

Consider appropriate management of chemically contaminated children, such as measures to reduce separation anxiety if a child is separated from a parent or other adult.

Decontamination Zone

Victims exposed only to chlorine gas who have no skin or eye irritation do not need decontamination. They may be transferred immediately to the Support Zone. All others require decontamination as described below.

Rescuer Protection

If exposure levels are determined to be safe, decontamination may be conducted by personnel wearing a lower level of protection than that worn in the Hot Zone (described above).

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. Stabilize the cervical spine with a collar and a backboard if trauma is suspected. Administer supplemental oxygen as required. Assist ventilation with a bag-valve-mask device if necessary.

Basic Decontamination

Victims who are able and cooperative may assist with their own decontamination. Remove and double-bag contaminated clothing and personal belongings.

Handle frostbitten skin and eyes with caution. Place frostbitten skin in warm water, about 108 °F (42 °C). If warm water is not available wrap the affected part gently in blankets. Let the circulation reestablish itself naturally. Encourage the victim to exercise the affected part while it is being warmed.

Flush exposed skin and hair with plain water for 3 to 5 minutes, then wash twice with mild soap. Rinse thoroughly with water.

Do not irrigate eyes that have sustained frostbite injury. Otherwise, irrigate exposed or irritated eyes with plain water or saline for 15 minutes. Eye irrigation may be carried out simultaneously with other basic care and transport. Remove contact lenses if it can be done without additional trauma to the eye. If a corrosive material is suspected or if pain or injury is evident, continue irrigation while transferring the victim to the support zone.

Consider appropriate management of chemically contaminated children, such as measures to reduce separation anxiety if a child is separated from a parent or other adult. If possible, seek assistance from a child separation expert.

Transfer to Support Zone

As soon as basic decontamination is complete, move the victim to the Support Zone.

Support Zone

Be certain that victims have been decontaminated properly (see *Decontamination Zone* above). Victims who have undergone decontamination or have been exposed only to chlorine gas pose no serious risks of secondary contamination to rescuers. In such cases, Support Zone personnel require no specialized protective gear.

ABC Reminders

Quickly access for a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Ensure adequate respiration and pulse. Administer supplemental oxygen as required and establish intravenous access if necessary. Place on a cardiac monitor. Watch for signs of airway swelling and obstruction such as progressive hoarseness, stridor, or cyanosis.

Additional Decontamination

Continue irrigating exposed skin and eyes, as appropriate.

Advanced Treatment

In cases of respiratory compromise secure airway and respiration via endotracheal intubation. Avoid blind nasotracheal intubation or use of an esophageal obturator. Use direct visualization to intubate. When the patient's condition precludes endotracheal intubation, perform cricothyroidectomy if equipped and trained to do so.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of *multiple* chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Chlorine poisoning is not known to pose additional risk during the use of bronchial or cardiac sensitizing agents.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.7 5 m of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed cautioning for myocardial variability.

Patients who are comatose, hypotensive, or having seizures or who have cardiac arrhythmias should be treated according to advanced life support (ALS) protocols.

If frostbite is present, treat by rewarming in a water bath at a temperature of 102 to 108 °F (40 to 42 °C) for 20 to 30 minutes and continue until a flush has returned to the affected area.

Transport to Medical Facility

Only decontaminated patients or those not requiring decontamination should be transported to a medical facility. “Body bags” are not recommended.

Report to the base station and the receiving medical facility the condition of the patient, treatment given, and estimated time of arrival at the medical facility.

Multi-Casualty Triage

Consult with the base station physician or the regional poison control center for advice regarding triage of multiple victims.

Patients with evidence of significant exposure (e.g., severe or persistent cough, dyspnea or chemical burns) should be transported to a medical facility for evaluation. Patients who have minor or transient irritation of the eyes or throat may be discharged from the scene after their names, addresses, and telephone numbers are recorded. They should be advised to seek medical care promptly if symptoms develop or recur (see *Patient Information Sheet* below).

Emergency Department Management

- **Hospital personnel are at minimal risk of secondary contamination from patients who have been exposed only to chlorine gas. However, clothing or skin soaked with industrial-strength bleach or similar solutions may be corrosive to personnel and may release harmful chlorine gas.**

- **Acute exposure to chlorine gas initially causes coughing, eye and nose irritation, lacrimation, and a burning sensation in the chest. Airway constriction, noncardiogenic pulmonary edema, hemoptysis, and bronchopneumonia may occur.**
- **Chlorine irritates the skin and can cause burning pain, inflammation, and blisters. Exposure to liquefied chlorine can result in frostbite.**

- **There is no specific antidote for chlorine poisoning. Treatment requires supportive care.**

Decontamination Area

Previously decontaminated patients and patients exposed only to chlorine gas who have no skin or eye irritation may be transferred immediately to the Critical Care Area. All others require decontamination as described below.

ABC Reminders

Evaluate and support airway, breathing, and circulation. Children may be more vulnerable to corrosive agents than adults because of the smaller diameter of their airways. In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, surgically secure an airway.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Chlorine poisoning is not known to pose additional risk during the use of bronchial or cardiac sensitizing agents.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed cautioning for myocardial variability.

Patients who are comatose, hypotensive, or having seizures or cardiac arrhythmias should be treated in the conventional manner.

Basic Decontamination

Patients who are able and cooperative may assist with their own decontamination. Remove and double bag contaminated clothing and personal belongings.

Handle frostbitten skin and eyes with caution. Place frostbitten skin in warm water, about 108 °F (42 °C). If warm water is not available, wrap the affected part gently in blankets. Let the circulation reestablish itself naturally. Encourage the victim to exercise the affected part while it is being warmed.

Flush exposed skin and hair with plain water for 2 to 3 minutes (preferably under a shower), then wash twice with mild soap. Rinse thoroughly with water. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Do not irrigate frostbitten eyes. Otherwise, begin irrigation of exposed eyes. Remove contact lenses if it can be done without additional trauma to the eye. Continue irrigation while transporting the patient to the Critical Care Area.

Critical Care Area

Be certain that appropriate decontamination has been carried out (see *Decontamination Area* above).

ABC Reminders

Evaluate and support airway, breathing, and circulation as in ABC Reminders above. Establish intravenous access in seriously ill patients if this has not been done previously. Continuously monitor cardiac rhythm.

Patients who are comatose, hypotensive, or having seizures or cardiac arrhythmias should be treated in the conventional manner.

Inhalation Exposure

Administer supplemental oxygen by mask to patients who have respiratory symptoms. Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Chlorine poisoning is not

known to pose additional risk during the use of bronchial or cardiac sensitizing agents.

Children may be more vulnerable to corrosive agents than adults because of their smaller airways.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed cautioning for myocardial variability.

Skin Exposure

If concentrated chlorine gas or chlorine-generating solutions contact the skin, chemical burns may occur; treat as thermal burns. If the liquefied compressed gas is released and contacts the skin, frostbite may result. If a victim has frostbite, treat by rewarming affected areas in a water bath at a temperature of 102 to 108 °F (40 to 42 °C) for 20 to 30 minutes and continue until a flush has returned to the affected area.

Because of their larger surface area:body weight ratio children are more vulnerable to toxicants absorbed through the skin.

Eye Exposure

Chlorine-exposed eyes should be irrigated for at least 15 minutes. Test visual acuity and examine the eyes for corneal damage and treat appropriately. Immediately consult an ophthalmologist for patients who have corneal injuries.

Antidotes and Other Treatments

There is no specific antidote for chlorine. Treatment is supportive.

Laboratory Tests

The diagnosis of acute chlorine toxicity is primarily clinical, based on respiratory difficulties and irritation. However, laboratory testing is useful for monitoring the patient and evaluating complications. Routine laboratory studies for all exposed patients include CBC, glucose, and electrolyte determinations. Patients who have respiratory complaints may require pulse oximetry (or ABG measurements) and chest radiography. Massive inhalation may be complicated by hyperchloremic metabolic acidosis; in addition to electrolytes, monitor blood pH.

Disposition and Follow-up

Consider hospitalizing patients who have a suspected significant exposure or have eye burns or serious skin burns.

Delayed Effects

Symptomatic patients complaining of persistent shortness of breath, severe cough, or chest tightness should be admitted to

the hospital and observed until symptom-free. Pulmonary injury may progress for several hours.

Patient Release

Asymptomatic patients and those who experienced only minor sensations of burning of the nose, throat, eyes, and respiratory tract (with perhaps a slight cough) may be released. In most cases, these patients will be free of symptoms in an hour or less. They should be advised to seek medical care promptly if symptoms develop or recur (see the *Chlorine—Patient Information Sheet* below).

Follow-up

Obtain the name of the patient's primary care physician so that the hospital can send a copy of the ED visit to the patient's doctor.

Follow up is recommended for all hospitalized patients because long-term respiratory problems can result. Respiratory monitoring is recommended until the patient is symptom-free. Chlorine-induced reactive airways dysfunction syndrome (RADS) has been reported to persist from 2 to 12 years.

Patients who have skin or corneal injury should be re-examined within 24 hours.

Reporting

If a work-related incident has occurred, you may be legally required to file a report; contact your state or local health department.

Other persons may still be at risk in the setting where this incident occurred. If the incident occurred in the workplace, discussing it with company personnel may prevent future incidents. If a public health risk exists, notify your state or local health department or other responsible public agency. When appropriate, inform patients that they may request an evaluation of their workplace from OSHA or NIOSH. See Appendices III and IV for a list of agencies that may be of assistance.

Chlorine
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to chlorine.

What is chlorine?
Chlorine is a yellowish-green gas with a sharp, burning odor. It is used widely in chemical manufacturing, bleaching, drinking-water and swimming-pool disinfecting, and in cleaning agents. Household chlorine bleach contains only a small amount of chlorine but it can release chlorine gas if mixed with other cleaning agents.

What immediate health effects can be caused by exposure to chlorine?
Even small exposures to the gas may cause immediate burning of the eyes, nose, and throat, and shortness of breath, as well as coughing, wheezing, shortness of breath, and tearing of the eyes. However, once exposure is stopped, symptoms usually clear up quickly. Breathing large amounts of chlorine may cause the lining of the throat and lungs to swell, making breathing difficult. Generally, the more serious the exposure, the more severe the symptoms.

Can chlorine poisoning be treated?
There is no antidote for chlorine, but its effects can be treated and most exposed persons get well. Persons who have experienced serious symptoms may need to be hospitalized.

Are any future health effects likely to occur?
A single small exposure from which a person recovers quickly is not likely to cause delayed or long-term effects. After a serious exposure, symptoms may worsen for several hours.

What tests can be done if a person has been exposed to chlorine?
Specific tests for the presence of chlorine in blood or urine generally are not useful to the doctor. If a severe exposure has occurred, blood and urine analyses and other tests may show whether the lungs, heart, or brain has been injured. Testing is not needed in every case.

Where can more information about chlorine be found?
More information about chlorine can be obtained from your regional poison control center, your state, county, or local health department; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in occupational and environmental health. If the exposure happened at work, you may wish to discuss it with your employer, the Occupational Safety and Health Administration (OSHA), or the National Institute for Occupational Safety and Health (NIOSH). Ask the person who gave you this form for help in locating these telephone numbers.

Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow *only* the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:

- coughing or wheezing
- difficulty breathing, shortness of breath, or chest pain
- increased pain or a discharge from injured eyes
- increased redness or pain or a pus-like discharge in the area of a skin burn

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.
[ ] Call for an appointment with Dr. _____ in the practice of _____. When you call for your appointment, please say that you were treated in the Emergency Department at _ _____ Hospital by _____ and were advised to be seen again in _____ days.
[ ] Return to the Emergency Department/ _____ Clinic on (date) _____ at _____ AM/PM for a follow-up examination.
[ ] Do not perform vigorous physical activities for 1 to 2 days.
[ ] You may resume everyday activities including driving and operating machinery.
[ ] Do not return to work for _____ days.
[ ] You may return to work on a limited basis. See instructions below.
[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.
[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.
[ ] Avoid taking the following medications: _____
[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: _____ _____ _____
[ ] Other instructions: _____ _____ __ _____

- Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.

- You or your physician can get more information on the chemical by contacting: _____ _____ or _____, or by checking out the following Internet Web sites: _____; _____.

Signature of patient _____ Date _____

Signature of physician _____ Date _____

Crotonaldehyde (C_4H_6O)
CAS 4170-30-3; CAS 123-73-9 (*trans* isomer); CAS 15798-64-8 (*cis* isomer); UN 1143

Synonyms include beta-methylacrolein; propylene aldehyde; ethylene propionate; crotonic aldehyde; but-2-enal; 2-butenal; crotonal; topanel; methyl acrolein; butenal; crotonaldehyde inhibited; (E)-crotonaldehyde; (E)-2-butenal; trans-2-butenal.

- **Persons exposed only to crotonaldehyde vapor do not pose secondary contamination risks. Persons whose clothing or skin is contaminated with liquid crotonaldehyde can secondarily contaminate others by direct contact or off-gassing vapor.**
- **At room temperature, crotonaldehyde is a clear, colorless to straw-colored liquid with a pungent, suffocating odor. It is highly flammable and burns to produce toxic gases (carbon dioxide and carbon monoxide). It is volatile, producing toxic concentrations at room temperature. Vapors may travel to a source of ignition and flash back. The odor of crotonaldehyde provides adequate warning of hazardous concentrations.**
- **Crotonaldehyde is highly toxic by all routes. Exposure causes inflammation and irritation of the skin, respiratory tract, and mucous membranes. Delayed pulmonary edema may occur after inhalation. Systemic effects occur in animals after oral exposure, but have not been reported in humans.**

Description

Crotonaldehyde exists in two isomeric forms (*cis* and *trans*) that have similar properties and effects. Crotonaldehyde is produced commercially as a mixture of the two isomers (>95% *trans* and <5% *cis*). At room temperature, the mixture is a clear, colorless liquid that turns yellow upon contact with air or exposure to light. It has a pungent, suffocating odor. Crotonaldehyde should be stored in a cool, dry, well-ventilated area in tightly sealed containers. It is very flammable and may polymerize violently. Crotonaldehyde should be stored separately from alkaline materials such as caustics, ammonia, organic amines, or mineral acids, strong oxidizers, and oxygen. Crotonaldehyde is soluble in water, alcohol, ether, acetone, and benzene.

Routes of Exposure

Inhalation

Inhaled crotonaldeyhyde is highly toxic. Crotonaldehyde is irritating to the upper respiratory tract even at low concentrations. Its odor threshold of 0.035 to 0.12 ppm is lower than the OSHA permissible exposure limit (2 ppm); thus, odor provides an adequate warning of potentially hazardous concentrations. Crotonaldehyde vapor is

heavier than air, but asphyxiation in enclosed, poorly ventilated, or low-lying areas is unlikely due to its strong odor.

Children exposed to the same levels of crotonaldehyde vapor as adults may receive a larger dose because they have greater lung surface area:body weight ratios and higher minute volume:weight ratios. In addition, they may be exposed to higher levels than adults in the same location because of their short stature and the higher levels of crotonaldehyde vapor found nearer to the ground.

Skin/Eye Contact

Crotonaldehyde is highly toxic by the dermal route. Direct contact with liquid crotonaldehyde causes rapid and severe eye and skin irritation or burns. Exposure to vapor produces inflammation of mucous membranes and it is a potent lacrimator.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants affecting the skin.

Ingestion

No information was located pertaining to ingestion of crotonaldehyde by humans. Crotonaldehyde is very irritating; thus, ingestion would probably produce chemical burns of the lips, mouth, throat, esophagus, and stomach. In animal studies, ingestion has led to systemic toxicity.

Sources/Uses

Crotonaldehyde is generally produced by aldol condensation of acetaldehyde, followed by dehydration. A process involving direct oxidation of 1,3-butadiene to crotonaldehyde with palladium catalysis has also been reported. Crotonaldehyde is produced during the combustion of paper, cotton, and plastics, and is a component of cigarette smoke.

Crotonaldehyde was formerly used in the manufacture of n-butanol, but currently, the most extensive use of crotonaldehyde is in the manufacture of sorbic acid. Crotonaldehyde has also been used as a warning agent in fuel gases, in the preparation of rubber accelerators, in leather tanning, as an alcohol denaturant, and as a stabilizer for tetraethyl-lead.

Standards and Guidelines

OSHA PEL (permissible exposure limit) = 2 ppm.

NIOSH IDLH (immediately dangerous to life or health) = 50 ppm.

AIHA ERPG-2 (maximum airborne concentration below which it is believed that nearly all persons could be exposed for up to 1 hour

without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action) = 10 ppm.

Physical Properties

Description: Clear, colorless liquid that becomes yellow with exposure to light or air.

Warning properties: Sharp, pungent odor at 0.035 to 0.12 ppm; adequate warning of acute or chronic exposures.

Molecular weight: 70.09 daltons

Boiling point (760 mm Hg): 215.6 °F (102 °C)

Freezing point: -105.7 °F (-76.5 °C)

Vapor pressure: 19 mm Hg at 68 °F (20 °C)

Gas density: 2.41 (air = 1)

Specific gravity: 0.85 (water = 1)

Water solubility: 181 g/L at 20 °C

Flammability: 55 °F (13 °C)

Flammable range: 2.1% to 15.5% (concentration in air)

Incompatibilities

Crotonaldehyde reacts with caustics, ammonia, organic amines, or mineral acids, strong oxidizers, and oxygen.

Health Effects

- **Crotonaldehyde is severely irritating to skin, eyes, and mucous membranes. Inhalation of crotonaldehyde may result in respiratory distress and delayed pulmonary edema. Contact with the skin or eyes produces irritation and lacrimation, and can result in chemical burns.**

- **The mechanism by which crotonaldehyde produces toxic symptoms is not known, but the compound is highly reactive. No information was found as to whether the health effects of crotonaldehyde in children are different than in adults. Exposure to crotonaldehyde produces severe respiratory problems and individuals with pre-existing breathing difficulties or skin disease may be more susceptible to its effects.**

Acute Exposure

The mechanism by which crotonaldehyde produces toxic symptoms is not known, but the compound is highly reactive, cross-links DNA, and inhibits the activities of some enzymes *in vitro*, including cytochrome P450 and aldehyde dehydrogenase. *In vitro* treatment of human polymorphonuclear leukocytes with crotonaldehyde produced a dose-related decrease in surface sulfhydryl and soluble sulfhydryl groups and inhibition of superoxide production. Onset of irritation is immediate, but pulmonary edema may be delayed.

Children do not always respond to chemicals in the same way that adults do. Different protocols for managing their care may be needed.

Respiratory

Crotonaldehyde produces irritation of the respiratory-tract. Relatively high-concentration inhalation can lead to pulmonary edema.

Clinical cases of sensitization have been reported.

Children may be more vulnerable because of higher minute ventilation per kg and failure to evacuate an area promptly when exposed.

Dermal

Crotonaldehyde is a skin irritant. Contact with the liquid may cause second- and third-degree skin burns. Skin contact may also result in allergic contact dermatitis.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants affecting the skin.

Ocular/Ophthalmic

Crotonaldehyde liquid or vapor can cause eye irritation and damage to the cornea.

Gastrointestinal

No cases involving ingestion were located. Because crotonaldehyde is a known irritant, it is likely to cause burns of the lips, mouth, throat, esophagus, and stomach.

Potential Sequelae

After an acute, relatively high-concentration exposure, persons may become sensitized to crotonaldehyde.

Chronic Exposure

Apart from rare cases of sensitization, no adverse effects in humans chronically exposed to relatively low concentrations of crotonaldehyde have been reported.

Chronic exposure may be more serious for children because of their potential for a longer latency period.

Carcinogenicity

The Department of Health and Human Services has determined that crotonaldehyde may possibly be a human carcinogen. The International Agency for Research on Cancer has determined that crotonaldehyde is not classifiable as to its carcinogenicity to humans.

Reproductive and Developmental Effects

No studies were located that address reproductive or developmental effects of crotonaldehyde in humans. Crotonaldehyde can cause degeneration of spermatocytes in mice. No information was found as to whether crotonaldehyde crosses the placenta, but it has been measured in breast milk. Crotonaldehyde is not included in *Reproductive and Developmental Toxicants,* a 1991 report published by the U.S. General Accounting Office (GAO) that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences.

No teratogenic effects from acute exposure have been reported.

Prehospital Management

- **Victims exposed only to crotonaldehyde vapor do not pose contamination risks to rescuers. Victims whose clothing or skin is contaminated with liquid crotonaldehyde can secondarily contaminate response personnel by direct contact or by off-gassing vapor.**
- **Crotonaldehyde is a direct irritant to mucous membranes, skin, eyes, and the respiratory system. Acute inhalation exposure may lead to respiratory distress and noncardiogenic pulmonary edema.**
- **There is no antidote for crotonaldehyde. Treatment consists of respiratory and cardiovascular support.**

Hot Zone

Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if rescuers have not been trained in its use, assistance should be obtained from a local or regional HAZMAT team or other properly equipped response organization.

Rescuer Protection

Crotonaldehyde is highly toxic via all routes, and it is severely irritating to the eyes, mucous membranes, respiratory tract, and skin. Crotonaldehyde is highly flammable, can form explosive mixtures with air, and burns to produce irritating, corrosive, and/or toxic gases. Crotonaldehyde vapor may travel to a source of ignition and flash back.

Respiratory Protection: Positive-pressure, self-contained breathing apparatus (SCBA) is recommended in response situations that involve exposure to potentially unsafe levels of crotonaldehyde.

Skin Protection: Chemical-protective clothing is recommended because crotonaldehyde can cause skin irritation, burns, and sensitization. Fully encapsulating, vapor protective clothing should be worn to deal with spills or leaks with no fire.

ABC Reminders

Quickly establish a patent airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible.

Victim Removal

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be

removed on backboards or gurneys; if these are not available, carefully carry or drag victims to safety.

Consider appropriate management of anxiety in victims with chemically-induced acute disorders, especially children who may suffer separation anxiety if separated from a parent or other adult.

Decontamination Zone

Patients exposed only to crotonaldehyde vapor who have no skin or eye irritation may be transferred immediately to the Support Zone. Other patients will require decontamination as described below.

Rescuer Protection

If exposure levels are determined to be safe, decontamination may be conducted by personnel wearing a lower level of protection than that worn in the Hot Zone (described above).

ABC Reminders

Quickly establish a patent airway, ensure adequate respiration and pulse. Stabilize the cervical spine with a collar and a backboard if trauma is suspected. Administer supplemental oxygen as required. Assist ventilation with a bag-valve-mask device if necessary.

Basic Decontamination

Victims who are able may assist with their own decontamination. Quickly remove and double-bag contaminated clothing and personal belongings.

Flush exposed skin and hair with copious amounts of water. Use caution to avoid hypothermia when decontaminating victims, particularly children or the elderly. Use blankets or warmers after decontamination as needed.

Flush exposed or irritated eyes with tepid water for 15 minutes. Remove contact lenses if easily removable without additional trauma to the eye. Continue eye irrigation during other basic care and transport. If pain or injury is evident, continue irrigation while transferring the victim to the Support Zone.

In cases of ingestion, **do not induce emesis**. If the victim is alert, asymptomatic, and has a gag reflex, administer a slurry of activated charcoal at a dose of 1 g/kg (infant, child, and adult dose). A soda can and a straw may be of assistance when offering charcoal to a child.

Victims who are conscious and able to swallow should be given 4 to 8 ounces of milk or water (not to exceed 15 mL/kg in a child). If

the victim is symptomatic, delay decontamination until other emergency measures have been instituted.

Consider appropriate management of chemically contaminated children at the exposure site. Provide reassurance to the child during decontamination, especially if separation from a parent occurs.

Transfer to Support Zone

As soon as basic decontamination is complete, move the victim to the Support Zone.

Support Zone

Be certain that victims have been decontaminated properly (see *Decontamination Zone,* above). Victims who have undergone decontamination or have been exposed only to vapor pose no serious risks of secondary contamination to rescuers. In such cases, Support Zone personnel require no specialized protective gear.

ABC Reminders

Quickly establish a patent airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Administer supplemental oxygen as required and establish intravenous access if necessary. Place on a cardiac monitor.

Additional Decontamination

Continue irrigating exposed skin and eyes, as appropriate.

In cases of ingestion, **do not induce emesis**. If the victim is alert, asymptomatic, and has a gag reflex, administer a slurry of activated charcoal at a dose of 1 g/kg (infant, child, and adult dose) if it has not already been administered. A soda can and a straw may be of assistance when offering charcoal to a child.

Victims who are conscious and able to swallow should be given 4 to 8 ounces of milk or water (not to exceed 15 mL/kg in a child) if it has not been given previously. If the victim is symptomatic, delay decontamination until other emergency measures have been instituted.

Advanced Treatment

In cases of respiratory compromise, secure airway and respiration via endotracheal intubation. If not possible, perform cricothyrotomy if equipped and trained to do so.

Treat patients who have bronchospasm with an aerosolized bronchodilator such as albuterol. Administer corticosteroids as indicated to patients who have persistent wheezing or hypersensitivity pneumonitis.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution, repeat every 20 minutes as needed, cautioning for myocardial variability.

Patients who are comatose, hypotensive, or having seizures or cardiac arrhythmias should be treated according to advanced life support (ALS) protocols.

If evidence of shock or hypotension is observed, begin fluid administration. For adults with systolic pressure less than 80 mm Hg, bolus perfusion of 1,000 mL/hour intravenous saline or lactated Ringer's solution may be appropriate. Higher adult systolic pressures may necessitate lower perfusion rates. For children with compromised perfusion, administer a 20 mL/kg bolus of normal saline over 10 to 20 minutes, then infuse at 2 to 3 mL/kg/hour.

Transport to Medical Facility

Only decontaminated patients or patients not requiring decontamination should be transported to a medical facility. "Body bags" are not recommended.

Report to the base station and the receiving medical facility the condition of the patient, treatment given, and estimated time of arrival at the medical facility.

If crotonaldehyde has been ingested, prepare the ambulance in case the victim vomits toxic material. Have ready several towels and open plastic bags to quickly clean up and isolate vomitus.

Multi-Casualty Triage

Consult with the base station physician or the regional poison control center for advice regarding triage of multiple victims.

Patients who are seriously symptomatic (as in cases of chest tightness or wheezing), patients who have histories or evidence of significant exposure, and all patients who have ingested crotonaldehyde should be transported to a medical facility for evaluation. Others may be discharged at the scene after their names, addresses, and telephone numbers are recorded. Those discharged should be advised to seek medical care promptly if symptoms develop (see *Patient Information Sheet* below).

Emergency Department Management

- **Hospital personnel in an enclosed area can be secondarily contaminated by direct contact or by off-gassing vapor from soaked skin or clothing. Patients do not pose contamination risks after contaminated clothing is removed and the skin is washed.**
- **Crotonaldehyde is irritating to mucous membranes, skin, eyes, and the respiratory tract. Acute inhalation exposure may lead to respiratory distress and noncardiogenic pulmonary edema.**
- **There is no antidote for crotonaldehyde. Treatment consists of respiratory and cardiovascular support.**

Decontamination Area

Unless previously decontaminated, all patients suspected of contact with crotonaldehyde liquid and all victims with skin or eye irritation require decontamination as described below. Because crotonaldehyde reacts with the skin, don gloves and/or protective clothing before treating patients. All other patients may be transferred immediately to the Critical Care Area.

Be aware that use of protective equipment by the provider may cause anxiety, particularly in children, resulting in decreased compliance with further management efforts.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants that affect the skin. Also, emergency room personnel should examine children's mouths because of the frequency of hand-to-mouth activity among children.

ABC Reminders

Evaluate and support airway, breathing, and circulation. In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, surgically create an airway.

Treat patients who have bronchospasm with an aerosolized bronchodilator such as albuterol. Administer corticosteroids as indicated to patients who have persistent wheezing or hypersensitivity pneumonitis.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution, repeat every 20 minutes as needed, cautioning for myocardial variability.

Patients who are comatose, hypotensive, or have seizures or ventricular arrhythmias should be treated in the conventional manner.

Basic Decontamination

Patients who are able may assist with their own decontamination. Remove and double-bag contaminated clothing and all personal belongings.

Because crotonaldehyde can cause burns, ED staff should don chemical-resistant jumpsuits (e.g., of Tyvek or Saranex) or butyl rubber aprons, rubber gloves, and eye protection if the patient's clothing or skin is wet. After the patient has been decontaminated, no special protective clothing or equipment is required for ED personnel.

Flush exposed skin and hair with water for 2 to 3 minutes (preferably under a shower), then wash thoroughly with mild soap. Rinse thoroughly with water. Use caution to avoid hypothermia when decontaminating victims, particularly children or the elderly. Use blankets or warmers after decontamination as needed.

Flush exposed eyes with plain tepid water for at least 15 minutes. Remove contact lenses if easily removable without additional trauma to the eye. If pain or injury is evident, continue irrigation while transporting the patient to the Critical Care Area.

In cases of ingestion, **do not induce emesis**. If the victim is alert, asymptomatic, and has a gag reflex, administer a slurry of activated charcoal at a dose of 1 g/kg (infant, child, and adult dose) if it has not already been administered. A soda can and a straw may be of assistance when offering charcoal to a child.

Victims who are conscious and able to swallow should be given 4 to 8 ounces of milk or water (not to exceed 15 mL/kg in a child) if it has not been given previously (see *Critical Care Area* below for more information on ingestion exposure).

Critical Care Area

Be certain that appropriate decontamination has been carried out (see *Decontamination Area* above).

ABC Reminders

Evaluate and support airway, breathing, and circulation as in ABC Reminders above under *Decontamination Zone*. Establish intravenous access in seriously ill patients if this has not been done previously. Continuously monitor cardiac rhythm.

Patients who are comatose, hypotensive, or have seizures or cardiac arrhythmias should be treated in the conventional manner.

Inhalation Exposure

Administer supplemental oxygen by mask to patients who have respiratory symptoms. Treat patients who have bronchospasm with an aerosolized bronchodilator such as albuterol. Administer corticosteroids as indicated to patients who have persistent wheezing or hypersensitivity pneumonitis.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution, repeat every 20 minutes as needed, cautioning for myocardial variability.

Skin Exposure

If the skin was in contact with liquid crotonaldehyde, chemical burns may occur; treat as thermal burns.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants affecting the skin.

Eye Exposure

Continue irrigation for at least 15 minutes. Test visual acuity. Examine the eyes for corneal damage and treat appropriately. Immediately consult an ophthalmologist for patients who have corneal injuries.

Ingestion Exposure

Do not induce emesis. If the victim is alert, asymptomatic, and has a gag reflex, administer a slurry of activated charcoal at a dose of 1 g/kg (infant, child, and adult dose) if it has not already been administered. A soda can and a straw may be of assistance when offering charcoal to a child.

Victims who are conscious and able to swallow should be given 4 to 8 ounces of milk or water (not to exceed 15 mL/kg in a child) if it has not been given previously.

Consider endoscopy to evaluate the extent of gastrointestinal-tract injury. Extreme throat swelling may require endotracheal intubation or cricothyrotomy. Gastric lavage is useful in certain circumstances to remove caustic material and prepare for endoscopic examination. Consider gastric lavage with a small nasogastric (NG) tube if: (1) a large dose has been ingested; (2) the patient's condition is evaluated within 30 minutes; (3) the patient has oral lesions or persistent esophageal discomfort; and (4) the lavage can be administered within one hour of ingestion. Care must be taken when placing the

gastric tube because blind gastric-tube placement may further injure the chemically damaged esophagus or stomach.

Because children do not ingest large amounts of corrosive materials, and because of the risk of perforation from NG intubation, lavage is discouraged in children unless performed under endoscopic guidance.

Toxic vomitus or gastric washings should be isolated, e.g., by attaching the lavage tube to isolated wall suction or another closed container.

Antidotes and Other Treatments

There is no antidote for crotonaldehyde. Treatment is supportive of respiratory and cardiovascular function.

Laboratory Tests

Routine laboratory studies for all exposed patients include CBC, glucose, and electrolyte determinations. Patients who have respiratory complaints may require pulse oximetry (or ABG measurements), chest radiography, and peak-flow spirometry.

Disposition and Follow-up

Consider hospitalizing patients who have histories of significant inhalation exposure and are symptomatic (e.g., chest tightness or wheezing) or who have ingested crotonaldehyde.

Delayed Effects

Pulmonary edema may be delayed after inhalation exposure.

Patient Release

Patients who remain asymptomatic for 8 to 12 hours after exposure may be discharged with instructions to seek medical care promptly if symptoms develop (see the *Crotonaldehyde—Patient Information Sheet* below).

Follow-up

Obtain the name of the patient's primary care physician so that the hospital can send a copy of the ED visit to the patient's doctor.

If significant inhalation or skin contact has occurred, monitor pulmonary function. In rare cases individuals may be permanently sensitized and may need to be removed from future work with crotonaldehyde; patients should consult an occupational medicine or pulmonary specialist before returning to work that entails exposure to crotonaldehyde.

Patients who have corneal injuries should be reexamined within 24 hours.

Reporting

If a work-related incident has occurred, you may be legally required to file a report; contact your state or local health department.

Other persons may still be at risk in the setting where this incident occurred. If the incident occurred in the workplace, discussing it with company personnel may prevent future incidents. If a public health risk exists, notify your state or local health department or other responsible public agency. When appropriate, inform patients that they may request an evaluation of their workplace from OSHA or NIOSH. See Appendix III for a list of agencies that may be of assistance.

Crotonaldehyde
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to crotonaldehyde.

What is crotonaldehyde?
Crotonaldehyde is a colorless to pale-yellow liquid with a strong, pungent odor. It is used most extensively in the manufacture of sorbic acid, but has also been used as a warning agent in fuel gases, in the preparation of rubber accelerators, in leather tanning, as an alcohol denaturant, and as a stabilizer for tetraethyl-lead.

What immediate health effects can be caused by exposure to crotonaldehyde?
Low levels of crotonaldehyde in the air can irritate the eyes, nose, throat, and lungs and cause cough, chest tightness, and shortness of breath. Higher levels can cause a build-up of fluid in the lungs, which may cause death. If liquid crotonaldehyde comes in contact with the skin or eyes, it can cause severe burns. Generally, the more serious the exposure, the more severe the symptoms.

Can crotonaldehyde poisoning be treated?
There is no antidote for crotonaldehyde, but its effects can be treated and most exposed persons get well. Seriously exposed persons may need to be hospitalized.

Are any future health effects likely to occur?
In rare cases, after exposure to crotonaldehyde, certain persons can become sensitized so that even small exposures to crotonaldehyde or other irritants can trigger skin irritation. Therefore, it is important to tell your doctor that you have been exposed to crotonaldehyde. The Department of Health and Human Services has determined that crotonaldehyde may possibly be a human carcinogen.

What tests can be done if a person has been exposed to crotonaldehyde?
Specific tests for the presence of crotonaldehyde in blood are not available. If a severe exposure has occurred, respiratory function tests and a chest x-ray may show whether damage has been done to the lungs. Testing is not needed in every case; however, lung complications such as pulmonary edema may develop some time after exposure.

Where can more information about crotonaldehyde be found?
More information about crotonaldehyde can be obtained from your regional poison control center; your state, county, or local health department; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor, or a clinic in your area that specializes in occupational and environmental health. If the exposure happened at work, you may wish to discuss it with your employer, the Occupational Safety and Health Administration (OSHA), or the National Institute for Occupational Safety and Health (NIOSH). Ask the person who gave you this form for help in locating these telephone numbers.

Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow *only* the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:

- coughing, wheezing, difficulty breathing, shortness of breath, or chest pain
- increased pain or a discharge from your eyes
- increased redness or pain or a pus-like discharge in the area of a skin burn

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.
[ ] Call for an appointment with Dr. _____ in the practice of _____.
When you call for your appointment, please say that you were treated in the Emergency Department at _____ Hospital by _____ and were advised to be seen again in _____ days.
[ ] Return to the Emergency Department/ _____ Clinic on (date) _____at _____ AM/PM for a follow-up examination.
[ ] Do not perform vigorous physical activities for 1 to 2 days.
[ ] You may resume everyday activities including driving and operating machinery.
[ ] Do not return to work for _____ days.
[ ] You may return to work on a limited basis. See instructions below.
[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.
[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.
[ ] Avoid taking the following medications: _____
[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: ___
_____
_____
[ ] Other instructions: _____
_____
_____

- Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.

- You or your physician can get more information on the chemical by contacting: _____ _____ or _____, or by checking out the following Internet Web sites: _____; _____.

Signature of patient _____ Date _____

Signature of physician _____ Date _____

Diborane (B_2H_6)
CAS 19287-45-7; UN 1911

Synonyms include boroethane, boron hydride, diboron hexahydride.

- **Persons exposed only to diborane pose little risk of secondary contamination to personnel outside the Hot Zone.**
- **Diborane is a colorless highly flammable gas with a repulsive, sickly sweet odor. At high concentrations, it ignites spontaneously in moist air at room temperature. It reacts with water to form hydrogen and boric acid. Diborane vapors are heavier than air and may collect in low-lying areas.**
- **Diborane is highly irritant when it contacts moist tissues such as the eyes, skin, and upper respiratory tract and can cause thermal burns. Burns are caused by the exothermic reaction of hydrolysis. Ingestion of diborane is unlikely since it is a gas at ambient temperatures.**

Description

At room temperature, diborane is a colorless gas with a repulsive, sickly sweet odor. It is generally shipped in pressurized cylinders diluted with hydrogen, argon, nitrogen, or helium. It reacts with water to form hydrogen and boric acid. It mixes well with air and explosive mixtures are easily formed. At high concentrations, it will ignite spontaneously in moist air at room temperature. The main toxic effect of exposure to diborane is irritation of the respiratory airway, skin, and eyes.

Routes of Exposure

Inhalation

Inhalation is the major route of exposure to diborane. An odor threshold between 2 and 4 ppm has been reported for diborane, which is higher than the OSHA permissible exposure limit (PEL) of 0.1 ppm. Prolonged, low-level exposures, such as those that occur in the workplace, can lead to olfactory fatigue and tolerance of diborane's irritant effects. **Odor does not provide adequate warning of hazardous concentrations.** Diborane is heavier than air; exposure to concentrations exceeding the PEL may result in skin, respiratory, and eye irritation in poorly ventilated, enclosed, or low-lying areas.

Children exposed to the same levels of diborane as adults may receive larger dose because they have a greater lung surface area:body weight ratios and higher minute volume:weight ratios. In addition, they may be exposed to higher levels than adults in the

same location because of their short stature and the higher levels of diborane found nearer to the ground.

Skin/Eye Contact

Direct contact with concentrated diborane vapors may cause severe eye or skin burns, leading to cell death and ulceration.

Ingestion

Ingestion is unlikely to occur because diborane is a gas at room temperature.

Sources/Uses

Diborane is produced by the reaction of lithium hydride with boron trifluoride catalyzed by ether at 25 °C.

Diborane is used in rocket propellants and as a reducing agent, as a rubber vulcanizer, as a catalyst for olefin polymerization, as a flame-speed accelerator, and as a doping agent in the manufacture of semiconductor devices.

Standards and Guidelines

OSHA PEL (permissible exposure limit) = 0.1 ppm

NIOSH REL (recommended exposure limit) = 0.1 ppm

NIOSH IDLH (immediately dangerous to life or health) = 15 ppm

AIHA ERPG-2 (maximum airborne concentration below which it is believed that nearly all persons could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action) = 1 ppm.

Physical Properties

Description: Colorless gas at room temperature

Warning properties: odor does not provide adequate warning of hazard

Molecular weight: 27.7 daltons

Boiling point: (760 mm Hg) = -135 °F (-92.8 °C)

Freezing point: -264.8 °F (-164.9 °C)

Specific gravity (liquid): 0.210 at 15 °C

Vapor pressure: >1 atm at 20 °C

Gas density: 0.965 (air = 1)

Water solubility: Decomposes in water

Flammability: Highly flammable, ignites spontaneously in air at 40-50 °C

Flammable Range: 0.8 % to 88 % (concentration in air)

Incompatibilities

Diborane is incompatible with oxidizers, aluminum, halogens, and water.

Health Effects

- **Diborane gas is irritating to the eyes, skin, and respiratory tract. It may cause burning of the eyes, nose, and throat; cough and constriction and edema of the airway and lungs can occur. Other possible effects include dizziness, headache, weakness, and lack of coordination. Kidney and liver damage may rarely occur.**
- **Local irritation is caused by the exothermic nature of the hydrolysis reaction.**
- **Individuals with pre-existing respiratory diseases may be more susceptible to exposure to diborane.**

Acute Exposure

The toxic effects of diborane are primarily due to its irritant properties. The local irritant action of diborane is due to the heat released as a consequence of its reaction with water and products formed by the hydrolysis reaction, such as boron oxide. Symptoms may be apparent immediately or delayed for a few hours.

Children do not always respond to chemicals in the same way that adults do. Different protocols for managing their care may be needed.

Respiratory

Exposure to diborane can cause a sensation of tightness of the chest leading to diaphragmatic pain, shortness of breath, cough, and wheezing. These signs and symptoms, which may be delayed for up to 24 hours, can be seen for 3 to 5 days after an exposure.

Children may be more vulnerable to gas exposure because of higher minute ventilation per kg and failure to evacuate an area promptly when exposed.

Dermal

Skin irritation manifested as reddened skin may occur from exposure to diborane vapors.

Ocular/Ophthalmic

High concentrations of diborane can cause eye irritation, pain, swelling, lacrimation, or photophobia.

Neurologic

Dizziness, headache, weakness, central nervous system depression, and incoordination have been seen following exposure to diborane.

Potential Sequelae

Weakness and fatigue may follow exposure to diborane. Damage to liver and kidneys may occur in some cases during metabolism and excretion.

Chronic Exposure

Chronic exposure to low concentrations of diborane were reported to have caused seizures, convulsions, fatigue, drowsiness, confusion, altered EEG responses, and spasms of the voluntary muscles. Others have reported headache, vertigo, chills, ans sometimes fever. Asthmatic bronchitis can also occur.

Chronic exposure may be more serious for children because of their potential for a longer latency period.

Carcinogenicity

Diborane has not been classified for carcinogenic effects.

Reproductive and Developmental Effects

No information is available regarding reproductive or developmental effects of diborane in experimental animals or humans. Diborane is not included in *Reproductive and Developmental Toxicants*, a 1991 report published by the U.S. General Accounting Office (GAO) that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences.

Prehospital Management

- **Rescue personnel are at low risk of secondary contamination from victims who have been exposed to diborane gas. However, rescuers entering areas with potential high concentrations should wear appropriate equipment to avoid self-exposure to diborane. An air concentration of 15 ppm is considered "immediately dangerous to life or health".**

- **Acute exposure to diborane gas causes chest tightness, coughing, skin, eye and nose irritation, and lacrimation. Respiratory impairment and noncardiogenic pulmonary edema may occur.**

- **There is no specific antidote for diborane poisoning. Treatment is supportive.**

Hot Zone

Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if rescuers have not been trained in its use, assistance should be obtained from a local or regional HAZMAT team or other properly equipped response organization.

Rescuer Protection

Diborane is a severe respiratory-tract and skin irritant.

Respiratory Protection: Positive-pressure, self-contained breathing apparatus (SCBA) is recommended in response situations that involve exposure to potentially unsafe levels of diborane.

Skin Protection: Chemical-protective clothing should be worn because diborane gas can cause skin irritation and burns.

ABC Reminders

Quickly establish a patent airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Apply direct pressure to stop bleeding.

Victim Removal

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be removed on backboards or gurneys; if these are not available, carefully carry or drag victims to safety.

Consider appropriate management of anxiety in victims with chemically-induced acute disorders, especially children who may suffer separation anxiety if separated from a parent or other adult.

Decontamination Zone

Victims exposed to diborane gas who have no skin or eye irritation do not need decontamination. They may be transferred immediately to the Support Zone. All others require decontamination as described below.

Rescuer Protection

If exposure levels are determined to be safe, decontamination may be conducted by personnel wearing a lower level of protection than that worn in the Hot Zone (described above).

ABC Reminders

Quickly establish a patent airway, ensure adequate respiration and pulse. Stabilize the cervical spine with a collar and a backboard if trauma is suspected. Administer supplemental oxygen as required. Assist ventilation with a bag-valve-mask device if necessary. Apply direct pressure to control bleeding.

Basic Decontamination

Victims who are able may assist with their own decontamination. Remove and double-bag contaminated clothing and personal belongings.

Flush exposed skin and hair with copious amounts of plain water for at least 15 minutes. Use caution to avoid hypothermia when decontaminating victims, particularly children or the elderly. Use blankets or warmers after decontamination as needed.

Do not irrigate eyes that have sustained frostbite injury. Otherwise, irrigate exposed or irritated eyes with plain water or saline for no less than 30 minutes. Eye irrigation may be carried out simultaneously with other basic care and transport. Remove contact lenses if it can be done without additional trauma to the eye. If pain or injury is evident, continue irrigation while transferring the victim to the support zone.

Consider appropriate management of chemically contaminated children a the exposure site. Provide reassurance to the child during decontamination, especially if separation from a parent occurs.

Transfer to Support Zone

As soon as basic decontamination is complete, move the victim to the Support Zone.

Support Zone

Be certain that victims have been decontaminated properly (see *Decontamination Zone* above). Victims who have undergone decontamination pose no serious risks of secondary contamination to rescuers. In such cases, Support Zone personnel require no specialized protective gear.

ABC Reminders

Quickly establish a patent airway and ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Administer supplemental oxygen as required and establish intravenous access if necessary. Place on a cardiac monitor. Watch for signs of airway swelling and obstruction such as progressive hoarseness, stridor, or cyanosis.

Additional Decontamination

Continue irrigating exposed skin and eyes, as appropriate.

Advanced Treatment

In cases of respiratory compromise, secure airway and respiration via endotracheal intubation. If not possible, perform cricothyrotomy if equipped and trained to do so.

Treat patients who have bronchospasm with an aerosolized bronchodilator such as albuterol.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution, repeat every 20 minutes as needed cautioning for myocardial variability.

Patients who are comatose, hypotensive, or having seizures or who have cardiac arrhythmias should be treated according to advanced life support (ALS) protocols.

If evidence of shock or hypotension is observed, begin fluid administration. For adults with systolic pressure less than 80 mm Hg, bolus perfusion of 1,000 mL/hour intravenous saline or lactated Ringer's solution may be appropriate. Higher adult systolic pressures may necessitate lower perfusion rates. For children with compromised perfusion administer a 20 mL/kg bolus of normal saline over 10 to 20 minutes, then infuse at 2 to 3 mL/kg/hour.

If frostbite is present, treat by rewarming in a water bath at a temperature of 102 to 108 °F (40 to 42 °C) for 20 to 30 minutes and continue until a flush has returned to the affected area.

Transport to Medical Facility

Only decontaminated patients or those not requiring decontamination should be transported to a medical facility. "Body bags" are not recommended.

Report to the base station and the receiving medical facility the condition of the patient, treatment given, and estimated time of arrival at the medical facility.

Multi-Casualty Triage

Consult with the base station physician or the regional poison control center for advice regarding triage of multiple victims.

Patients with evidence of significant exposure (e.g., severe or persistent cough, dyspnea, or chemical burns) should be transported to a medical facility for evaluation. Patients who have minor or transient irritation of the eyes or throat may be discharged from the scene after their names, addresses, and telephone numbers are recorded. They should be advised to seek medical care promptly if symptoms develop or recur (see *Patient Information Sheet* below). The development of serious respiratory symptoms may be delayed for up to 24 hours.

Emergency Department Management

- **Hospital personnel are at minimal risk of secondary contamination from patients who have been exposed to diborane gas. However, hospital personnel in an enclosed area can be secondarily contaminated by vapors off-gassing from heavily contaminated clothing or skin.**
- **Acute exposure to diborane initially causes coughing, eye and nose irritation, lacrimation, and a burning sensation in the chest. Airway constriction and noncardiogenic pulmonary edema may occur.**
- **Diborane irritates the skin and can cause burning pain, inflammation, and blisters. Exposure to liquefied diborane can result in frostbite.**
- **There is no specific antidote for diborane poisoning. Treatment requires supportive care.**

Decontamination Area

Unless previously decontaminated, all patients with skin or eye irritation require decontamination as described below.

Be aware that use of protective equipment by the provider may cause anxiety, particularly in children, resulting in decreased compliance with further management efforts.

ABC Reminders

Evaluate and support airway, breathing, and circulation. In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, surgically secure an airway.

Treat patients who have bronchospasm with an aerosolized bronchodilator such as albuterol.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution, repeat every 20 minutes as needed cautioning for myocardial variability.

Patients who are comatose, hypotensive, or having seizures or cardiac arrhythmias should be treated in the conventional manner.

Basic Decontamination

Patients who are able may assist with their own decontamination. Remove and double bag contaminated clothing and personal belongings.

If skin and eye contact with liquified diborane occurred, handle frostbitten with caution. Place frostbitten skin in warm water, about 108 °F (42 °C). If warm water is not available, wrap the affected part gently in blankets. Let the circulation reestablish itself naturally. Encourage the victim to exercise the affected part while it is being warmed.

Flush exposed skin and hair with plain water for no less than 15 minutes. Use caution to avoid hypothermia when decontaminating victims, particularly children or the elderly. Use blankets or warmers after decontamination as needed.

Do not irrigate frostbitten eyes. Otherwise, begin irrigation of exposed eyes. Remove contact lenses if it can be done without additional trauma to the eye. Continue irrigation while transporting the patient to the Critical Care Area.

Critical Care Area

Be certain that appropriate decontamination has been carried out.

ABC Reminders

Evaluate and support airway, breathing, and circulation as in ABC Reminders above under *Decontamination Zone*. Establish intravenous access in seriously ill patients if this has not been done previously. Continuously monitor cardiac rhythm.

Patients who are comatose, hypotensive, or having seizures or cardiac arrhythmias should be treated in the conventional manner.

Inhalation Exposure

Administer supplemental oxygen by mask to patients who have respiratory symptoms. Treat patients who have bronchospasm with an aerosolized bronchodilator such as albuterol.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution, repeat every 20 minutes as needed cautioning for myocardial variability.

If pulmonary edema develops, maintain ventilation and oxygenation and evaluate with frequent arterial blood gas or pulse oximetry monitoring. Early use of PEEP and mechanical ventilation may be needed. Prophylactic antibiotic therapy may reduce the chances of respiratory infection.

Skin Exposure

If the skin was in contact with diborane, thermal burns may occur. Treat thermal burns by assuring that affected area is cool by flushing

with cool water, then apply dry sterile dressings. If the patient is burned on the face, neck head, or chest, assume that the airway may also have been burned.

If the liquefied diborane gas contacts the skin, frostbite may result. If a victim has frostbite, treat by rewarming affected areas in a water bath at a temperature of 102 to 108 °F (40 to 42 °C) for 20 to 30 minutes and continue until a flush has returned to the affected area.

Eye Exposure

Diborane-exposed eyes should be irrigated for at least 15 minutes. Test visual acuity and examine the eyes for corneal damage and treat appropriately. Immediately consult an ophthalmologist for patients who have corneal injuries.

Antidotes and Other Treatments

There is no specific antidote for diborane. Treatment is supportive.

Laboratory Tests

The diagnosis of acute diborane toxicity is primarily clinical, based on respiratory difficulties and irritation. However, laboratory testing is useful for monitoring the patient and evaluating complications. Routine laboratory studies for all exposed patients include CBC, glucose, and electrolyte determinations. Patients who have respiratory complaints may require pulse oximetry (or ABG measurements) and chest radiography. Massive inhalation may be complicated by hyperchloremic metabolic acidosis; in addition to electrolytes, monitor blood pH.

Disposition and Follow-up

Consider hospitalizing patients who have a suspected significant exposure or have eye burns or serious skin burns.

Delayed Effects

Symptomatic patients complaining of persistent shortness of breath, severe cough, or chest tightness should be admitted to the hospital and observed until symptom-free. Pulmonary injury may progress for several hours.

Patient Release

Asymptomatic patients and those who experienced only minor sensations of burning of the nose, throat, eyes, and respiratory tract (with perhaps a slight cough) may be released. In most cases, these patients will be free of symptoms in an hour or less. They should be advised to seek medical care promptly if symptoms develop or recur (see the *Diborane—Patient Information Sheet* below).

Follow-up

Obtain the name of the patient's primary care physician so that the hospital can send a copy of the ED visit to the patient's doctor.

Follow up is recommended for all hospitalized patients because long-term respiratory problems can result. Respiratory monitoring is recommended until the patient is symptom-free. In addition, long-term follow-up should seek neuropsychiatric abnormality. Kidney and liver tests are also indicated.

Patients who have skin or corneal injury should be re-examined within 24 hours. Anyone who had significant dermal exposure should be followed for several months.

Reporting

If a work-related incident has occurred, you may be legally required to file a report; contact your state or local health department.

Other persons may still be at risk in the setting where this incident occurred. If the incident occurred in the workplace, discussing it with company personnel may prevent future incidents. If a public health risk exists, notify your state or local health department or other responsible public agency. When appropriate, inform patients that they may request an evaluation of their workplace from OSHA or NIOSH. See Appendix III for a list of agencies that may be of assistance.

Diborane
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to diborane.

What is diborane?
Diborane is a colorless gas with a repulsive, sweet odor. It is used in rocket propellants and as reducing agent, as a rubber vulcanizer, as a catalyst for olefin polymerization, as a flame-speed accelerator, and as a doping agent. Because diborane is a gas a ambient temperature, the most likely exposure routes are inhalation and dermal.

What immediate health effects can be caused by exposure to diborane?
Even small exposures to diborane may cause immediate irritation of the eyes, nose, and throat, and shortness of breath, as well as coughing, wheezing, shortness of breath, and tearing of the eyes. Some of these signs and symptoms may develop several hours after exposure occurred. Exposure to diborane can also cause dizziness, headache, drowsiness, and lack of coordination. Breathing large amounts of diborane may cause the lining of the throat and lungs to swell, making breathing difficult. Generally, the more serious the exposure, the more severe the symptoms.

Can diborane poisoning be treated?
There is no antidote for diborane, but its effects can be treated and most exposed persons get well. Persons who have experienced serious symptoms may need to be hospitalized.

Are any future health effects likely to occur?
A single small exposure from which a person recovers quickly is not likely to cause delayed or long-term effects. After a serious exposure, symptoms may worsen for several hours and respiratory and neurologic alterations may persist for long time.

What tests can be done if a person has been exposed to diborane?
Specific tests for the presence of diborane in blood or urine generally are not useful to the doctor. If a severe exposure has occurred, blood and urine analyses and other tests may show whether the upper respiratory airways and lungs or brain have been injured. Testing is not needed in every case.

Where can more information about diborane be found?
More information about diborane can be obtained from your regional poison control center, your state, county, or local health department; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in occupational and environmental health. If the exposure happened at work, you may wish to discuss it with your employer, the Occupational Safety and Health Administration (OSHA), or the National Institute for Occupational Safety and Health (NIOSH). Ask the person who gave you this form for help in locating these telephone numbers.

Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow *only* the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:

- coughing or wheezing
- difficulty breathing, shortness of breath, or chest pain
- increased pain or a discharge from injured eyes
- increased redness or pain or a pus-like discharge in the area of a skin burn

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.
[ ] Call for an appointment with Dr. _____ in the practice of _____. When you call for your appointment, please say that you were treated in the Emergency Department at _____ Hospital by _____ and were advised to be seen again in _____ days.
[ ] Return to the Emergency Department/ _____ Clinic on (date) _____ at _____ AM/PM for a follow-up examination.
[ ] Do not perform vigorous physical activities for 1 to 2 days.
[ ] You may resume everyday activities including driving and operating machinery.
[ ] Do not return to work for _____ days.
[ ] You may return to work on a limited basis. See instructions below.
[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.
[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.
[ ] Avoid taking the following medications: _____
[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: _____
_____
_____
[ ] Other instructions: _____
_____
_____

- Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.

- You or your physician can get more information on the chemical by contacting: _____ _____ or _____, or by checking out the following Internet Web sites: _____; _____.

Signature of patient _____ Date _____

Signature of physician _____ Date _____

Ethylene Dibromide ($C_2H_4Br_2$)
CAS 106-93-4; UN 1605

Synonyms include 1,2-dibromoethane, glycoldibromide, and bromofume.

- **Persons whose clothing or skin is contaminated with liquid ethylene dibromide (above 50 °F) can secondarily contaminate others by direct contact or through off-gassing vapor.**
- **A liquid at room temperature, ethylene dibromide readily penetrates skin, cloth, and other protective materials such as rubber and leather. It is nonflammable.**
- **Ethylene dibromide is a colorless, heavy liquid with a sweet chloroform-like odor. It's odor is not detectable at a low enough concentration to be considered a warning of excessive exposure.**
- **Absorption can occur by the inhalation, oral, and dermal routes. It is toxic by these three routes of exposure. Toxicity is thought to be due to metabolic products of ethylene dibromide.**

Description

Ethylene dibromide is a nonflammable colorless liquid with a sweet chloroform-like odor at room temperature above 50 °F (10 °C). It is slightly soluble in water and soluble in most organic solvents. It is heavier than water. When heated to decomposition, it may release gases and vapors such as hydrogen bromide, bromine, and carbon monoxide. Ethylene dibromide should be stored in a dry place at ambient temperature.

Routes of Exposure

Inhalation

Inhalation is an important route of exposure. Ethylene dibromide's odor is not detectable at a low enough concentration to be considered a good warning of excessive exposure. Ethylene dibromide vapors are heavier than air and can accumulate in poorly ventilated or low-lying areas.

Fatalities have occurred among workers cleaning a tank containing residues of ethylene dibromide. The dermal route also contributed to the exposure.

Children exposed to the same levels of ethylene dibromide as adults may receive larger doses because they have greater lung surface

area:body weight ratios and higher minute volume:weight ratios. In addition, they may be exposed to higher levels than adults in the same location because of their short stature and the higher levels of ethylene dibromide vapors found nearer to the ground.

Skin/Eye Contact

Ethylene dibromide can penetrate ordinary rubber gloves and leather. Prolonged skin contact with the liquid may cause erythema, blistering, and skin ulcers. Skin absorption may contribute to systemic toxicity.

Because of their relatively larger surface area:weight ratio, children are more vulnerable to toxicants absorbed through the skin.

Ingestion

Acute toxic effects, including fatal systemic poisoning, can result from ingestion. Rapid effects following ingestion can include abdominal pain, diarrhea, nausea, vomiting, and drowsiness.

Sources/Uses

Ethylene dibromide is produced by liquid-phase bromination of ethylene at 35–85 °C. This is followed by neutralization to free acid and purification by distillation. Ethylene dibromide was used extensively as a scavenger for lead in gasoline and as a pesticide and an ingredient of soil, vegetable, fruit, and grain fumigant formulations. However, these uses have almost disappeared in the United States. It is used to some extent as a chemical intermediate, gauge fluid, and as a nonflammable solvent for resins, gums, and waxes.

Standards and Guidelines

OSHA 8-hour TWA = 20 ppm; acceptable ceiling concentration = 30 ppm

NIOSH REL-TWA = 0.045 ppm; 15-min ceiling limit = 0.13 ppm

NIOSH IDLH (immediately dangerous to life or health) = 100 ppm

Physical Properties

Description: Colorless; liquid at room temperature and solid below 50 °F (10 °C)

Warning properties: **Inadequate** for exposure to vapors

Molecular weight: 187.9 daltons

Boiling point (760 mm Hg): 268 °F (131 °C)

Freezing point: 50°F (10 °C)

Vapor pressure: 11 mm Hg at 77 °F (25 °C)

Liquid specific gravity: 2.172 at 77° F (25 °C)

Gas density: 6.48 (air = 1)

Water solubility: Water soluble (0.43% at 86 °F) (30 °C)

Flammability: Nonflammable

Incompatibilities Incompatible with strong oxidizers, magnesium, alkali metals, and liquid ammonia.

Health Effects

- **Ethylene dibromide is a liquid at ambient temperatures that can cause skin, eye, mucous membrane, and respiratory tract irritation. It may also cause damage to the lungs, liver, and kidneys. These effects can result from all routes of exposure.**
- **The systemic effects of ethylene dibromide are in part due to metabolic conversion to the cell toxicant 2-bromoacetaldehyde.**
- **Persons with pre-existing skin disorders or eye problems, or impaired liver, kidney, or respiratory tract function may be more susceptible to the effects of ethylene dibromide.**

Acute Exposure

Ethylene dibromide alkylates macromolecules causing cellular disruption and reduced glutathione levels. Cellular disruption in tissues and organs, such as liver and kidneys, results in progressive dysfunction. Manifestation of some of the effects of acute high exposure may be delayed a few days.

Children do not always respond to chemicals in the same way that adults do. Different protocols for managing their care may be needed.

Respiratory

Early symptoms of acute exposure include irritation of the nose and throat. Exposures of moderate to severe intensity produce respiratory manifestations ranging from cough, chest pain, and dyspnea to bronchitis, pneumonitis, pulmonary edema, and hemorrhage. Pulmonary edema occurred 3 days after oral poisoning in one fatal human case.

Children may be more vulnerable because of higher minute ventilation per kg and failure to evacuate an area promptly when exposed. Hydrocarbon pneumonitis may be a problem in children.

CNS

Ethylene dibromide is a mild central nervous system depressant. Drowsiness has been reported following ingestion and inhalation. Inhalation of vapors in a confined oxygen-deficient space has caused rapid loss of consciousness, coma, and death.

Dermal

Liquid ethylene dibromide is a skin irritant. Brief skin contact or contact with contaminated clothing causes erythema and discomfort. Splashing of the liquid on the skin causes a sensation of cooling

because the liquid evaporates quickly. Prolonged skin contact may cause blistering and skin ulcers (may be delayed 24–48 hours). Ethylene dibromide can be absorbed through the skin to produce systemic effects.

Exposure to certain chemicals can lead to Reactive Airway Dysfunction Syndrome (RADS), a chemically- or irritant-induced type of asthma.

Because of their larger relatively surface area:body weight ratio, children are more vulnerable to toxins absorbed through the skin.

Ocular/Ophthalmic

Conjunctivitis has been reported after exposure to ethylene dibromide. Eye contact with the compound may cause temporary loss of vision because of destruction of tissues in the eye.

Hepatic

Ethylene dibromide poisoning often affects the liver. Significant liver damage has resulted from inhalation and ingestion of ethylene dibromide. Necrosis of the liver was a chief finding in a fatal case of acute oral poisoning. In two fatal cases of inhalation/dermal exposure, serum aspartate aminotransferase and lactic dehydrogenase were elevated before death.

Renal

The kidney is often affected in ethylene dibromide poisoning. Severe renal lesions were reported in fatal cases of acute oral poisoning and also inhalation poisoning. Lesions included necrosis of the tubular epithelium, cytoplasmic vacuolization of the proximal convoluted tubules, and tubular protein casts.

Gastrointestinal

Abdominal pain, nausea, vomiting, and diarrhea have been reported after ethylene dibromide ingestion.

Metabolic

Metabolic acidosis can occur after high exposure to ethylene dibromide.

Potential Sequelae

Patients who develop severe acute neurologic injury but survive may have both central and peripheral neurologic effects that persist indefinitely.

Chronic Exposure

No reliable reports exist of adverse health effects in humans exposed chronically to ethylene dibromide.

Chronic exposure may be more serious for children because of their potential for a longer latency period.

Carcinogenicity

The Department of Health and Human Services (DHHS) has determined that ethylene dibromide can reasonably be anticipated to be a human carcinogen, based on ethylene dibromide-induced tumors in multiple sites and by various routes of exposure in animals. Results from epidemiological studies have been inconclusive.

Reproductive and Developmental Effects

There is inconclusive but suggestive evidence that ethylene dibromide may reduce fertility in men. Antispermatogenic effects have been demonstrated in various animal species. Ethylene dibromide is included in *Reproductive and Developmental Toxicants*, a 1991 report published by the U.S. General Accounting Office (GAO) that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences.

Special consideration regarding the exposure of pregnant women is warranted, since ethylene dibromide has been shown to be a genotoxin; thus, medical counseling is recommended for pregnant women.

Prehospital Management

- **Victims exposed only to ethylene dibromide gas do not pose substantial risks of secondary contamination to personnel outside the Hot Zone; however, some ethylene dibromide may permeate clothing. Victims whose clothing or skin is contaminated with liquid ethylene dibromide (i.e., ambient temperature higher than 50 °F) can secondarily contaminate response personnel by direct contact or through off-gassing vapor.**
- **Ethylene dibromide is a mucous membrane, skin, and eye irritant. It may also cause respiratory distress and pulmonary noncardiogenic pulmonary edema, liver and kidney toxicity, drowsiness, coma, and death. Dermal absorption may contribute to systemic toxicity.**
- **There is no antidote for ethylene dibromide. Treatment consists of support of respiratory and cardiovascular functions.**

Hot Zone

Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if rescuers have not been trained in its use, assistance should be obtained from a local or regional HAZMAT team or other properly equipped response organization.

Rescuer Protection

Ethylene dibromide is a highly toxic systemic poison that is readily absorbed following inhalation and dermal exposure.

Respiratory Protection: Positive-pressure, self-contained breathing apparatus (SCBA) with a full facepiece is recommended in response situations that involve exposure to potentially unsafe levels of methyl bromide vapor.

Skin Protection: Chemical-protective clothing (including boots and gloves) is recommended because ethylene dibromide vapor or liquid can be absorbed through the skin and may contribute to systemic toxicity. Contact with liquid ethylene dibromide can cause skin irritation and blisters. Ethylene dibromide can penetrate ordinary rubber gloves and leather.

ABC Reminders

Quickly establish a patent airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible.

Victim Removal

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be removed on backboards or gurneys; if these are not available, carefully carry or drag victims to safety.

Consider appropriate management of anxiety in victims with chemically-induced acute disorders, especially children who may suffer separation anxiety if separated from a parent or other adult.

Decontamination Zone

Remove clothing, including footwear, from all victims because ethylene dibromide persists in cloth, leather, and rubber. After clothing has been removed, patients exposed only to the gas who have no skin or eye irritation may be transferred immediately to the Support Zone. All others require decontamination as described below.

Rescuer Protection

If exposure levels are determined to be safe, decontamination may be conducted by personnel wearing a lower level of protection than that worn in the Hot Zone (described above).

ABC Reminders

Quickly establish a patent airway, ensure adequate respiration and pulse. Stabilize the cervical spine with a collar and a backboard if trauma is suspected. Administer supplemental oxygen as required. Assist ventilation with a bag-valve-mask device if necessary.

Basic Decontamination

Victims who are able may assist with their own decontamination. Remove all contaminated clothing including footwear. Ethylene dibromide can persist in cloth, leather, and rubber, and these materials may contribute to severe chemical burns after prolonged skin contact. Double-bag contaminated clothing and personal belongings. **Leave these items in the Hot Zone.**

Flush exposed skin and hair with water for at least 15 minutes, then wash twice with mild soap. Rinse thoroughly with water. Use caution to avoid hypothermia when decontaminating patients, particularly children or the elderly. Use blankets or warmers after decontamination as needed..

Irrigate exposed or irritated eyes with plain water or saline for 15 to 20 minutes. Remove contact lenses if easily removable without additional trauma to the eye. If pain or injury is evident, continue irrigation while transferring the victim to the Support Zone.

If ingestion of liquid ethylene dibromide occurs, **do not induce emesis**. If the victim is alert and able to swallow, administer a slurry of activated charcoal at a dose of 1 g/kg (infant, child, and adult dose). A soda can and straw may be of assistance when offering charcoal to a child.

Consider appropriate management of chemically contaminated children at the exposure site. Also, provide reassurance to the child during decontamination, especially if separation from a parent occurs.

Transfer to Support Zone

As soon as basic decontamination is complete, move the victim to the Support Zone.

Support Zone

Be certain that victims have been decontaminated properly (see *Decontamination Zone* above). Victims who have undergone decontamination pose no serious risks of secondary contamination. Support Zone personnel require no specialized protective gear in such cases.

ABC Reminders

Quickly establish a patent airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Administer supplemental oxygen as required and establish intravenous access if necessary. Place on a cardiac monitor.

Additional Decontamination

Continue irrigating exposed skin and eyes, as appropriate.

In cases of ingestion of liquid ethylene dibromide, **do not induce emesis**. If the victim is alert and able to swallow, administer a slurry of activated charcoal at a dose of 1 g/kg (infant, child, and adult dose). A soda can and straw may be of assistance when offering charcoal to a child.

Advanced Treatment

In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, perform cricothyrotomy if equipped and trained to do so.

Treat patients who have bronchospasm with an aerosolized bronchodilator such as albuterol.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution,

repeat every 20 minutes as needed, cautioning for myocardial variability.

Patients who are comatose, hypotensive, or are having seizures or cardiac arrhythmias should be treated according to advanced life support (ALS) protocols.

If evidence of shock or hypotension is observed, begin fluid administration. For adults with systolic pressure less than 80 mmHg, bolus perfusion of 1,000 mL/hour intravenous saline or lactated Ringer's solution may be appropriate. Higher adult systolic pressures may necessitate lower perfusion rates. For children with compromised perfusion administer a 20 mL/kg bolus of normal saline over 10 to 20 minutes, then infuse at 2 to 3 mL/kg/hour.

Transport to Medical Facility

Only decontaminated patients or patients not requiring decontamination should be transported to a medical facility. "Body bags" are not recommended.

Report to the base station and the receiving medical facility the condition of the patient, treatment given, and estimated time of arrival at the medical facility.

If the patient has ingested ethylene dibromide, prepare the ambulance in case the patient vomits toxic material or has diarrhea. Have ready several towels and open plastic bags to quickly clean up and isolate vomitus.

Multi-Casualty Triage

Consult with the base station physician or the regional poison control center for advice regarding triage of multiple victims. Because systemic symptoms may be delayed for several hours after exposure, all exposed patients should be transported to a medical facility for evaluation. Symptomatic patients should receive priority in transport.

Emergency Department Management

- **Hospital personnel away from the scene are not at significant risk of secondary contamination from patients exposed to vapors of ethylene dibromide or to liquid ethylene dibromide (ambient temperatures greater than 50 °F); however, some ethylene dibromide may have permeated clothing.**
- **Ethylene dibromide is a mucous membrane irritant and exposures to high concentrations can cause eye, skin, and respiratory tract irritation, as well as pulmonary edema. Dermal absorption can contribute to systemic toxicity.**
- **High concentrations can also cause drowsiness, coma, and death.**
- **There is no antidote for ethylene dibromide. Treatment consists of support of respiratory and cardiovascular functions.**

Decontamination Area

Unless previously decontaminated, all patients suspected of contact with liquid ethylene dibromide and all victims with skin or eye irritation require decontamination as described below. Because ethylene dibromide is absorbed through the skin, don butyl rubber gloves and apron before treating patients. Ethylene dibromide readily penetrates most rubbers and barrier fabrics or creams, but butyl rubber provides good skin protection. All other patients may be transferred immediately to the Critical Care Area.

Be aware that use of protective equipment by the provider may cause anxiety, particularly in children, resulting in decreased compliance with further management efforts.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants absorbed through the skin. Also, emergency department personnel should examine children's mouths because of the frequency of hand-to-mouth activity among children.

ABC Reminders

Evaluate and support airway, breathing, and circulation. In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, surgically create an airway.

Treat patients who have bronchospasm with an aerosolized bronchodilator such as albuterol.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution, repeat every 20 minutes as needed, cautioning for myocardial variability.

Patients who are comatose, hypotensive, or have seizures or cardiac arrhythmias should be treated in the conventional manner.

Basic Decontamination

Patients who are able may assist with their own decontamination. Remove and double-bag all clothing, including footwear, because ethylene dibromide penetrates many materials and can remain trapped in them. Leather absorbs ethylene dibromide; items such as leather shoes, gloved, and belts may require disposal by incineration.

Flush exposed skin and hair with water for at least 15 minutes, then wash **twice** with mild soap. Rinse thoroughly with water. Use caution to avoid hypothermia when decontaminating patients, particularly children or the elderly. Use blankets or warmers after decontamination as needed.

Irrigate exposed or irritated eyes with tap water or saline for 15 to 20 minutes. Remove contact lenses if easily removable without additional trauma to the eye. If pain or injury is evident, continue irrigation while transferring the victim to the Critical Care Area. An ophthalmic anesthetic, such as 0.5% tetracaine, may be necessary to alleviate blepharospasm, and lid retractors may be required to allow adequate irrigation under the eyelids.

If ingestion occurs, **do not induce emesis**. If the victim is alert and able to swallow, and if not already done, administer a slurry of activated charcoal at a dose of 1 g/kg (infant, child, and adult dose). A soda can and straw may be of assistance when offering charcoal to a child.

Critical Care Area

Be certain that appropriate decontamination has been carried out (see *Decontamination Area*, above).

ABC Reminders

Evaluate and support airway, breathing, and circulation as in *ABC Reminders* above. Establish intravenous access in seriously ill patients. Continuously monitor cardiac rhythm.

Patients who are comatose, hypotensive, or have seizures or cardiac arrhythmias should be treated in the conventional manner.

Inhalation Exposure

Administer supplemental oxygen by mask to patients who have respiratory complaints. Treat patients who have bronchospasm with an aerosolized bronchodilator such as albuterol.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution, repeat every 20 minutes as needed, cautioning for myocardial variability.

Observe these patients for 24 hours using repeated chest examinations and other appropriate tests. Follow-up as clinically indicated.

Skin Exposure

If the skin was in contact with concentrated ethylene dibromide vapor or liquid, chemical burns may result; treat as thermal burns. Burns may be delayed in onset.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants absorbed through the skin.

Eye Exposure

Continue irrigation for at least 15 minutes. Test visual acuity. Examine the eyes for corneal damage and treat appropriately. Immediately consult an ophthalmologist for patients who have corneal injuries.

Ingestion

If ingestion of liquid ethylene dibromide occurs, **do not induce emesis.** If the victim is alert and able to swallow, and if not already done, administer a slurry of activated charcoal at a dose of 1 g/kg (infant, child, and adult dose). A soda can and straw may be of assistance when offering charcoal to a child.

Antidotes and Other Treatments

There is no proven antidote for ethylene dibromide poisoning. Dimercaprol (BAL) or acetylcysteine (Mucomyst) have been suggested as antidotes based on the postulated mechanism of ethylene dibromide's toxicity. However, no adequate studies have tested the efficacy of these therapies, and they are not recommended for routine use.

Laboratory Tests

Serum bromide levels can be used to document that exposure did occur. However, bromide levels do not accurately predict the clinical course. Routine laboratory studies include CBC, glucose, and electrolyte determinations. Additional studies for patients exposed to ethylene dibromide include liver-function tests and renal-

function tests. In cases of inhalation exposure, chest radiography and arterial blood gas measurements may be helpful.

Disposition and Follow-up

Decisions to admit or discharge a patient should be based on exposure history, physical examination, and test results. The probable delay in onset of serious effects from ethylene dibromide exposure should be considered.

Delayed Effects

Because the onset of pulmonary edema may be delayed for up to several days, patients who have severe exposure should be monitored with serial examinations before absence of toxic effects can be assured. If pulmonary edema is suspected, admit patients to an intensive care unit. Neurological symptoms also may not develop for several days or weeks.

Patient Release

Patients who have no evidence of neuropsychiatric or pulmonary effects 24 hours after exposure may be discharged with instructions to return to the emergency department (ED) if symptoms develop or recur (see the *Ethylene Dibromide—Patient Information Sheet* below).

Follow-up

Obtain the name of the patient's primary care physician so that the hospital can send a copy of the ED visit to the patient's doctor.

Patients exposed to ethylene dibromide should be monitored for late neuropsychiatric sequelae.

Patients who have corneal injuries should be reexamined within 24 hours.

Reporting

Ethylene dibromide is a pesticide. If a pesticide- or work-related incident has occurred, you may be legally required to file a report; contact your state or local health department.

Other persons may still be at risk in the setting where this incident occurred. If the incident occurred in the workplace, discussing it with company personnel may prevent future incidents. If a public health risk exists, notify your state or local health department or other responsible public agency. When appropriate, inform patients that they may request an evaluation of their workplace from OSHA or NIOSH. See Appendix III for a list of agencies that may be of assistance.

Ethylene Dibromide
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to ethylene dibromide.

What is ethylene dibromide?
Ethylene dibromide is a colorless liquid at ambient temperature, with a sweetish odor. Ethylene dibromide has been used as a scavenger for lead in gasoline and as a pesticide and an ingredient of soil and grain fumigant formulations. These uses have virtually disappeared in the United States. Minor uses include use as a chemical intermediate and as a nonflammable solvent for resins, gums, and waxes.

What immediate health effects can be caused by exposure to ethylene dibromide?
Ingestion of the ethylene dibromide or inhalation of vapors can cause injury to the brain, lungs, and throat. High doses can also injure the kidneys and liver. Contact with the skin and eyes can lead to irritation and burns and can also contribute to systemic toxicity. Ethylene dibromide may cause cardiac arrhythmias and sensitization. Generally, the more serious the exposure, the more severe the symptoms.

Can ethylene dibromide poisoning be treated?
There is no antidote for ethylene dibromide poisoning, but its effects can be treated and most persons recover. Persons who have experienced serious symptoms may need to be hospitalized and may need follow-up examinations or treatment later on.

Are any future health effects likely to occur?
A single small exposure from which a person recovers quickly is not likely to cause delayed or long-term effects. After a serious exposure that causes lung or nervous system-related problems, permanent brain or lung damage can result. The Department of Health and Humans Services has determined that ethylene dibromide can reasonably be anticipated to be a carcinogen.

What tests can be done if a person has been exposed to ethylene dibromide?
Specific tests for the presence of bromide in blood may provide some useful information to the doctor. If a severe exposure has occurred, blood and urine analyses and other tests may show whether the lungs, brain, liver, or kidneys have been damaged. Testing is not needed in every case.

Where can more information about ethylene dibromide be found?
More information about ethylene dibromide can be obtained from your regional poison control center; your state, county, or local health department; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in occupational and environmental health. If the exposure happened at work, you may wish to discuss it with your employer, the Occupational Safety and Health Administration (OSHA), or the National Institute for Occupational Safety and Health (NIOSH). Ask the person who gave you this form for help in locating these telephone numbers.

Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow *only* the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:

- coughing or wheezing
- difficulty in breathing, shortness of breath, or chest pain
- difficulty in walking
- confusion, dizziness, or fainting
- increased pain or a discharge from exposed eyes
- increased redness or pain or a pus-like discharge in the area of a skin burn

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.

[ ] Call for an appointment with Dr. _____ in the practice of _____. When you call for your appointment, please say that you were treated in the Emergency Department at _____ Hospital by _____ and were advised to be seen again in _____ days.

[ ] Return to the Emergency Department/ _____ Clinic on (date) _____at _ _____ AM/PM for a follow-up examination.

[ ] Do not perform vigorous physical activities for 1 to 2 days.

[ ] You may resume everyday activities including driving and operating machinery.

[ ] Do not return to work for _____ days.

[ ] You may return to work on a limited basis. See instructions below.

[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.

[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.

[ ] Avoid taking the following medications: _____

[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: __ _____ _____

[ ] Other instructions: _____ _____ _____

- Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.
- You or your physician can get more information on the chemical by contacting: _____ _____ or _____, or by checking out the following Internet Web sites: _____; _____.

Signature of patient _____ Date _____

Signature of physician _____ Date _____

Mercury (Hg)
CAS 7439-97-6; UN 2024 (liquid compounds)

Synonyms include colloidal mercury, quicksilver, liquid silver, metallic mercury, and hydrargyrum.

- **Persons exposed to elemental mercury vapor do not pose a significant risk of secondary contamination to response personnel outside the Hot Zone. Persons whose skin or clothing is contaminated with liquid mercury can contaminate response personnel by direct contact or off-gassing vapor and can also contaminate equipment leading to a risk of chronic exposure for response personnel.**
- **Elemental mercury is a heavy, shiny, silver-white, odorless liquid. It is nonflammable, but releases toxic vapor, especially when heated. Odor does not provide any warning of hazardous concentrations.**
- **Inhalation is the primary route of exposure to elemental mercury vapor or aerosols, which are readily absorbed. Virtually no elemental mercury is absorbed from the gastrointestinal tract or by the skin. Mercury crosses the placenta and can be transferred to infants via breast milk.**

Description

There are three classes of mercury: metallic elemental mercury (quicksilver, Hg^0), inorganic mercurial salts (e.g., Hg_2Cl_2, Hg^+, $HgCl_2$, Hg^{+2}), and organic mercurials (e.g., methylmercury, phenylmercury). Adverse effects from exposure to mercury differ depending on the form and the route of exposure. This Medical Management Guideline focuses on elemental mercury. At room temperature, metallic or elemental mercury is a heavy, shiny, silver-white, odorless liquid. It is only slightly volatile at room temperatures and significantly more volatile when heated. Elemental mercury is nonflammable and has low solubility in both water and organic solvents.

Routes of Exposure

Inhalation

Inhalation of mercury vapor is the primary route of exposure to elemental mercury. Inhaled vapor is almost completely absorbed by the lungs (75–80%). Neither liquid mercury nor mercury vapor has an odor and thus, **chemical odor provides no warning of hazardous concentrations.** Mercury vapor is heavier than air and may therefore accumulate in poorly ventilated or low-lying areas.

Children exposed to the same levels of mercury vapor as adults may receive larger doses because they have greater lung surface area:body weight ratios and increased minute volumes:weight ratios. In addition, they may be exposed to higher levels than adults in the same location because of their short stature and the higher levels of mercury vapor found nearer to the ground.

Skin/Eye Contact

Elemental mercury vapor is only slowly absorbed through the skin, but causes irritation of both skin and eyes and may produce contact dermatitis.

Ingestion

Elemental mercury, a liquid at room temperature, is essentially nontoxic when ingested because virtually none (less than 0.1%) is absorbed. Anatomic gastrointestinal abnormalities such as enteric fistulas or intestinal perforation can sequester sufficient quantities of ingested elemental mercury to allow significant oxidation and subsequent absorption.

Sources/Uses

Elemental mercury is inexpensively produced by heating mercury-containing ores and condensing the vapor. Metallic mercury has many applications in the electrical industry (e.g., alkaline batteries, electrical switches, lights), in dental amalgrams, and in medical equipment (e.g., thermometers, electroanalysis). In the chemical and mining industries, mercury is used as a catalyst in reactions to form polymers, in manufacturing chlorine and caustic soda, and in extracting gold from ore. Mishandled or spilled mercury from devices used in the home or workplace is often the source of unintentional exposures.

Standards and Guidelines

OSHA PEL (permissible exposure limit) = 0.1 mg/m^3 (vapor) (ceiling)

NIOSH IDLH (immediately dangerous to life or health) = 10 mg/m^3

Physical Properties

Description: Liquid is shiny, silvery-white, and heavy; vapor is colorless and odorless.

Warning properties: Odor is inadequate to warn of toxic exposure.

Molecular weight: 200.59 daltons

Boiling point (760 mm Hg): 674 °F (356.72 °C)

Freezing point: -102 °F (-38.9 °C)

Specific gravity: 13.6 at 77 °F (25 °C) (water = 1.00)

Vapor pressure: 0.002 mm Hg at 77 °F (25 °C)

[Note: Although the vapor pressure of elemental mercury is low, at 24 °C, an atmosphere that is fully saturated with mercury vapor contains approximately 18 mg/m^3. The levels attainable in indoor airs at room temperature can therefore greatly exceed safe levels and result in poisoning.]

Gas density: 6.9 (air = 1)

Water solubility: 0.006% at 77 °F (25 °C)

Flammability: Nonflammable

Incompatibilities

Elemental mercury reacts vigorously with ground mixtures of sodium carbide, aluminum, lead, or iron. A violent exothermic reaction, possibly an explosion, occurs when mercury comes in contact with chlorine dioxide, lithium, or rubidium. It also reacts with acetylenic compounds, ammonia, azides, boron diiodophosphide, ethylene oxide, methyl azide, methylsilane, oxygen, oxidants, and tetracarbonylnickel. Pure dry ammonia and mercury do not react even under pressure and heat, but if water is present, a compound forms that can explode during depressurization. Heating mercury vapor produces mercuric oxide, which is highly irritating to mucous membranes and more likely than elemental mercury vapor to cause chemical pneumonitis.

Health Effects

- **The major route of exposure to elemental mercury is inhalation of mercury vapor. Symptoms of acute toxicity following high-level exposure to mercury vapor occur within hours of the exposure.**

- **Respiratory symptoms include corrosive bronchitis with fever chills and dyspnea, which can progress to pulmonary edema or fibrosis. Abdominal cramps, diarrhea, renal dysfunction, visual disturbances, and central nervous system damage leading to neuropsychiatric disturbances and intention tremors may also occur.**

- **Mercury can cross the blood-brain and placental barriers. It is also excreted in breast milk. Children may be at increased risk for pulmonary toxicity and are more likely to develop respiratory failure.**

Acute Exposure

Many acute health effects are associated with exposure to high levels of elemental mercury vapor. Respiratory symptoms may predominate (cough, sore throat, shortness of breath). Gastrointestinal effects are frequent in the initial set of symptoms (metallic taste, nausea, vomiting, diarrhea, abdominal pain) as are CNS effects such as headache, weakness, and visual disturbances. Several days after the initial exposure, symptoms are more similar to those that develop following inorganic mercury poisoning, including ptyalism (heavy salivation), enteritis, and renal damage; there can also be chronic CNS effects, which develop as a result of the ability of absorbed elemental mercury to cross the blood-brain barrier.

Children do not always respond to chemicals in the same way that adults do. Different protocols for managing their care may be needed.

Respiratory

Acute exposure to high levels of elemental mercury vapor can cause chemical pneumonitis. Within a few hours of exposure, dyspnea, chest pain, and dry cough develop, often associated with fever, chills, and headache. Symptoms might resolve or gradually progress to pulmonary edema, respiratory failure, and death.

The acute mercury-induced lung damage usually resolves completely, but some cases of diffuse pulmonary fibrosis, restrictive lung disease, and chronic respiratory insufficiency have been reported. At autopsy, microscopic examination of lung tissue reveals interstitial pneumonitis, necrotizing bronchitis, bronchiolitis, and atelectasis.

Children may be more vulnerable to gas exposure because of relatively increased minute ventilation per kg and failure to evacuate an area promptly when exposed.

Renal

Acute high-dose inhalation of elemental mercury vapor has been associated with proteinuria, nephrotic syndrome, temporary tubular dysfunction, acute tubular necrosis, and oliguric renal failure.

Cardiovascular

Acute inhalation of high levels of elemental mercury vapor can cause tachycardia and hypertension. In children, tachycardia associated with the inhalation of elemental mercury vapor might be related to a non-allergenic hypersensitivity reaction to mercury.

Gastrointestinal

A metallic taste, salivation, dysphagia, abdominal cramps, diarrhea, and nausea have been reported following inhalation of large amounts of elemental mercury vapor. Oral and dermal exposures to elemental mercury are not normally associated with GI symptoms.

Dermal

Dermal reactions associated with dermal contact with liquid elemental mercury or the vapor are rare. Acrodynia (or pink disease) is associated with hypersensitivity to mercury absorbed from vapor inhalation or dermal exposure. Symptoms of acrodynia include abnormal redness of the skin, followed by peeling of skin on the hands, nose, and soles of the feet.

CNS

Acute inhalation of mercury vapor may produce CNS effects such as headache, weakness, and visual disturbances.

Potential Sequelae

Respiratory effects from high-dose acute exposures might resolve or gradually progress to adult respiratory distress syndrome (ARDS), respiratory failure, and death. Patients with severe pulmonary toxicity can develop interstitial fibrosis and residual restrictive pulmonary disease. Other sequelae of exposure to elemental mercury include effects on the CNS and kidneys. These can occur after high-dose acute inhalation exposure and are similar to the effects observed following chronic lower-dose exposures (see below).

Chronic Exposure

Repeated or continuous exposure to elemental mercury can result in accumulation of mercury in the body and permanent damage to the nervous system and kidneys. Classic symptoms of poisoning include neuropsychiatric effects, renal impairment, and oropharyngeal inflammation. The neuropsychiatric effects include tremor, anxiety, emotional lability, forgetfulness,

insomnia, anorexia, erethism (abnormal irritation, sensitivity, or excitement), fatigue, and cognitive and motor dysfunction.

Although less common, neuromuscular changes (weakness, muscle atrophy, and muscle twitching) and polyneuropathy (paresthesias, stocking-glove sensory loss, hyperactive tendon reflexes, slowed sensory and motor nerve conduction velocities) have also been reported.

A delayed idiosyncratic non-allergic hypersensitivity to mercury called acrodynia (pink disease) is sometimes seen in children chronically exposed to mercury vapor; in some cases, it occurs when exposure lasts for only a few days. Symptoms include irritability, sleeplessness, sweating, severe leg cramps, and a painful peeling rash.

Chronic exposure may be more serious for children because of their potential longer latency period.

Carcinogenicity

The Department of Health and Human Services (DHHS), the International Agency for Research on Cancer (IARC), and the Environmental Protection Agency (EPA) have not had sufficient evidence to classify elemental mercury as a carcinogen or a noncarcinogen.

Reproductive and Developmental Effects

Elemental mercury is not included in *Reproductive and Developmental Toxicants*, a 1991 report published by the U.S. General Accounting Office (GAO) that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences.

Chronic inhalation of elemental mercury vapor has not been shown to have any effect on spermatozoa in men. An increased incidence of spontaneous abortion among the wives of men chronically exposed to elemental mercury has been reported.

In female workers, menstrual disorders (dysmenorrhea) have been associated with chronic exposure to high concentrations of mercury vapor. At high levels, inhaled elemental mercury is able to cross the placental barrier, but fetotoxic or significant developmental effects have not been well studied in humans. Adverse developmental effects have been observed in animals but not humans.

Prehospital Management

- **Victims exposed to mercury vapor do not pose secondary contamination risks to rescuers. Rescuers may treat urgently ill patients without concern about acute secondary contamination to themselves or their equipment.**

- **Victims whose skin or clothing is visibly contaminated with liquid mercury can contaminate rescuers' equipment, clothing, or the indoor environment. Contamination of clothing or equipment can result in a subsequent chronic inhalation hazard to others as the elemental liquid mercury off-gasses.**

- **Symptoms of acute exposure to elemental mercury vapor inhalation occur within hours of the exposure and consist of cough, chills, fever, and shortness of breath. Symptoms might resolve or gradually progress to a chemical pneumonitis, adult respiratory distress syndrome (ARDS), respiratory failure, and renal failure. Inhalation of mercury vapor can also cause nausea, vomiting, diarrhea, renal dysfunction, visual disturbances, and CNS damage.**

- **Treatment of acute mercury exposure generally consists of removal of the patient from further exposure followed by support of respiratory and cardiovascular function. There is no antidote for mercury, but chelation therapy is warranted in some cases.**

Hot Zone

Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if the rescuers have not been trained in its use, call for assistance from a local or regional HAZMAT team or other properly equipped response organization.

Rescuer Protection

Elemental mercury vapor can be highly toxic if inhaled and can cause a life-threatening chemical pneumonitis and respiratory failure. Both the liquid and vapor forms of elemental mercury are poorly absorbed through the skin. Heating mercury vapor produces mercuric oxide, which is highly irritating to mucous membranes and more likely than elemental mercury vapor to cause chemical pneumonitis. Mercury clean-up kits are available which can remove the liquid without spreading contamination.

Respiratory protection: Positive-pressure, self-contained breathing apparatus (SCBA) is recommended in response situations that involve exposure to potentially unsafe levels of elemental mercury.

Skin protection: No special clothing is needed unless mercury vapor is being heated; in that case chemical protective clothing is recommended to avoid contamination. However, gloves and

foot protection are recommended as mercury spreads under nails etc., very easily. Any clothing that comes in contact with liquid mercury should be properly decontaminated or disposed of to prevent the possibility of subsequent chronic exposure to off-gassed mercury vapor.

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. If trauma is suspected, maintain manually and apply a cervical collar and a backboard when feasible.

Victim Removal

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be removed on backboards or gurneys; if these are not available, carefully carry or drag victims to safety.

Consider appropriate management of chemically contaminated children, such as measures to reduce separation anxiety if a child is separated from a parent or other adult.

Decontamination Zone

Victims exposed only to mercury vapor who have no skin or eye irritation may be transferred immediately to the Support Zone. Other patients will require decontamination as described below.

Rescuer Protection

If exposure levels are determined to be safe, decontamination may be conducted by personnel wearing a lower level of protection than that worn in the Hot Zone (described above).

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. Stabilize the cervical spine with a collar and a backboard if trauma is suspected. Administer supplemental oxygen as required. Assist ventilation with a bag-valve-mask device if necessary.

Basic Decontamination

Victims who are able may assist with their own decontamination. Remove and double-bag contaminated clothing and all personal belongings.

Wash exposed skin and hair with mild soap and water (preferably under a shower). Rinse thoroughly with water. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Flush exposed or irritated eyes with plain water or saline for at least 5 minutes. Remove contact lenses if easily removable without additional trauma to the eye. If pain or injury is evident, continue irrigation while transferring the victim to the Support Zone.

In cases of ingestion, **do not induce emesis**. Elemental mercury is not readily absorbed from the gastrointestinal tract and generally does not produce acute toxicity from this route of exposure. Activated charcoal is not effective for ingested mercury exposure.

Consider appropriate management of chemically contaminated children, such as measures to reduce separation anxiety if a child is separated from a parent or other adult. If possible, seek assistance from a child separation expert.

Transfer to Support Zone

As soon as basic decontamination is complete, move the victim to the Support Zone.

Support Zone

Rescuers may treat urgently ill patients without concern about acute secondary contamination to themselves or their equipment. However, rescuer clothing or equipment that has been contaminated with liquid mercury can cause chronic exposures to rescuers from off-gassed mercury vapor. Be certain that victims have been decontaminated properly (see *Decontamination Zone* above) and that any rescuer equipment or clothing that has been contaminated with liquid mercury is properly decontaminated or disposed of. Victims who have undergone decontamination or have been exposed only to vapor pose no serious risks of secondary contamination. In such cases, Support Zone personnel require no specialized gear.

ABC Reminders

Quickly access for a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Ensure adequate respiration and pulse. Administer supplemental oxygen as required and establish intravenous access if necessary. Place on a cardiac monitor.

Additional Decontamination

Continue irrigating exposed skin and eyes, as appropriate.

In cases of ingestion, **do not induce emesis**. Elemental mercury is not usually absorbed from the gastrointestinal tract and does not produce acute toxicity from this route of exposure. Activated charcoal is not effective.

Advanced Treatment

In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, perform cricothyroidotomy if equipped and trained to do so.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in

situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Mercury poisoning is not known to pose additional risk during the use of bronchial or cardiac sensitizing agents and sympathomimetic bronchodilators may reverse bronchospasm in patients exposed to mercury.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Patients who are comatose, hypotensive, or have seizures or cardiac arrhythmias should be treated according to advanced life support (ALS) protocols.

Transport to Medical Facility

Only decontaminated patients or patients not requiring decontamination should be transported to a medical facility. “Body bags” are not recommended.

Report to the base station and the receiving medical facility the condition of the patient, treatment given, and estimated time of arrival at the medical facility.

If elemental mercury has been ingested, prepare the ambulance in case the patient vomits. The vomit might contain elemental mercury that can contaminate the transport vehicle. Have a suction apparatus ready and prepare several towels and double-sealable plastic bags to quickly clean up and isolate vomitus.

Only a professional mercury clean-up kit with a self-contained vacuum system should be used to decontaminate the transport vehicle. Ordinary vacuum cleaners can vaporize elemental mercury and increase the concentration of airborne mercury.

Multi-Casualty Triage

Consult with the base station physician or the regional poison control center for advice regarding triage of multiple victims.

Patients with evidence of significant inhalation exposure such as cough, shortness of breath, nausea, or headache and patients who have ingested large amounts of elemental mercury should

be transported to a medical facility for evaluation. Asymptomatic patients who have not had a significant exposure and show no evidence of respiratory-tract irritation may be discharged from the scene after their names, addresses, and telephone numbers are recorded. Those discharged should be advised to seek medical care promptly if symptoms develop (see *Patient Information Sheet* below).

Emergency Department Management

- **Victims exposed to mercury vapor do not pose secondary contamination risks to rescuers. Victims whose skin or clothing is visibly contaminated with liquid mercury can contaminate equipment, clothing, or the indoor environment by translocation of the liquid, but do not pose a risk of acute secondary exposure for hospital personnel.**

- **Contaminated clothing or equipment will subsequently pose a chronic inhalation hazard to others as the elemental liquid mercury off-gasses. Victims do not pose risks of secondary contamination after their clothing is removed, the mercury is contained, and their skin is washed.**

- **Symptoms of acute inhalation exposure to elemental mercury vapor occur within hours of the exposure and consist of coughs, chills, fever, and shortness of breath. Symptoms might resolve or gradually progress to a chemical pneumonitis, adult respiratory distress syndrome (ARDS), respiratory failure, renal failure, nausea, vomiting, and diarrhea. Exposure may also result in visual disturbances and CNS damage.**

- **There is no antidote for mercury. Treatment consists of cessation of exposure, supportive care, and timely chelation therapy when warranted.**

Decontamination Area

Previously decontaminated patients and patients exposed only to mercury vapor who have no skin or eye irritation may be transferred immediately to the Critical Care Area. Others require decontamination as described below.

Be aware that use of protective equipment by the provider may cause fear in children, resulting in decreased compliance with further management efforts.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants absorbed through the skin. Also emergency room personnel should examine children's mouths because of the frequency of hand-to-mouth activity among children.

ABC Reminders

Evaluate and support airway, breathing, and circulation. In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, surgically create an airway.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing

which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Mercury poisoning is not known to pose additional risk during the use of bronchial or cardiac sensitizing agents. Sympathomimetic bronchodilators may reverse bronchospasm in patients exposed to mercury vapor.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Patients who are comatose, hypotensive, or have seizures or ventricular arrhythmias should be treated in the conventional manner.

Basic Decontamination

Patients who are able may assist with their own decontamination. Remove and double-bag contaminated clothing and personal belongings.

Wash exposed skin and hair with mild soap and water (preferably under a shower). Rinse thoroughly with water. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Flush exposed or irritated eyes with plain water or saline for at least 5 minutes. Remove contact lenses if easily removable without additional trauma to the eye. If pain or injury is evident, continue irrigation while transferring the victim to the Critical Care Area.

In cases of ingestion, **do not induce emesis or give activated charcoal**. Elemental mercury is not usually absorbed from the gastrointestinal tract and is unlikely to cause any acute toxicity from this route of exposure. Decontamination is not necessary. However, if an individual with gastrointestinal perforation or fistula ingests an extremely large amount, the mercury might be retained for a long period in the GI tract and decontamination should be considered. Cathartic whole-bowel lavage (repeated once daily) or even surgical removal might be necessary at a later time depending on radiographic evidence of large pockets of mercury. In cases of large-volume ingestion, obtain an abdominal radiograph to document the location of the mercury, and explain to the patient the importance of follow-up. The patient should be referred to a primary-care or specialist physician for follow-up.

If elemental mercury has been ingested and the patient vomits, the vomitus might contain elemental mercury that can contaminate the emergency department. Have a suction apparatus ready and prepare several towels and double-sealable plastic bags to quickly clean up and isolate any mercury. If there is widespread contamination, only a professional mercury clean-up kit with a self-contained vacuum system should be used to decontaminate. Ordinary vacuum cleaners can vaporize elemental mercury and increase the concentration of airborne mercury.

Critical Care Area

Be certain that appropriate decontamination has been carried out (see *Decontamination Area* above).

ABC Reminders

Evaluate and support airway, breathing, and circulation as in *ABC Reminders* above. Establish intravenous access in seriously ill patients if this has not been done previously. Continuously monitor cardiac rhythm.

Patients who are comatose, hypotensive, or have seizures or cardiac arrhythmias should be treated in the conventional manner.

Fluids should be titrated to maintain acceptable urine output and blood pressure. Care must be taken not to overhydrate the patient.

Inhalation Exposure

Administer supplemental oxygen by mask to patients who have respiratory complaints. Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Mercury poisoning is not known to pose additional risk during the use of bronchial or cardiac sensitizing agents and sympathomimetic bronchodilators may reverse bronchospasm in patients exposed to mercury vapor.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Young children are particularly susceptible to the acute pulmonary effects of mercury vapor. Both adults and children are treated by respiratory support and in some cases, mechanical ventilation may be necessary.

Early dyspnea can indicate upper-airway obstruction from swelling, reflex bronchospasm, or direct pulmonary injury, which all require treatment. Patients require careful assessment for stridor, wheezing, and rales. Patients who have chemically induced adult respiratory distress syndrom (ARDS) do not usually benefit from digoxin, morphine, afterload reduction, or diuretics. Supplemental oxygen, delivered by mechanical ventilation and positive end-expiratory pressure, if needed, are standard treatments. Corticosteroids and antibiotics have been commonly recommended for treatment of chemical pneumonitis, but their effectiveness has not been substantiated.

Skin Exposure

Elemental mercury does not cause a chemical burn. Washing the exposed skin with soap and water should remove any residual liquid mercury.

Eye Exposure

Ensure that adequate eye irrigation has been completed. Test visual acuity. Examine the eyes for conjunctival or corneal damage and treat appropriately. Patients should be referred to an ophthalmologist when they have apparent or suspected corneal injury.

Ingestion Exposure

In cases of ingestion, **do not induce emesis or give activated charcoal**. Elemental mercury is not usually absorbed from the gastrointestinal tract and does not produce acute toxicity from this route of exposure. Decontamination is not necessary. However, if an individual with gastrointestinal perforation or fistula ingests an extremely large amount, the mercury might be retained for a long period in the GI tract and decontamination should be considered. Mercury is radiopaque and abdominal radiographs should be obtained in all cases of ingestion. Cathartic whole-bowel irrigation (with a polyethylene glycol [PEG-3350] electrolyte lavage solution, repeated once daily) or even surgical removal might be necessary depending on the radiographic evidence of the amount of mercury present.

Antidotes and Other Treatments

Chelation therapy should be considered for any patient with a clear history of acute elemental mercury exposure who is symptomatic. However, the decision to chelate for a particular patient should be made only by professionals experienced in the use of chelation, preferably in consultation with the regional poison control center.

Chelation therapy becomes less effective in reducing the severity of poisoning and the risk of sequelae as time after exposure increases. Since timely administration of the chelating agent is essential for its efficacy, when treating significantly symptomatic patients, it might be necessary to administer the chelating agent prior to laboratory confirmation of mercury overexposure. Do not chelate an asymptomatic patient without the guidance provided by blood and 24-hour urine mercury levels. There may be no apparent benefit in chelating patients with established neurotoxicity after chronic exposure.

The most frequently used agent for acute inorganic mercury exposures is dimercaprol (also known as BAL). BAL, however, has been found to increase brain mercury in mice exposed to short-chain organic mercury; such an increase could lead to increased neurotoxicity. The implications for the use of BAL in humans are unclear, and no information is available on the effects of BAL following exposure to inhaled elemental mercury. Since elemental mercury has toxicokinetic properties more similar to organic mercury than inorganic mercury, chelation with 2,3-dimercaptosuccinic acid (DMSA) should also be considered (see below).

The standard dosage regiment of BAL for inorganic mercury poisoning is 3 mg/kg IM every 4 hours for 2 days, and every 12 hours thereafter for 7 to 10 days or until 24-hour urinary excretion levels are less than 50 µg/L. Contraindications to BAL include concurrent use of medicinal iron (which can form a toxic complex with BAL), organic mercury poisoning, pre-existing renal impairment, and pregnancy (except in life-threatening circumstances). Patients often complain of pain at the injection site. Adverse effects are dose-related and may include: pain, a self-limited increase in heart rate and blood pressure; nausea; vomiting; headache; burning sensation of the lips, mouth, throat, and eyes; lacrimation; rhinorrhea; salivation; muscle aches; burning and tingling in the extremities; tooth pain, diaphoresis; chest pain; anxiety; and agitation. Dimercaprol must not be administered in patients with glucose-6-phosphate dehydrogenase deficiency, because it can produce hemolysis.

Oral agents such as 2,3-dimercaptosuccinic acid (DMSA) or D-penicillamine have been used as alternatives when dimercaprol toxicity or intolerance develops. DMSA has very few side effects and is approved for the treatment of pediatric lead poisoning in the United States. Although not currently an FDA-labeled indication, DMSA has been used to treat mercury poisoning and is undergoing further evaluation. DMSA might prove to be the treatment of choice for methylmercury because of its lower toxicity.

Other Treatments

Alkalization of the urine stabilizes the dimercaprol-metal complex, and has been recommended to protect the kidneys during chelation therapy. There is no role for hemodialysis in removing mercury. However, hemodialysis might be required for supportive therapy in the treatment of renal failure and it might enhance the removal of the dimercaprol-mercury complexes.

Laboratory Tests

The diagnosis of acute mercury toxicity is partly clinical, based on symptoms of respiratory distress. Laboratory evaluation of acute mercury poisoning should also include a complete blood count and differential, serum electrolytes, glucose, liver, and renal function tests, and urinalysis. Obtain hourly intake/output and urine pH in severely ill patients when renal perfusion is in question. Pulse oximetry might yield insufficient information to carefully monitor impending pneumonitis, ARDS, or respiratory failure. Chest radiography and serial ABG measurements are recommended for severe inhalation exposures.

Blood and urine mercury levels are useful to confirm exposure but there is no definite correlation between blood and urine mercury levels and degree of mercury toxicity. Blood mercury level confirms whether the exposure was recent, because the initial half-life for the elimination of blood mercury is 3 days. Urinary mercury levels indicate the total mercury body burden since mercury is largely excreted by the kidneys. The half-life of elimination for whole body mercury is 60 to 90 days. Urinary mercury levels are generally below 10 µg/L. Blood mercury levels are generally less than 40 µg/L and should not exceed 50 µg/L. Long-term exposure to mercury can be estimated from levels in hair.

If large-volume ingestion (more than the contents of a thermometer) is suspected, abdominal radiographs should be ordered to detect and follow the transit of any mercury (which is radiopaque) in the gastrointestinal tract. Neuropsychiatric testing, nerve conduction studies, and urine assays for N-acetyl-

B-D-glucosaminidase and β_2-microglobulin have been used to assess delayed and chronic nervous system and renal toxicity.

Disposition and Follow-up

Consider hospitalizing patients who have a suspected serious exposure and/or persistent or exhibit progressive respiratory symptoms.

Delayed Effects

Respiratory effects from high-dose exposures might resolve or gradually progress to ARDS, respiratory failure, and death. Infrequently, severe pulmonary effects can progress to interstitial fibrosis and residual restrictive pulmonary disease. Other potential sequelae of exposure to elemental mercury include effects on the kidneys and central nervous system. These effects can occur after high-dose acute exposure to mercury vapor, and are similar to the effects observed from chronic lower-dose exposures. **Children under 30 months of age are at increased risk for pulmonary toxicity and are more susceptible to death from respiratory failure**.

Patient Release

Exposed patients who are asymptomatic, but who might have been exposed to mercury vapors, can be discharged, but should be subsequently tested for blood or urine mercury levels and advised about potential delayed effects. Patients should be advised to seek medical attention promptly if symptoms develop (see the *Elemental Mercury—Patient Information Sheet* below).

Follow-up

Obtain the name of the patient's primary care physician so that the hospital can send a copy of the ED visit to the patient's doctor.

Follow-up laboratory evaluation of respiratory, gastrointestinal, renal and nervous-system status should be arranged for severely exposed patients.

Reporting

If a work-related incident has occurred, you may be legally required to file a report; contact your state or local health department.

Other persons may still be at risk in the setting where this incident occurred. If the incident occurred in the workplace, discussing it with company personnel may prevent future incidents. If a public health risk exists, notify your state or local health department or other responsible public agency. When appropriate, inform patients that they may request an evaluation of their workplace from OSHA or NIOSH. See Appendices III and IV for a list of agencies that may be of assistance.

Mercury (Hg)
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to elemental mercury.

What is elemental mercury?
Elemental mercury metal is a very heavy, shiny, silver-white, odorless liquid at room temperature. It is used to make many different kinds of products including electrical switches, batteries, and medical devices such as thermometers. It is used in industry to manufacture chlorine and process gold ore. The body does not readily absorb liquid mercury through the skin or stomach. However, the liquid evaporates at room temperature, especially when heated. If inhaled, mercury vapors can be highly toxic.

What immediate health effects can be caused by exposure to elemental mercury?
Inhaling high concentrations of mercury vapor can cause a cough, chills, fever, and shortness of breath, and sometimes nausea, vomiting, and diarrhea. These symptoms do not usually develop immediately: they might appear a few hours after exposure. Symptoms might resolve or gradually progress to cause serious damage to the lungs and kidneys. Unintentional swallowing of liquid mercury usually causes no health effects.

Can elemental mercury poisoning be treated?
Typically, low-level exposure to elemental mercury leads to no lasting health effects and treatment is not needed. Severely affected individuals must be hospitalized.

Are any future health effects likely to occur?
A single small exposure from which a person recovers quickly is not likely to cause delayed or long-term effects. After a serious exposure, damage to the lungs, kidneys, and central nervous system might occur.

What tests can be done if a person has been exposed to elemental mercury?
Specific tests for the presence of mercury in blood and urine can be useful to assess the level of exposure. If a severe exposure has occurred, x-rays and blood and urine tests might show whether or not the lungs and kidneys have been damaged. Testing is not needed in every case.

Where can more information about elemental mercury be found?
If the exposure happened at work, you might be required to contact your employer and the Occupational Safety and Health Administration (OSHA). Employees may request a Health Hazard Evaluation from the National Institute for Occupational Safety and Health (NIOSH).

You can obtain more information about mercury from your regional poison control center; your state, county, or local health department; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in occupational and environmental health. Ask the person who gave you this form for help in locating these telephone numbers.

Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow *only* the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:

- coughing, wheezing, chest tightness, or shortness of breath
- excessive saliva (spit)
- decreased urine or change in color

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.
[ ] Call for an appointment with Dr. _____ in the practice of _____.
When you call for your appointment, please say that you were treated in the Emergency Department at _ _____ Hospital by _____ and were advised to be seen again in _____ days.
[ ] Return to the Emergency Department/ _____ Clinic on (date) _____at ___ _____ AM/PM for a follow-up examination.
[ ] Do not perform vigorous physical activities for 1 to 2 days.
[ ] You may resume everyday activities including driving and operating machinery.
[ ] Do not return to work for _____ days.
[ ] You may return to work on a limited basis. See instructions below.
[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.
[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.
[ ] Avoid taking the following medications: _____
[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: __
_____
_____
[ ] Other instructions: _____
_____
_____

- Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.

- You or your physician can get more information on the chemical by contacting: _____ _____ or _____, or by checking out the following Internet Web sites: _____; _____.

Signature of patient _____ Date _____

Signature of physician _____ Date _____

Ethylene Glycol ($C_2H_6O_2$)
CAS 107-21-1

Synonyms include 1,2-dihydroxyethane, 1,2-ethanediol, 2-hydroxyethanol, ethylene alcohol, glycol, glycol alcohol, monoethylene glycol, and ethylene dihydrate. Ethylene glycol is sold under a variety of brand names as automobile radiator antifreeze. It should not be confused with ethylene glycol ethers, which are a different group of chemicals.

- **Persons exposed to ethylene glycol do not pose a significant risk of secondary contamination to response personnel outside the Hot Zone.**
- **Ethylene glycol is a clear, odorless, slightly viscous liquid. It is combustible and has a low vapor pressure. Odor does not provide any warning of hazardous concentrations.**
- **Ingestion is the most important exposure route. Dermal absorption is negligible and does not contribute significantly to systemic toxicity.**
- **Significant inhalation exposure does not occur at room temperature, but respiratory tract irritation is possible when the liquid is heated, agitated, or sprayed.**

Description

Ethylene glycol is a clear, odorless, slightly viscous liquid with a sweet taste. It is combustible and has a low vapor pressure. Ethylene glycol is a very useful industrial compound because of its low freezing point and high boiling point. It is widely available as automotive antifreeze; in that application, it is often mixed with a yellow-green fluorescent.

Routes of Exposure

Inhalation

Toxic inhalation of ethylene glycol is unlikely at room temperature because of the chemical's low volatility, but can occur when the liquid is heated, agitated, or sprayed. Ethylene glycol is odorless and thus, **odor does not provide any warning of hazardous concentrations**. Ethylene glycol vapor is lighter than air.

Children exposed to the same levels of ethylene glycol as adults may receive larger doses because they have greater lung surface area:body weight ratios and increased minute volumes:weight ratios.

Skin/Eye Contact

Ethylene glycol is only mildly irritating to mucous membranes or skin and is slowly and poorly absorbed through the skin.

Ingestion

Ethylene glycol is rapidly absorbed following ingestion, which is the predominant route of exposure. Ingestion of ethylene glycol leads to systemic toxicity beginning with CNS effects, followed by cardiopulmonary effects, and finally renal failure.

Sources/ Uses

Ethylene glycol is produced commercially in large amounts and widely used as an antifreeze and de-icer. It is also used in chemical synthesis, including synthesis of plastics, films, and solvents. Ethylene glycol can be found in many consumer products, including automotive antifreeze, hydraulic brake fluids, inks used in some stamp pads, ballpoint pens, solvents, paints, plastics, and solar energy systems.

Standards and Guidelines

ACGIH ceiling limit = 100 mg/m^3 (39 ppm)

Physical Properties

Description: odorless, colorless, slightly viscous, sweet-tasting liquid. Many antifreeze products also contain yellow-green fluorescent dyes and a bitter taste to reduce the chances of accidental ingestion.

Warning properties: **odor is inadequate to protect against acute inhalation exposure**

Molecular weight: 62.07 daltons

Boiling point: (760 mm HG): 387 °F (198 °C)

Freezing point: 8.6 °F (-13 °C)

Specific gravity: 1.11 at 68 °F (20 °C) (water = 1)

Vapor pressure: 0.06 mm Hg at 68 °F (20 °C)

Gas density: 0.092 (air = 1)

Water solubility: miscible with water; can absorb twice its weight of water

Flammability: 232 ° F (111 °C)

Flammable range: 3.2% to 21.6% (concentration in air)

Incompatibilities

Ethylene glycol reacts with strong oxidizers and acids, including chromium trioxide, potassium permanganate, sodium peroxide, potassium dichromate, chlorosulfonic acid, sulfuric acid, perchloric acid, and diphosphorous pentasulfide.

Health Effects

- **Ethylene glycol is only mildly irritating to skin and mucous membranes and is not absorbed well through the skin or by inhalation.**
- **Ingestion of ethylene glycol produces CNS depression which may be accompanied by nausea, vomiting, and abdominal cramps.**
- **Metabolites of ethylene glycol produce severe metabolic acidosis and damage to the brain, heart, and kidneys.**
- **Severe poisoning is potentially fatal if treatment is inadequate or delayed.**

Acute Exposure

Ethylene glycol is a dehydrating agent and is mildly irritating to the skin and mucous membranes after prolonged contact.

Upon ingestion, it is rapidly absorbed (within 1 to 4 hours). Less than 20% is excreted unmetabolized; most is successively metabolized to very toxic compounds. A characteristic progression of toxic effects can be roughly divided into three stages, although overlap is possible:

Stage 1: From 30 minutes to 12 hours after exposure, unmetabolized ethylene glycol produces CNS depression, intoxication, and hyperosmolarity similar to that produced by ethanol.

Stage 2: From 12 to 48 hours, metabolites produce severe acidosis with compensatory hyperventilation. The acidosis is primarily the result of an increase in glycolic acid, although glyoxylic, oxalic, and lactic acids also contribute in small part. Calcium oxalate crystals are deposited in the brain, lungs, kidneys, and heart.

Stage 3: From 24 to 72 hours, the direct toxic effects of ethylene glycol metabolites in the kidneys can cause acute renal failure.

Children do not always respond to chemicals in the same way that adults do. Different protocols for managing their care may be needed.

CNS

Unmetabolized ethylene glycol can produce an ethanol-like intoxication. Symptoms include dizziness, ataxia, disorientation, irritation, restlessness, nystagmus, headache, slurred speech, and somnolence. Severe poisoning can lead to coma and death.

Cerebral edema and deposits of calcium oxalate crystals in the walls of small blood vessels contribute to the CNS toxicity.

Renal

Kidney toxicity is a major consequence of ethylene glycol absorption. Acute cell death (i.e., tubular necrosis) and kidney failure can occur within 24 to 28 hours as a result of the direct cytotoxic action of oxalic, glyoxylic, and glycolic acids or due to precipitation of calcium oxalate crystals in the renal tubules. Focal tubular degeneration, atrophy, and tubular interstitial inflammation have also been observed. Renal damage, if untreated, can lead to acute oliguric renal failure and can necessitate long-term hemodialysis. The resulting hyperkalemia can cause life-threatening cardiac dysrhythmias.

Metabolic

An osmolar gap can be present early after ingestion; this represents unmetabolized ethylene glycol. It will resolve as metabolism proceeds. A severe metabolic acidosis with elevated anion gap develops as metabolism to glycolic, glyoxylic, and oxalic acids occurs. Large quantities of sodium bicarbonate can be administered without affecting the acidosis because of the ongoing generation of acid metabolites. However, over zealous alkanization could cause ionized calcium deficits. Hypocalcemia and tetany can occur as a result of calcium oxalate deposition.

Respiratory

Very high levels of inhaled ethylene glycol vapors can irritate the upper respiratory tract. Levels higher than 80 ppm produce intolerable respiratory discomfort and cough. Ethylene glycol's CNS effects can cause respiratory depression, and metabolic acidosis can result in hyperventilation and respiratory alkalosis. Aspiration of ethylene glycol following ingestion can result in pulmonary edema.

Children may be more vulnerable to gas exposure because of relatively increased minute ventilation per kg and failure to evacuate an area promptly when exposed.

Cardiovascular

Cardiovascular effects include tachycardia, dysrhythmias, congestive heart failure, hypertension or hypotension, and circulatory collapse. Hyperkalemia resulting from kidney toxicity can cause life-threatening cardiac dysrhythmias.

Gastrointestinal

Nausea and vomiting can be present in the initial stage of intoxication.

Dermal

Ethylene glycol is a minor skin irritant, although a few cases of allergic contact dermatitis have been reported.

Ocular

Mild ocular irritation may occur after contact with ethylene glycol.

Potential Sequelae

Renal failure can occur 24 to 72 hours after an acute ingestion and can necessitate hemodialysis. Some loss of renal function can be permanent. There are infrequent reports of cranial nerve palsies (e.g., facial palsy, hearing loss, visual disturbances) or peripheral neuropathy one or more weeks after an acute poisoning.

Chronic Exposure

There are only a few reports on the adverse health effects in humans of chronic exposure to ethylene glycol. Irritation of the throat, mild headache, low backache, loss of consciousness, and nystagmus have been reported. These symptoms were resolved when the exposure ceased.

Carcinogenicity

The U.S. Department of Health and Human Services (DHHS), the International Agency for Research on Cancer (IARC) and EPA have not classified ethylene glycol in terms of its carcinogenic potential. Studies in humans and animals have not yielded any associations between ethylene glycol exposure and the incidence of any cancer.

Reproductive and Developmental Effects

Ethylene glycol is not included in *Reproductive and Developmental Toxicants*, a 1991 report published by the U.S. General Accounting Office (GAO) that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences. Some experimental animal studies of exposure to glycols have shown teratogenicity, specifically craniofacial and neural tube closure defects and skeletal dysplasia. Human effects are not known or documented.

Prehospital Management

- **Persons exposed to ethylene glycol liquid or vapor do not pose significant risks of secondary contamination to rescuers.**
- **Ethylene glycol is a CNS depressant, similar to ethanol. Its metabolites are toxic and cause profound metabolic acidosis, cerebral edema, cardiovascular collapse, acute renal failure, and possibly death.**
- **Timely treatment is effective and consists of supportive care, hemodialysis, and administration of a specific antidote.**

Hot Zone

Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if the rescuers have not been trained in its use, call for assistance from a local or regional HAZMAT team or other properly equipped response organization.

Rescuer Protection

Ethylene glycol is a mild respiratory tract irritant. It is not well absorbed through the lungs or skin.

Respiratory protection: Respirable concentrations of ethylene glycol are significant only when the liquid is heated (e.g., during a fire) or aerosolized. Positive-pressure, self-contained breathing apparatus (SCBA) is recommended under these circumstances.

Skin protection: Chemical-protective clothing is generally not required because ethylene glycol (whether vapor or liquid) is only a minor skin irritant and is absorbed poorly and slowly through the skin.

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible.

Victim Removal

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be removed on backboards or gurneys. If these are not available, carefully carry or drag victims to safety.

Consider appropriate management of chemically contaminated children, such as measures to reduce separation anxiety if a child is separated from a parent or other adult.

Decontamination Zone

Victims exposed only to ethylene glycol vapor who have no skin or eye irritation do not need to undergo decontamination. These individuals may be transferred immediately to the Support Zone. Others can undergo decontamination, but even severely exposed victims need only external decontamination (see *Basic Decontamination* below) because ingestion is the major toxic exposure route.

Rescuer Protection

Ethylene glycol acts as a systemic toxicant only when ingested. Rescuers need not take any special precautions.

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. Stabilize the cervical spine with a collar and a backboard if trauma is suspected. Administer supplemental oxygen as required. Assist ventilation with a bag-valve-mask device if necessary.

Basic Decontamination

Victims who are able may assist with their own decontamination. Quickly remove and double-bag contaminated clothing and personal belongings.

Wash exposed skin and hair with mild soap and water (preferably under a shower). Rinse thoroughly with water. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Irrigate exposed eyes with plain water or saline for at least 15 minutes. Remove contact lenses if easily removable without additional trauma to the eye. If pain or injury is evident, continue irrigation while transferring the victim to the Support Zone.

In cases of recent ingestion (less than one hour), in an alert, awake patient, emesis may be induced with ipecac. For other patients, perform gastric lavage. **Early treatment is important to reduce absorption of ethylene glycol and subsequent production of highly toxic metabolites.** Activated charcoal absorbs ethylene glycol poorly, but may be of use if there is suspicion of multiple chemical ingestion. Administer activated charcoal at 1 gm/kg (usual adult dose 60–90 g, child dose 25–50 g).

Consider appropriate management of chemically contaminated children at the exposure site. Also, provide reassurance to the child during decontamination, especially if separation from a parent occurs. If possible, seek assistance from a child separation expert.

Transfer to Support Zone

As soon as basic decontamination is complete, move the victim to the Support Zone.

Support Zone

Victims pose no serious risk of secondary contamination to rescuers. Therefore, Support Zone personnel require no specialized protective gear.

ABC Reminders

Quickly access for a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Ensure adequate respiration and pulse. Administer supplemental oxygen as required and establish intravenous access if necessary. Place on a cardiac monitor.

Additional Decontamination

Continue irrigating exposed skin and eyes, as appropriate.

In cases of recent ingestion (less than one hour), in an alert, awake patient, emesis may be induced with ipecac. For other patients, perform gastric lavage (if the patient has not already undergone gastric lavage in the Decontamination Zone). **Early treatment is important to reduce absorption of ethylene glycol and subsequent production of highly toxic metabolites.** Activated charcoal absorbs ethylene glycol poorly, but may be of use if there is suspicion of multiple chemical ingestion. Administer activated charcoal at 1 gm/kg (usual adult dose 60–90 g, child dose 25–50 g).

Advanced Treatment

In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, perform cricothyroidotomy if equipped and trained to do so.

Patients who are comatose, hypotensive, or are having seizures or cardiac arrhythmias should be treated according to advanced life support (ALS) protocols.

A pH of less than 7.0 and a serum bicarbonate of less than 7 mmol/L are common with severe ethylene glycol intoxication. Treatment of this metabolic acidosis may be difficult. Liberal use of sodium bicarbonate solution is appropriate to correct the acidemia.

Transport to Medical Facility

Only decontaminated patients or patients not requiring decontamination should be transported to a medical facility. “Body bags” are not recommended.

Report to the base station and the receiving medical facility the condition of the patient, treatment given, and estimated time of arrival at the medical facility.

Vomit containing ethylene glycol requires no chemical safety precautions since there is little exposure potential or risk of secondary contamination.

Multi-Casualty Triage

Consult with the base station physician or the regional poison control center for advice regarding triage of multiple victims.

Patients with evidence suggesting ingestion of ethylene glycol should be rapidly transported to a medical facility for evaluation. All patients who have ingested more than a taste or sip of ethylene glycol, even if asymptomatic, should be evaluated in a hospital where appropriate laboratory studies can be carried out. Delays in treatment can result in more severe toxicity and potentially irreversible damage to major organ systems.

Patients with a history suggesting insignificant exposure and who have no symptoms of ethylene glycol toxicity may be discharged from the scene after their names, addresses, and telephone numbers have been recorded. Those discharged should be advised to seek medical care promptly if symptoms develop (see *Patient Information Sheet* below).

Emergency Department Management

- **Patients exposed to ethylene glycol liquid or vapor pose no risk of secondary contamination to hospital personnel.**
- **Ethylene glycol is only mildly irritating to skin and mucous membranes and is not absorbed well through the skin or by inhalation.**
- **Ingestion of ethylene glycol causes CNS depression. If the patient is not treated, ethylene glycol's metabolites can cause acidosis, hyperventilation, and renal failure requiring hemodialysis.**
- **Timely treatment is effective and consists of supportive care, hemodialysis, and administration of a metabolic antidote such as ethanol or 4-methylpyrazole (fomepizole).**

Decontamination Area

Patients exposed to ethylene glycol do not require extensive decontamination. Remove contaminated clothing and personal belongings.

Be aware that use of protective equipment by the provider may cause fear in children, resulting in decreased compliance with further management efforts.

Emergency room personnel should examine children's mouths because of the frequency of hand-to-mouth activity among children.

ABC Reminders

Evaluate and support airway, breathing, and circulation. In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, surgically create an airway.

Patients who are comatose, hypotensive, or have seizures or ventricular dysrhythmias should be treated in the conventional manner.

A pH of less than 7.0 and a serum bicarbonate of less than 7 mmol/L are common with severe ethylene glycol intoxication. Treatment of this metabolic acidosis may be difficult. Liberal use of sodium bicarbonate solution is appropriate to correct the acidemia.

Basic Decontamination

Patients who are able may assist with their own decontamination. Remove and double-bag contaminated clothing and personal belongings.

Wash exposed skin and hair with mild soap and water (preferably under a shower). Rinse thoroughly with water. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Flush exposed or irritated eyes with plain water or saline for at least 15 minutes. Remove contact lenses if easily removable without additional trauma to the eye. If pain or injury is evident, continue irrigation while transferring the victim to the Critical Care Area.

In cases of substantial recent ingestion (less than 1 hour), where the patient is alert and awake, emesis can be induced with ipecac. In unconscious or symptomatic patients, consider gastric lavage if it can be administered within 1 hour of ingestion. Activated charcoal absorbs ethylene glycol poorly, but may be of use if there is suspicion of ingestion of multiple chemicals. Administer activated charcoal at 1 gm/kg (usual adult dose 60–90 g, child dose 25–50 g). Ethylene glycol is rapidly absorbed and little benefit is expected from these procedures if more than an hour has elapsed. Early antidotal treatment with ethanol or 4-methylpyrazole to prevent formation of toxic metabolites is the most effective intervention. (More information is provided in *Antidotes and Other Treatments* under *Critical Care Area* below)

Critical Care Area

ABC Reminders

Evaluate and support the airway, breathing, and circulation as in *ABC Reminders* above. Establish intravenous access in seriously ill patients if this has not been done previously. Continuously monitor cardiac rhythm.

Patients who are comatose, hypotensive, or have seizures or cardiac arrhythmias should be treated in the conventional manner.

A pH of less than 7.0 and a serum bicarbonate of less than 7 mL/dL are common with severe ethylene glycol intoxication. Treatment of this metabolic acidosis may be difficult. Liberal use of sodium bicarbonate solution is appropriate to correct the acidemia.

Inhalation Exposure

Administer supplemental oxygen by mask to patients who have respiratory complaints.

Skin Exposure

In most cases, no further treatment is needed after washing. If irritation or allergic contact dermatitis occurs, treatment with emollient creams, antihistamines, or topical steroids might be indicated.

Eye Exposure

Ensure that adequate eye irrigation has been completed. Test visual acuity. Examine the eyes for conjunctival or corneal damage and treat appropriately. Immediately consult an ophthalmologist for patients with suspected severe corneal injuries.

Ingestion Exposure

In cases of substantial recent ingestion where the patient is alert and awake, emesis can be induced with ipecac. In unconscious or symptomatic patients, consider gastric lavage if it can be administered within 1 hour of ingestion. Activated charcoal absorbs ethylene glycol poorly, but may be of use if there is suspicion of ingestion of multiple chemicals. Administer activated charcoal at 1 gm/kg (usual adult dose 60–90 g, child dose 25–50 g)

Antidotes and Other Treatments

Contact a medical toxicologist or a regional poison control center for assistance in evaluating the anion and osmolar gaps, and to decide whether antidotal therapy, intravenous sodium bicarbonate, or hemodialysis is needed.

In severe poisoning by ingestion, prompt administration of ethanol or another blocking agent (e.g., 4-methylpryrazole) prevents further metabolism of ethylene glycol. Rapid treatment with a blocking agent is very important; do not wait for symptoms to appear before treatment. Time elapsed between ingestion and treatment and the dose ingested are major factors of fatality.

Administration of thiamine and pyridoxine may aid metabolism of ethylene glycol to nontoxic products, but these compounds are less effective that ethanol or 4-methylpyrazole. Hemodialysis is indicated in cases of severe acidosis and/or renal dysfunction.

By competing with ethylene glycol as a substrate for alcohol dehydrogenase, ethanol inhibits the formation of toxic ethylene glycol metabolites. A medical toxicologist or the poison control center should be contacted to determine the proper dosage, which depends on many factors (e.g., age, degree of alcohol use by the victim, and effect on blood sugar). In general, the optimal

blood ethanol level is 100 to 150 mg/dL; this level should be attained quickly by administering 10% ethanol intravenously over 30 to 60 minutes.

Alternatively, ethanol can be administered orally with a 20% ethanol solution until a blood ethanol level of 100 to 150 mg/dL is reached. **Patients previously treated with ipecac/charcoal cannot tolerate oral loading.** The dosage must be adjusted if the patient is undergoing hemodialysis. Repeatedly monitor blood ethanol and glucose levels, as under dosing and overdosing of ethanol regularly occur; this can lead to hypoglycemia, especially in children.

An alternative to ethanol that also inhibits the action of alcohol dehydrogenase on ethylene glycol has recently become available in the United States. This drug, 4-methylpyrazole, has low toxicity and is easier to administer than ethanol. It is available as fomepizole (Antizol) in packages of 1.5 mL vials (concentration = 1 g/1 mL). Each vial is diluted to 100 mL with sodium chloride. Treatment consists of a 15-mg/kg loading dose followed in 12 hours by 10 mg/kg every 12 hours for four doses, then 15 mg/kg every 12 hours as long as indicated. Although fomepizole has been less widely used than ethanol, its use is rapidly increasing because of advantages over ethanol in terms of its predictable pharmacokinetics, ease of administration and lack of adverse effects.

Laboratory Tests

In all patients with known or suspected ethylene glycol poisoning, blood tests should be performed to measure blood glucose, serum electrolyte, calcium, BUN, creatinine, ethylene glycol, and ethanol levels. ABG levels and osmolarity should also be measured. These tests should be repeated as necessary to closely monitor the progression of toxic effects. Expected values depend on the time elapsed since the ingestion of ethylene glycol, so this must be considered in interpreting laboratory results.

Methanol levels should be measured in patients with elevated anion and osmolar gaps. Other conditions that can elevate anion and osmolar gaps include methanol poisoning and diabetic ketoacidosis.

Traditionally, a serum ethylene glycol level greater than 50 mg/dL has been associated with significant toxicity. Nevertheless, although the toxicokinetics are not well known, if enough time has passed for metabolism to toxic metabolites to

occur, significant poisoning can be present when serum ethylene glycol levels are less than 50 mg/dL.

Chest radiography and pulse oximetry (or ABG measurements) are recommended for patients with respiratory complaints.

A cardiac monitor should be placed to look for QT prolongation, an indication of hypocalcemia.

Calcium oxalate crystals can be seen on microscopic examination of the urine, but their absence does not preclude ethylene glycol poisoning. A Woods (UV) lamp test of the urine detects the fluorescent compound, fluorescein, which is commonly added as a coloring agent to automotive antifreezes. Urine fluorescence cannot be relied upon to diagnose the presence or absence of ethylene glycol ingestion. If present, it supports the diagnosis.

Disposition and Follow-up

All patients with ethylene glycol poisoning should be evaluated and treated without delay. Even patients with no or mild symptoms should undergo appropriate blood and urine tests if they have a history of significant ingestion. Patients requiring ethanol infusions, 4-methylpyrazole, or hemodialysis should be admitted to an intensive care unit.

Delayed Effects

Renal effects typically take 24 to 72 hours to develop. Hemodialysis to treat acute renal failure is essential.

Patient Release

Patients who have no history suggestive of significant exposure and who have no symptoms or laboratory findings of ethylene glycol poisoning may be discharged with instructions to seek medical care promptly if symptoms develop (see the *Ethylene Glycol—Patient Information Sheet* below).

Follow-up

Obtain the name of the patient's primary care physician so that the hospital can send a copy of the ED visit to the patient's doctor.

In cases of severe exposure, follow-up laboratory evaluation of renal function should be arranged and neurologic examination for post-hypoxic or oxalate crystal injury is recommended.

Patients who have corneal lesions should be re-examined within 24 hours.

Reporting

If a work-related incident has occurred, you may be legally required to file a report; contact your state or local health department.

Other persons might still be at risk in the setting where this incident occurred. If the incident occurred in the workplace, discussing it with company personnel might prevent future incidents. If a public health risk exists, notify your state or local health department or other responsible public agency. When appropriate, inform patients that they may request an evaluation of their workplace from OSHA or NIOSH. See Appendices III and IV for a list of agencies that may be of assistance.

Ethylene Glycol ($C_2H_6O_2$)
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to ethylene glycol.

What is ethylene glycol?
Ethylene glycol is a colorless, syrupy liquid used in antifreeze solutions and as a solvent in making certain chemicals. When used in antifreeze solutions, it is usually mixed with a fluorescent yellow dye to create a bright yellow color. Ethylene glycol is odorless and can have a sweet taste.

What immediate health effects can be caused by exposure to ethylene glycol?
Drinking even small amounts (from 1 to 3 ounces) of ethylene glycol can result in damage to the kidneys if the poisoning is not treated. Consumption of larger quantities can be fatal. Skin contact with liquid ethylene glycol or breathing low levels of vapors in the air is generally not harmful or causes only minor irritation. Very few individuals develop an allergic rash when the liquid is on their skin.

Can ethylene glycol poisoning be treated?
Persons who have swallowed large amounts of ethylene glycol should be hospitalized. In severe exposures, special antidotes and hemodialysis might be needed. Treatment is generally successful if begun within 3 hours of swallowing, and most people recover completely after treatment.

Are any future health effects likely to occur?
Kidney damage is the most common effect if severe exposure by ingestion is not treated.

What tests can be done if a person has been exposed to ethylene glycol?
Ethylene glycol and its breakdown products can be measured in blood and urine. After significant exposure, diagnostic tests are needed to measure kidney function and the levels of the toxicant in the blood.

Where can more information about ethylene glycol be found?
More information about ethylene glycol can be obtained from your regional poison control center; your state, county, or local health department; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in occupational and environmental health. If the exposure happened at work, you may wish to discuss it with your employer, the Occupational Safety and Health Administration (OSHA), or the National Institute for Occupational Safety and Health (NIOSH). Ask the person who gave you this form for help in locating these telephone numbers.

Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow *only* the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:

- headache, dizziness, or a feeling of intoxication
- nausea, vomiting, or abdominal cramps.

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.
[ ] Call for an appointment with Dr. _____ in the practice of _____.
When you call for your appointment, please say that you were treated in the Emergency Department at _ _____ Hospital by _____ and were advised to be seen again in _____ days.
[ ] Return to the Emergency Department/ _____ Clinic on (date) _____at ___ _____ AM/PM for a follow-up examination.
[ ] Do not perform vigorous physical activities for 1 to 2 days.
[ ] You may resume everyday activities including driving and operating machinery.
[ ] Do not return to work for _____ days.
[ ] You may return to work on a limited basis. See instructions below.
[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.
[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.
[ ] Avoid taking the following medications: _____
[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: __
_____
_____
[ ] Other instructions: _____
_____
_____

- Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.

- You or your physician can get more information on the chemical by contacting: _____ _____ or _____, or by checking out the following Internet Web sites: _____; _____.

Signature of patient _____ Date _____

Signature of physician _____ Date _____

Ethylene Oxide ($[CH_2]_2O$)
CAS 75-21-8; UN 1040

Synonyms include dimethylene oxide, 1,2-epoxyethane, EtO, EO, ethene oxide, and oxirane.

- **Persons exposed only to ethylene oxide gas do not pose substantial risks of secondary contamination. Persons whose clothing or skin is contaminated with ethylene oxide liquid or solution can secondarily contaminate personnel by direct contact or through off-gassing vapor.**
- **Ethylene oxide is a flammable, explosive, and highly penetrating gas; its sweet, ether-like odor does not provide sufficient warning of hazardous concentrations.**
- **Ethylene oxide is rapidly absorbed after inhalation, and solutions of ethylene oxide can penetrate human skin.**

Description

Ethylene oxide is a colorless gas at room temperature and a colorless liquid below 51 °F (10.7 °C). It is shipped as a liquefied, compressed gas. Both the gas and liquid are potential fire and explosion hazards. Ethylene oxide has a sweet, ether-like odor at air concentrations above 500 ppm. Ethylene oxide is soluble in water and organic solvents.

Routes of Exposure

Inhalation

Most ethylene oxide exposures occur by inhalation or skin contact. The gas is readily absorbed by the lungs. **Odor is not a reliable indicator of ethylene oxide's presence and does not provide adequate warning of hazardous concentrations.** The odor threshold is 500 ppm, while the OSHA PEL is 1 ppm. The gas is heavier than air and can cause asphyxiation in enclosed, poorly ventilated, or low-lying areas.

Children exposed to the same levels of ethylene oxide as adults may receive larger dose because they have greater lung surface area:body weight ratios and increased minute volumes:weight ratios. In addition, they may be exposed to higher levels than adults in the same location because of their short stature and the higher levels of ethylene oxide found nearer to the ground.

Skin/Eye Contact

Skin contact with concentrated solutions of ethylene oxide, liquid ethylene oxide, or high vapor concentrations may cause chemical burns. Contact with liquefied ethylene oxide may result in frostbite. Exposure to high levels of the gas may cause corneal burns and cataracts. Prolonged skin contact with dilute solutions

of ethylene oxide (e.g., from contaminated clothing) can cause irritation and dermatitis.

Children are more vulnerable to toxicants absorbed through the skin because of their relatively larger surface area:body weight ratio.

Ingestion

Ingestion is unlikely to occur because ethylene oxide is a gas at room temperature.

Sources/Uses

Ethylene oxide is produced by catalytically reacting ethylene and oxygen. Ethylene oxide ranks 26th in volume among the major industrial chemicals produced in the United States. About 65% of ethylene oxide is used for synthesis of ethylene glycol, an antifreeze product. A mixture of 88% Freon and 12% ethylene oxide is used as a cold sterilizing agent for foods and medical equipment and supplies. Ethylene oxide is also used as a fumigant and fungicide in the manufacture of medical products and spices, and as a chemical intermediate.

Standards and Guidelines

OSHA PEL (permissible exposure limit) = 1 ppm (averaged over an 8-hour workshift)

OSHA STEL (short-term exposure limit) = 5 ppm (15 minute exposure)

NIOSH IDLH (immediately dangerous to life or health) = 800 ppm

AIHA ERPG-2 (emergency response planning guideline) (maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms which could impair an individual's ability to take protective action) = 50 ppm

Physical Properties

Description: Colorless gas above 51 °F (10.7 °C); colorless liquid below 51 °F.

Warning properties: Inadequate; sweet, ether-like odor detectable at about 500 ppm. Sensitized persons may experience symptoms below the odor threshold and at levels that do not affect others.

Molecular weight: 44.1 daltons

Boiling point (760 mm Hg): 51 °F (10.7 °C)

Freezing point: -171 °F (-113 °C)

Specific gravity: 0.82 (liquid at 50 °F)

Vapor pressure: 1,110 mm Hg at 68 °F (20 °C)

Gas density: 1.49 (air = 1)

Water solubility: Miscible with water.

Flammability: -20 °F (-29 °C). Extremely flammable liquid; may be ignited by heat, sparks, or flames, vapors may travel to a source of ignition and flash back.

Flammable range: Flammable gas between 3% and 100% (concentration in air).

Incompatibilities

Ethylene oxide reacts with water, strong acids, alkalies, and oxidizers; chlorides of iron, tin, and aluminum; and oxides of iron and aluminum.

Health Effects

- **Ethylene oxide gas may produce immediate local irritation of the skin, eyes, and upper respiratory tract. At high concentrations, it may cause an immediate or delayed accumulation of fluid in the lungs.**
- **Inhalation of ethylene oxide can produce CNS depression, and in extreme cases, respiratory distress and coma.**
- **In some persons, ethylene oxide exposure may result in allergic sensitization, and future exposure may cause hives or a life-threatening allergic reaction.**

Acute Exposure

Ethylene oxide is a highly reactive alkylating agent that reacts with many constituents of tissue resulting in cellular and tissue dysfunction and destruction. Evidence for human exposure to this chemical is the presence of ethylene oxide adducts of DNA and hemoglobin. Direct contact with liquid ethylene oxide or solutions of ethylene oxide produces immediate local irritation of skin and mucous membranes. Inhalation of high concentrations of ethylene oxide can cause CNS depression or pulmonary edema. The onset of symptoms may be delayed for up to 72 hours.

Children do not always respond to chemicals in the same way that adults do. Different protocols for managing their care may be needed.

Respiratory

Initially, ethylene oxide affects the nose and throat. Concentrations as low as 200 ppm produce rapid onset of nose and throat irritation. Higher concentrations may cause inflammation of the lining in the trachea and bronchi, narrowing of the bronchi, and partial lung collapse. Accumulation of fluid in the lungs may evolve up to 72 hours after exposure. Severe respiratory distress may lead to cardiovascular collapse.

Children may be more vulnerable to gas exposure because of relatively increased minute ventilation per kg and failure to evacuate an area promptly when exposed.

CNS

Ethylene oxide is a CNS depressant. High-dose exposures can result in diverse neurologic manifestations including seizures, loss of consciousness, and coma. Onset of neurologic signs and symptoms may be delayed 6 hours or more after exposure. Respiratory paralysis and delayed peripheral nerve damage have been reported after massive exposure.

Gastrointestinal

Exposure to low vapor concentrations of ethylene oxide can result in nausea and vomiting, which is often delayed.

Dermal

Skin contact with concentrated vapor or aqueous solutions of ethylene oxide may cause inflammation with redness of the skin, blisters, and crusted ulcerations. Initially, lesions are painless, but later can become painful and itchy. Skin reactions may be delayed 5 hours or more after exposure. Exposure to liquefied ethylene oxide can cause frostbite due to rapid evaporation and consequent cooling.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants absorbed through the skin.

Ocular

Exposure to high concentrations of ethylene oxide vapor or eye splashes of concentrated solutions can cause eye irritation, inflammation of the eye membrane and corneal injury. Exposure to ethylene oxide has also been linked to the development of cataracts.

Potential Sequelae

Inhalation and skin exposure may cause exposed individuals to become sensitized to ethylene oxide which could result in allergic contact dermatitis following subsequent skin exposures. Skin burns may result in scarring or increased pigment. Cataracts may develop after a serious eye exposure. Repeated contact of patients with medical equipment sterilized with ethylene oxide (e.g., dialysis patients) may lead to sensitization and an immediate, life-threatening allergic reaction.

Inhalation does not normally lead to permanent neurological damage, but in one case, coma was followed by an irreversible parkinsonism.

Survivors of severe inhalation injury may suffer residual chronic lung disease.

Chronic Exposure

Chronic ethylene oxide exposure may cause delayed peripheral nerve damage (neuropathy), especially in the lower extremities. Although the results are inconclusive, some data suggest that chronic ethylene oxide exposure impairs cognitive function. Ethylene oxide may also damage the liver and kidneys. Skin allergy can occur, and some persons may become sensitized to the chemical. Cataracts and corneal burns have been reported from occupational exposure.

Chronic exposure may be more serious for children because of their potential longer latency period.

Carcinogenicity

The DHHS has determined that ethylene oxide may reasonably be anticipated to be a human carcinogen (NTP 2000). In animals, chronic exposure causes leukemia and intra-abdominal cancer, and there is some evidence that it increases the risk of leukemia in human workers. The International Agency for Research on Cancer has determined that ethylene oxide is carcinogenic to humans.

Reproductive and Developmental Effects

Shepard's Catalog of Teratogenic Agents describes one study in which the spontaneous abortion frequency in hospital workers exposed to ethylene oxide during pregnancy was average for the general population (6.7%); however, the frequency for appropriate hospital controls was below average for the general population (5.6%). Ethylene oxide is included in *Reproductive and Developmental Toxicants*, a 1991 report published by the U.S. General Accounting Office (GAO) that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences.

Special consideration regarding the exposure of pregnant women is warranted, since ethylene oxide has been shown to be a teratogen and genotoxin; thus, medical counseling is recommended for the acutely exposed pregnant woman.

Prehospital Management

- **Victims exposed only to ethylene oxide gas do not pose substantial risks of secondary contamination to personnel outside the Hot Zone. Victims whose clothing or skin is contaminated with ethylene oxide liquid or solution can secondarily contaminate personnel by direct contact or through off-gassing vapor.**
- **Ethylene oxide can produce CNS depression and immediate eye, skin, and respiratory-tract irritation and may lead to seizures, coma, or respiratory paralysis. Noncardiogenic pulmonary edema may evolve up to 72 hours after exposure.**
- **There is no antidote for ethylene oxide poisoning. Treatment is supportive of respiratory and cardiovascular functions.**

Hot Zone

Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if rescuers have not been trained in its use, assistance should be obtained from a local or regional HAZMAT team or other properly equipped response organization.

Rescuer Protection

Ethylene oxide is a severe respiratory tract and skin irritant and can also produce CNS depression and injuries.

Respiratory Protection: Positive-pressure, self-contained breathing apparatus (SCBA) is recommended in response situations that involve exposure to potentially unsafe levels of ethylene oxide.

Skin Protection: Chemical-protective clothing is recommended because ethylene oxide can cause skin irritation and burns.

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible.

Victim Removal

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be removed on backboards or gurneys; if these are not available, carefully carry or drag victims to safety.

Consider appropriate management of chemically contaminated children, such as measures to reduce separation anxiety if a child is separated from a parent or other adult.

Decontamination Zone

Patients exposed only to ethylene oxide gas who have no skin or eye irritation may be transferred immediately to the Support Zone. Other patients will require decontamination as described below.

Rescuer Protection

If exposure levels are determined to be safe, decontamination may be conducted by personnel wearing a lower level of protection than that worn in the Hot Zone (described above).

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. Stabilize the cervical spine with a collar and a backboard if trauma is suspected. Administer supplemental oxygen as required. Assist ventilation with a bag-valve-mask device if necessary.

Basic Decontamination

Victims who are able may assist with their own decontamination. If the exposure involved liquid ethylene oxide (ambient temperature below 51 °F) and there is evidence of wet clothing, remove and double-bag the contaminated clothing and personal belongings.

If liquid is spilled on the skin ethylene oxide should be washed off with water as quickly as possible. Flush exposed skin and hair with plain water for 3 to 5 minutes. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Flush exposed or irritated eyes with plain water or saline for at least 15 minutes. Remove contact lenses if easily removable without additional trauma to the eye. If a corrosive material is suspected or if pain or injury is evident, continue irrigation while transferring the victim to the Support Zone.

Consider appropriate management of chemically contaminated children, such as measures to reduce separation anxiety if a child is separated from a parent or other adult. If possible, seek assistance from a child separation expert.

Transfer to Support Zone

As soon as basic decontamination is complete, move the victim to the Support Zone.

Support Zone

Be certain that victims have been decontaminated properly (see *Decontamination Zone* above). Victims who have undergone decontamination or have been exposed only to ethylene oxide gas pose no serious risks of secondary contamination. In such cases, Support Zone personnel require no specialized protective gear.

ABC Reminders

Quickly access for a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Ensure adequate respiration and pulse. Administer supplemental oxygen as required and establish intravenous access if necessary. Place on a cardiac monitor.

Additional Decontamination

Continue irrigating exposed skin and eyes, as appropriate.

Advanced Treatment

In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, perform cricothyroidotomy if equipped and trained to do so.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Ethylene oxide poisoning is not known to pose additional risk during the use of bronchial or cardiac sensitizing agents.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Patients who are comatose, hypotensive, or are having seizures or cardiac arrhythmias should be treated according to advanced life support (ALS) protocols.

Transport to Medical Facility

Only decontaminated patients or patients not requiring decontamination should be transported to a medical facility. “Body bags” are not recommended.

Report to the base station and the receiving medical facility the condition of the patient, treatment given, and estimated time of arrival at the medical facility.

Multi-Casualty Triage

Consult with the base station physician or the regional poison control center for advice regarding triage of multiple victims.

Because some effects may occur several hours after exposure, all patients who have potential exposure should be transported to a medical facility for evaluation.

Emergency Department Management

- **Patients exposed only to ethylene oxide gas do not pose substantial risks of secondary contamination to personnel outside the Hot Zone. Patients whose clothing or skin is contaminated with ethylene oxide liquid or solution can secondarily contaminate personnel by direct contact or through off-gassing vapor. Patients do not pose serious contamination risks after contaminated clothing is removed and the skin is thoroughly washed.**

- **Ethylene oxide can produce CNS depression and immediate eye, skin, and respiratory tract irritation and may lead to seizures, coma, or respiratory paralysis. Non-cardiogenic pulmonary edema may evolve up to 72 hours after exposure.**

- **There is no antidote for ethylene oxide poisoning. Treatment is supportive of respiratory and cardiovascular functions.**

Decontamination Area

Previously decontaminated patients and patients exposed only to ethylene oxide gas who have no skin or eye irritation may be transferred immediately to the Critical Care Area. Other patients will require decontamination as described below.

Be aware that use of protective equipment by the provider may cause fear in children, resulting in decreased compliance with further management efforts.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants absorbed through the skin. Also, emergency room personnel should examine children's mouths because of the frequency of hand-to-mouth activity among children.

ABC Reminders

Evaluate and support airway, breathing, and circulation. In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, surgically create an airway.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Ethylene oxide poisoning is not known to pose

additional risk during the use of bronchial or cardiac sensitizing agents.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Patients who are comatose, hypotensive, or have seizures or ventricular arrhythmias should be treated in the conventional manner.

Basic Decontamination

Patients who are able may assist in their own decontamination. Because contact with ethylene oxide may cause burns, ED staff should don chemical-resistant jumpsuits (e.g., of Tyvek or Saranex) or butyl rubber aprons, rubber gloves, and eye protection if the patient's clothing or skin is wet with ethylene oxide solution. After the patient has been decontaminated, no special protective clothing or equipment is required for ED personnel.

Quickly remove contaminated clothing while flushing the skin with water (preferably under a shower). Double-bag the contaminated clothing and personal. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Flush exposed eyes with water for at least 15 minutes. Remove contact lenses if easily removable without additional trauma to the eye. An ophthalmic anesthetic, such as tetracaine, may be necessary to alleviate blepharospasm, and lid retractors may be required to allow adequate irrigation under the eyelids. If a corrosive material is suspected or if pain or injury is evident, continue irrigation while transferring the patient to the Critical Care Area.

Critical Care Area

Be certain that appropriate decontamination has been carried out (see *Decontamination Area* above).

ABC Reminders

Evaluate and support airway, breathing, and circulation as in ABC Reminders above. Establish intravenous access in seriously ill patients if this has not already been done. Continuously monitor cardiac rhythm.

Patients who are comatose, hypotensive, or are having seizures or cardiac arrhythmias should be treated in the conventional manner.

Inhalation Exposure

Administer supplemental oxygen by mask to patients who have respiratory symptoms. Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Ethylene oxide poisoning is not known to pose additional risk during the use of bronchial or cardiac sensitizing agents.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.7 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Observe patients who are in respiratory distress for up to 72 hours and periodically reexamine their chests and order other appropriate studies. Follow up as clinically indicated.

Skin Exposure

If ethylene oxide was in contact with the skin, chemical burns may result; treat as thermal burns.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants absorbed through the skin.

Eye Exposure

Ensure that adequate eye irrigation has been completed. Examine the eyes for corneal damage and treat appropriately. Immediately consult an ophthalmologist for patients who have corneal injuries.

Antidotes and Other Treatments

There is no antidote for ethylene oxide poisoning. Treatment is supportive of respiratory and cardiovascular functions.

Laboratory Tests

The diagnosis of acute ethylene oxide toxicity is primarily clinical, based on symptoms of CNS depression or irritation. Routine laboratory studies for all exposed patients include CBC, glucose, and electrolyte determinations. Depending on the initial evaluation, additional studies for patients exposed to ethylene oxide might include renal-function tests and liver-function tests. Chest radiography and pulse oximetry (or ABG measurements) are also recommended for severe inhalation exposure.

Disposition and Follow-up

Consider hospitalizing patients who have evidence of systemic toxicity from any route of exposure.

Patients who have symptoms of severe respiratory distress or extensive skin burns should be admitted to an intensive care unit.

Delayed Effects

Because neurologic and respiratory signs and symptoms may not be evident for as long as 72 hours after exposure, patients suspected to have serious exposure should be observed and reexamined periodically. Patients who have bronchospasm or pulmonary edema should be admitted and watched for signs of impending respiratory failure and treated accordingly.

Patient Release

Patients who have mild exposure and those who are asymptomatic initially should be observed for 4 to 6 hours, then discharged if no symptoms occur during this period. Advise discharged patients to seek medical care promptly if symptoms develop (see the *Ethylene Oxide—Patient Information Sheet* below).

Follow-up

Obtain the name of the patient's primary care physician so that the hospital can send a copy of the ED visit to the patient's doctor.

Inhalation and skin exposure may cause dermatitis and skin burns may result in scarring or increased pigmentation. A single acute exposure does not normally lead to permanent neurological damage, but in one case, coma was followed by an irreversible parkinsonism. Survivors of severe inhalation injury may suffer residual chronic lung disease. Cataracts may develop after a serious eye exposure.

Patients who have corneal injuries should be reexamined within 24 hours.

Reporting

If a work-related incident has occurred, you may be legally required to file a report; contact your state or local health department.

Other persons may still be at risk in the setting where this incident occurred. If the incident occurred in the workplace, discussing it with company personnel may prevent future incidents. If a public health risk exists, notify your state or local health department or other responsible public agency. When appropriate, inform patients that they may request an evaluation of their workplace from OSHA or NIOSH. See Appendices III and IV for a list of agencies that may be of assistance.

Ethylene Oxide ($([CH_2])_2O$)
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to ethylene oxide.

What is ethylene oxide?
Ethylene oxide is a colorless liquid at temperatures below 51 °F and a colorless gas at room temperature. It is used in the sterilization of hospital supplies and cosmetics; as a fumigant for such products as spices, tobacco, furs, and bedding; and in the manufacture of antifreeze and other chemicals. At high concentrations, ethylene oxide may have a sweet, ether-like odor. However, dangerous exposures may occur at levels too low to smell.

What immediate health effects can result from ethylene oxide: exposure?
Most people are exposed to ethylene oxide by breathing the gas. Exposure to small amounts can cause eye, nose, and throat irritation; and skin rash. More serious exposure can cause severe breathing difficulty, skin burns, weakness, twitching, convulsions, and coma. Generally, the more serious the exposure, the more severe the symptoms.

Can ethylene oxide poisoning be treated?
There is no antidote for ethylene oxide, but its effects can be treated, and most exposed persons get well. Persons who have had serious exposures may need to be hospitalized.

Are any future health effects likely to occur?
A single, small exposure from which a person quickly recovers is not likely to cause delayed or long-term effects. After a severe exposure, symptoms may not develop for 12 hours (see *Follow-up Instructions*). Ethylene oxide is suspected of causing cancer of the blood, and birth defects may occur in infants whose mothers were repeatedly and excessively exposed during pregnancy.

What tests can be done if a person has been exposed to ethylene oxide?
Specific tests for the presence of ethylene oxide in blood or urine generally are not useful to the doctor. If a severe exposure has occurred, blood and urine analyses and other tests may show whether the blood, heart, lungs, liver, or kidneys have been injured. Testing is not needed in every case.

Where can more information about ethylene oxide be found?
More information about ethylene oxide-can be obtained from your regional poison control center; your state, county, or local health department; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in occupational and environmental health. If the exposure happened at work, you may wish to discuss it with your employer, the Occupational Safety and Health Administration (OSHA), or the National Institute for Occupational Safety and Health (NIOSH). Ask the person who gave you this form for help in locating these telephone numbers.

Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow *only* the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:

- difficulty breathing, shortness of breath, or chest pain
- increased pain or a discharge from eyes
- increased redness or pain, or a pus-like discharge in the area of a skin burn
- fever
- numbness or weakness in the arms or legs
- unexplained drowsiness, fatigue, or headache
- stomach pain, vomiting, or diarrhea

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.
[ ] Call for an appointment with Dr. _____ in the practice of _____.
When you call for your appointment, please say that you were treated in the Emergency Department at _ _____ Hospital by _____ and were advised to be seen again in _____ days.
[ ] Return to the Emergency Department/ _____ Clinic on (date) _____at ___ _____ AM/PM for a follow-up examination.
[ ] Do not perform vigorous physical activities for 1 to 2 days.
[ ] You may resume everyday activities including driving and operating machinery.
[ ] Do not return to work for _____ days.
[ ] You may return to work on a limited basis. See instructions below.
[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.
[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.
[ ] Avoid taking the following medications: _____
[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: __
_____
_____
[ ] Other instructions: _____
_____
_____

- Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.

- You or your physician can get more information on the chemical by contacting: _____ _____ or _____, or by checking out the following Internet Web sites: _____; _____.

Signature of patient _____ Date _____
Signature of physician _____ Date _____

Formaldehyde (HCHO)
CAS 50-00-0; UN 1198, UN 2209 (formalin)

Synonyms include formalin, formic aldehyde, methanal, methyl aldehyde, methylene oxide, oxomethane, and paraform.

Persons exposed only to formaldehyde vapor do not pose substantial risks of secondary contamination. Persons whose clothing or skin is contaminated with a solution of formaldehyde can cause secondary contamination by direct contact or through off-gassing vapor.

- **Formaldehyde is a colorless, highly toxic, and flammable gas at room temperature that is slightly heavier than air. It has a pungent, highly irritating odor that is detectable at low concentrations, but may not provide adequate warning of hazardous concentrations for sensitized persons.**
- **It is used most often in an aqueous solution stabilized with methanol (formalin).**
- **Most formaldehyde exposures occur by inhalation or by skin or eye contact. Formaldehyde is absorbed well by the lungs, gastrointestinal tract, and, to a lesser extent, skin.**

Description

Formaldehyde is a nearly colorless gas with a pungent, irritating odor even at very low concentrations (below 1 ppm). Its vapors are flammable and explosive. Because the pure gas tends to polymerize, it is commonly used and stored in solution. Formalin, the aqueous solution of formaldehyde (30% to 50% formaldehyde), typically contains up to 15% methanol as a stabilizer.

Routes of Exposure

Inhalation

Most formaldehyde exposures occur by inhalation or by skin/eye contact. Formaldehyde vapor is readily absorbed from the lungs. In cases of acute exposure, formaldehyde will most likely be detected by smell; however, persons who are sensitized to formaldehyde may experience headaches and minor eye and airway irritation at levels below the odor threshold (odor threshold is 0.5 to 1.0 ppm; OSHA PEL is 0.75 ppm). **For sensitized persons, odor is not an adequate indicator of formaldehyde's presence and may not provide reliable warning of hazardous concentrations. Odor adaptation can occur.** Low-dose acute exposure can result in headache, rhinitis, and dyspnea; higher doses may cause severe mucous membrane irritation, burning, and lacrimation, and lower respiratory effects

such as bronchitis, pulmonary edema, or pneumonia. Sensitive individuals may experience asthma and dermatitis, even at very low doses. Formaldehyde vapors are slightly heavier than air and can result in asphyxiation in poorly ventilated, enclosed, or low-lying areas.

Children exposed to the same levels of formaldehyde as adults may receive larger doses because they have greater lung surface area:body weight ratios and increased minute volumes:weight ratios. In addition, they may be exposed to higher levels than adults in the same location because of their short stature and the higher levels of formaldehyde found nearer to the ground.

Skin/Eye Contact

Ocular exposure to formaldehyde vapors produces irritation and lacrimation. Depending on the concentration, formaldehyde solutions may cause transient discomfort and irritation or more severe effects, including corneal opacification and loss of vision. Formaldehyde is absorbed through intact skin and may cause irritation or allergic dermatitis; rapid metabolism makes systemic effects unlikely following dermal exposure.

Children are more vulnerable to toxicants absorbed through the skin because of their relatively larger surface area:body weight ratio.

Ingestion

Ingestion of as little as 30 mL (1 oz.) of a solution containing 37% formaldehyde has been reported to cause death in an adult. Ingestion may cause corrosive injury to the gastrointestinal mucosa, with nausea, vomiting, pain, bleeding, and perforation. Corrosive injuries are usually most pronounced in the pharyngeal mucosa, epiglottis and esophagus. Systemic effects include metabolic acidosis, CNS depression and coma, respiratory distress, and renal failure.

Sources/Uses

Formaldehyde is synthesized by the oxidation of methanol. It is among the 25 most abundantly produced chemicals in the world and is used in the manufacture of plastics, resins, and urea-formaldehyde foam insulation. Formaldehyde or formaldehyde-containing resins are used in the manufacture of chelating agents, a wide variety of organic products, glass mirrors, explosives, artificial silk, and dyes. It has been used as a disinfectant, germicide, and in embalming fluid. In the agricultural industry, formaldehyde has been used as a fumigant, preventative for mildew in wheat and rot in oats, a germicide and fungicide for plants, an insecticide, and in the manufacture of slow-release fertilizers. Formaldehyde is found in construction materials such as plywood adhesives. Formaldehyde also is or has been used in

the sugar, rubber, food, petroleum, pharmaceuticals, and textiles industries.

Standards and Guidelines

OSHA PEL (permissible exposure limit) = 0.75 ppm (averaged over an 8-hour workshift)

OSHA STEL (short-term exposure limit) = 2 ppm (15 minute exposure)

NIOSH IDLH (immediately dangerous to life or health) = 20 ppm

AIHA ERPG-2 (emergency response planning guideline) (the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms which could impair an individual's ability to take protective action) = 10 ppm

Physical Properties

Description: Nearly colorless gas with a pungent, irritating odor

Warning properties: Odor is detectable at less than 1 ppm, but many sensitive persons experience symptoms below the odor threshold.

Molecular weight: 30.0 daltons

Boiling point (760 mm Hg): - 6 °F (-21 °C)

Vapor pressure: 3883 mm Hg at 77°F (25 °C)

Gas density: 1.07 (air = 1)

Water solubility: 55% at 68 °F (20 °C)

Flammability: Flammable gas between 7% and 73% at 77 °F (25 °C) (concentration in air); combustible liquid (formalin)

Incompatibilities

Formaldehyde reacts with strong oxidizers, alkalis, acids, phenols, and urea. Pure formaldehyde has a tendency to polymerize.

Health Effects

Formaldehyde is an eye, skin, and respiratory tract irritant. Inhalation of vapors can produce narrowing of the bronchi and an accumulation of fluid in the lungs.

- **Children may be more susceptible than adults to the respiratory effects of formaldehyde.**
- **Formaldehyde solution (formalin) causes corrosive injury to the gastrointestinal tract, especially the pharynx, epiglottis, esophagus, and stomach.**

The systemic effects of formaldehyde are due primarily to its metabolic conversion to formate, and may include metabolic acidosis, circulatory shock, respiratory insufficiency, and acute renal failure.

Formaldehyde is a potent sensitizer and a probable human carcinogen.

Acute Exposure

Formaldehyde vapor produces immediate local irritation in mucous membranes, including eyes, nose, and upper respiratory tract. Ingestion of formalin causes severe injury to the gastrointestinal tract. The exact mechanism of action of formaldehyde toxicity is not clear, but it is known that it can interact with molecules on cell membranes and in body tissues and fluids (e.g., proteins and DNA) and disrupt cellular functions. High concentrations cause precipitation of proteins, which results in cell death. Absorption from the respiratory tract is very rapid; absorption from the gastrointestinal tract is also rapid, but may be delayed by ingestion with food. Once absorbed, formaldehyde is metabolized to formic acid, which may cause acid-base imbalance and a number of other systemic effects.

Children do not always respond to chemicals in the same way that adults do. Different protocols for managing their care may be needed.

CNS

Malaise, headache, sleeping disturbances, irritability, and impairment of dexterity, memory, and equilibrium may result from a single, high level, exposure to formaldehyde.

Respiratory

Even fairly low concentrations of formaldehyde can produce rapid onset of nose and throat irritation, causing cough, chest pain, shortness of breath, and wheezing. Higher exposures can cause significant inflammation of the lower respiratory tract, resulting in swelling of the throat, inflammation of the windpipe

and bronchi, narrowing of the bronchi, inflammation of the lungs, and accumulation of fluid in the lungs. Pulmonary injury may continue to worsen for 12 hours or more after exposure.

Previously sensitized individuals can develop severe narrowing of the bronchi at very low concentrations (e.g., 0.3 ppm). Bronchial narrowing may begin immediately or can be delayed for 3 to 4 hours; effects may worsen for up to 20 hours after exposure and can persist for several days.

Exposure to certain chemical irritants can lead to Reactive Airway Dysfunction Syndrome (RADS), a chemically- or irritant-induced type of asthma.

Children may be more vulnerable to corrosive agents than adults because of the relatively smaller diameter of their airways.

Children may be more vulnerable because of relatively increased minute ventilation per kg and failure to evacuate an area promptly when exposed.

Metabolic Accumulation of formic acid can cause an anion-gap acid-base imbalance. If formalin is ingested, absorption of the methanol stabilizer may contribute to the imbalance and can result in an osmolal gap, as well as an anion gap.

Immunologic In persons who have been previously sensitized, inhalation and skin contact may cause various skin disorders, asthma-like symptoms, anaphylactic reactions and, rarely, hemolysis. The immune system in children continues to develop after birth, and thus, children may be more susceptible to certain chemicals.

Gastrointestinal Ingestion of aqueous solutions of formaldehyde can result in severe corrosive injury to the esophagus and stomach. Nausea, vomiting, diarrhea, abdominal pain, inflammation of the stomach, and ulceration and perforation of the oropharynx, epiglottis, esophagus, and stomach may occur. Both formaldehyde and the methanol stabilizer are easily absorbed and can contribute to systemic toxicity.

Ocular Exposure to low concentrations of formaldehyde vapor can cause eye irritation, which abates within minutes after exposure has ended. Formalin splashed in the eyes can result in corneal ulceration or cloudiness of the eye surface, death of eye surface cells, perforation, and permanent loss of vision; these effects may be delayed for 12 hours or more.

Dermal

Exposure to formaldehyde vapor or to formalin solutions can cause skin irritation and burns. In sensitized persons, contact dermatitis may develop at very low exposure levels.

Potential Sequelae

In survivors of inhalation injury, pulmonary function usually returns to normal. Eye exposure to high concentrations of formaldehyde vapor or formalin can eventually cause blindness. Narrowing of the esophagus and severe corrosive damage to the stomach lining can result from ingesting formalin.

Chronic Exposure

The major concerns of repeated formaldehyde exposure are sensitization and cancer. In sensitized persons, formaldehyde can cause asthma and contact dermatitis. In persons who are not sensitized, prolonged inhalation of formaldehyde at low levels is unlikely to result in chronic pulmonary injury. Adverse effects on the central nervous system such as increased prevalence of headache, depression, mood changes, insomnia, irritability, attention deficit, and impairment of dexterity, memory, and equilibrium have been reported to result from long-term exposure. Chronic exposure may be more serious for children because of their potential longer latency period.

Carcinogenicity

The Department of Health and Human Services has determined that formaldehyde may reasonably be anticipated to be a carcinogen. In humans, formaldehyde exposure has been weakly associated with increased risk of nasal cancer and nasal tumors were observed in rats chronically inhaling formaldehyde.

Reproductive and Developmental Effects

There is limited evidence that formaldehyde causes adverse reproductive effects. The TERIS database states that the risk of developmental defects to the exposed fetus ranges from none to minimal. Formaldehyde is not included in *Reproductive and Developmental Toxicants*, a 1991 report published by the U.S. General Accounting Office (GAO) that lists 30 chemicals widely acknowledged to have reproductive and developmental consequences.

There have been reports of menstrual disorders in women occupationally exposed to formaldehyde, but they are controversial. Studies in experimental animals have reported some effects on spermatogenesis. Formaldehyde has not been proven to be teratogenic in animals and is probably not a human teratogen at occupationally permissible levels. Formaldehyde has been shown to have genotoxic properties in human and laboratory animal studies producing sister chromatid exchange and chromosomal aberrations.

Special consideration regarding the exposure of pregnant women is warranted, since formaldehyde has been shown to be a genotoxin; thus, medical counseling is recommended for the acutely exposed pregnant woman.

Prehospital Management

Victims exposed only to formaldehyde gas do not pose significant risks of secondary contamination to personnel outside the Hot Zone. Victims whose clothing or skin is contaminated with a formaldehyde-containing solution (formalin) can secondarily contaminate personnel by direct contact or through off-gassing vapor.

Inhalation of formaldehyde can cause airway irritation, bronchospasm, and pulmonary edema.

Absorption of large amounts of formaldehyde via any route can cause severe systemic toxicity, leading to metabolic acidosis, tissue and organ damage, and coma.

There is no antidote for formaldehyde. Treatment consists of supportive measures including decontamination (flushing of skin and eyes with water, gastric lavage, and administration of activated charcoal), administration of supplemental oxygen, intravenous sodium bicarbonate and/or isotonic fluid, and hemodialysis.

Hot Zone

Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if rescuers have not been trained in its use, assistance should be obtained from a local or regional HAZMAT team or other properly equipped response organization.

Rescuer Protection

Formaldehyde is a highly toxic systemic poison that is absorbed well by inhalation. The vapor is a severe respiratory tract and skin irritant and may cause dizziness or suffocation. Contact with formaldehyde solution may cause severe burns to the eyes and skin.

Respiratory Protection: Positive-pressure, self-contained breathing apparatus (SCBA) is recommended in response situations that involve exposure to potentially unsafe levels of formaldehyde vapor.

Skin Protection: Chemical-protective clothing is recommended because formaldehyde can cause skin irritation and burns.

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible.

Victim Removal

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be

removed on backboards or gurneys; if these are not available, carefully carry or drag victims to safety.

Consider appropriate management of chemically contaminated children, such as measures to reduce separation anxiety if a child is separated from a parent or other adult.

Decontamination Zone

Victims exposed only to formaldehyde vapor who have no skin or eye irritation may be transferred immediately to the Support Zone. All others require decontamination (see *Basic Decontamination* below).

Rescuer Protection

If exposure levels are determined to be safe, decontamination may be conducted by personnel wearing a lower level of protection than that worn in the Hot Zone (described above).

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. Stabilize the cervical spine with a collar if trauma is suspected. Administer supplemental oxygen as required. Assist ventilation with a bag-valve-mask device if necessary.

Basic Decontamination

Victims who are able may assist with their own decontamination. Remove and double-bag contaminated clothing and personal belongings.

Flush liquid-exposed skin and hair with plain water for 3 to 5 minutes. Wash area thoroughly with soap and water when possible. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Irrigate exposed or irritated eyes with plain water or saline for 15 minutes. Remove contact lenses if easily removable without additional trauma to the eye. If pain or injury is evident, continue eye irrigation while transferring the victim to the Support Zone.

In cases of formalin ingestion, **do not induce emesis**. Victims who are conscious and able to swallow should be given 4 to 8 ounces of water or milk. Gastric lavage with a small bore NG tube should be considered if it can be performed within 1 hour after ingestion. The effectiveness of activated charcoal administration is unknown, but it is suggested following lavage (administer activated charcoal at 1 gm/kg, usual adult dose 60–90 g, child dose 25–50 g). A soda can and straw may be of assistance when offering charcoal to a child.

Consider appropriate management of chemically contaminated children at the exposure site. Also, provide reassurance to the child during decontamination, especially if separation from a parent occurs. If possible, seek assistance from a child separation expert.

Transfer to Support Zone

As soon as basic decontamination is complete, move the victim to the Support Zone.

Support Zone

Be certain that victims have been decontaminated properly (see *Decontamination Zone* above). Persons who have undergone decontamination or who have been exposed only to vapor pose no serious risks of secondary contamination. Support Zone personnel require no specialized protective gear in such cases.

ABC Reminders

Quickly access for a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Ensure adequate respiration and pulse. Administer supplemental oxygen as required and establish intravenous access if necessary. Place on a cardiac monitor. Watch for signs of airway swelling and obstruction such as progressive hoarseness, stridor, or cyanosis.

Additional Decontamination

Continue irrigating exposed skin and eyes, as appropriate.

In cases of formalin ingestion, **do not induce emesis**. If water has not been given previously, administer 4 to 8 ounces of milk or water if the patient is able to swallow.

Advanced Treatment

In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, perform cricothyroidotomy if equipped and trained to do so.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Formaldehyde poisoning is not known to pose additional risk during the use of bronchial or cardiac sensitizing agents.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine

solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Patients who are comatose, hypotensive, or have seizures or cardiac dysrhythmias should be treated according to advanced life support (ALS) protocols. Treat acidosis with intravenous sodium bicarbonate (adult dose = 1 ampule; pediatric dose = 1 Eq/kg). Further bicarbonate therapy should be guided by arterial blood gas (ABG) measurements. Hemodialysis should be considered in patients with severe acid-base disturbances that are refractory to conventional therapy or in cases with significant methanol levels.

If evidence of shock or hypotension is observed begin fluid administration. For adults, bolus 1,000 mL/hour intravenous saline or lactated Ringer's solution if blood pressure is under 80 mm Hg; if systolic pressure is over 90 mm Hg, an infusion rate of 150 to 200 mL/hour is sufficient. For children with compromised perfusion administer a 20 mL/kg bolus of normal saline over 10 to 20 minutes, then infuse at 2 to 3 mL/kg/hour. Follow with administration of dopamine (2 to 20 µg/kg/min) or norepinephrine (0.1 to 0.2 µg/kg/min), if necessary.

Transport to Medical Facility

Only decontaminated patients or patients not requiring decontamination should be transported to a medical facility. "Body bags" are not recommended.

Report to the base station and the receiving medical facility the condition of the patient, treatment given, and estimated time of arrival at the medical facility.

If formaldehyde has been ingested, prepare the ambulance in case the victim vomits toxic material. Have ready several towels and open plastic bags to quickly clean up and isolate vomitus.

Multi-Casualty Triage

If possible, consult with the base station physician or the regional poison control center for advice regarding triage of multiple victims.

Patients who have ingested formalin or have symptoms (e.g., severe wheezing or dyspnea) or obvious injuries (e.g., skin or eye burns) should be transported immediately to a medical facility for evaluation.

Patients who have no eye, skin, or throat irritation, or only mild or transient symptoms may be released from the scene after their names, addresses, and telephone numbers are recorded. Those

discharged should be advised to seek medical care promptly if symptoms develop (see *Patient Information Sheet* below).

Emergency Department Management

Hospital personnel in an enclosed area can be secondarily contaminated by direct contact, by vapors off-gassing from heavily soaked clothing, or from the vomitus of victims who have ingested formaldehyde. Patients do not pose serious contamination risks after contaminated clothing is removed and the skin is thoroughly washed.

Inhalation of formaldehyde can cause airway irritation, bronchospasm, and pulmonary edema.

Absorption of large amounts of formaldehyde via any route can cause severe systemic toxicity, leading to metabolic acidosis, tissue and organ damage, and coma.

There is no antidote for formaldehyde. Treatment consists of supportive measures including decontamination (flushing of skin and eyes with water, gastric lavage, and administration of activated charcoal), administration of supplemental oxygen, intravenous sodium bicarbonate and/or isotonic fluid, and hemodialysis.

Decontamination Area

Previously decontaminated patients and patients exposed only to formaldehyde vapor who have no skin or eye irritation may be transferred immediately to the Critical Care Area. Other patients will require decontamination as described below. Because formaldehyde is absorbed (although poorly) through the skin, don butyl rubber gloves and apron before treating patients. Formaldehyde readily penetrates most rubbers and barrier fabrics or creams, but butyl rubber provides good skin protection.

Be aware that use of protective equipment by the provider may cause fear in children, resulting in decreased compliance with further management efforts.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants absorbed through the skin. Also, emergency room personnel should examine children's mouths for corrosive injury because of the frequency of hand-to-mouth activity among children.

ABC Reminders

Evaluate and support airway, breathing, and circulation. Children may be more vulnerable to corrosive agents than adults because of the smaller diameter of their airways. In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, surgically create an airway.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in

situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Formaldehyde poisoning is not known to pose additional risk during the use of bronchial or cardiac sensitizing agents.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Patients who are comatose, hypotensive, or have seizures or ventricular dysrhythmias should be treated in the conventional manner.

Correct acidosis in the patient who has coma, seizures, or cardiac dysrhythmias by administering intravenously sodium bicarbonate (adult dose = 1 ampule; pediatric dose = 1 Eq/kg). Further bicarbonate therapy should be guided by ABG measurements. Hemodialysis should be considered in patients with severe acid-base disturbances that are refractory to conventional therapy or in cases with significant methanol levels.

If evidence of shock or hypotension is observed begin fluid administration. For adults, bolus 1,000 mL/hour intravenous saline or lactated Ringer's solution if blood pressure is under 80 mm Hg; if systolic pressure is over 90 mm Hg, an infusion rate of 150 to 200 mL/hour is sufficient. For children with compromised perfusion administer a 20 mL/kg bolus of normal saline over 10 to 20 minutes, then infuse at 2 to 3 mL/kg/hour. Follow with administration of dopamine (2 to 20 µg/kg/min) or norepinephrine (0.1 to 0.2 µg/kg/min), if necessary.

Basic Decontamination

Patients who are able may assist with their own decontamination.

Because contact with formalin may cause burns, ED staff should don chemical-resistant jumpsuits (e.g., of Tyvek or Saranex) or butyl rubber aprons, rubber gloves, and eye protection if the patient's clothing or skin is wet with formalin. After the patient has been decontaminated, no special protective clothing or equipment is required for ED personnel.

Quickly remove and double-bag contaminated clothing and personal belongings. Flush exposed skin and hair with water (preferably under a shower) for 5 minutes. If possible, wash hair and skin with soap and water, then rinse thoroughly with water. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Flush exposed eyes with water or saline for at least 15 minutes. Remove contact lenses if easily removable without additional trauma to the eye. An ophthalmic anesthetic, such as 0.5% tetracaine, may be necessary to alleviate blepharospasm, and lid retractors may be required to allow adequate irrigation under the eyelids. If pain or injury is evident, continue irrigation while transporting the patient to the Critical Care Area.

In cases of formalin ingestion, **do not induce emesis**. If water has not been given previously, administer 4 to 8 ounces if the patient is alert and able to swallow. The effectiveness of activated charcoal administration is unknown, but may be beneficial (if not administered previously) following lavage if it can be performed within 1 hour after ingestion (administer activated charcoal at 1 gm/kg, usual adult dose 60–90 g, child dose 25–50 g). A soda can and straw may be of assistance when offering charcoal to a child. (More information is provided in *Ingestion Exposure* under *Critical Care Area* below.)

Critical Care Area

Be certain that appropriate decontamination has been carried out (see *Decontamination Area* above).

ABC Reminders

Evaluate and support airway, breathing, and circulation as in *ABC Reminders* above. Children may be more vulnerable to corrosive agents than adults because of the relatively smaller diameter of their airways. Establish intravenous access in seriously ill patients if this has not been done previously. Continuously monitor cardiac rhythm.

Patients who are comatose, hypotensive, or have seizures or cardiac dysrhythmias should be treated in the conventional manner. Correct acidosis in the patient who has coma, seizures, or cardiac dysrhythmias by administering intravenously sodium bicarbonate (adult dose = 1 ampule; pediatric dose = 1 Eq/kg). Further bicarbonate therapy should be guided by ABG measurements. Hemodialysis should be considered in patients with severe acid-base disturbances that are refractory to conventional therapy or in cases with significant methanol levels.

If evidence of shock or hypotension is observed begin fluid administration. For adults, bolus 1,000 mL/hour intravenous saline or lactated Ringer's solution if blood pressure is under 80 mm Hg; if systolic pressure is over 90 mm Hg, an infusion rate of 150 to 200 mL/hour is sufficient. For children with compromised perfusion administer a 20 mL/kg bolus of normal saline over 10 to 20 minutes, then infuse at 2 to 3 mL/kg/hour. Follow with administration of dopamine (2 to 20 µg/kg/min) or norepinephrine (0.1 to 0.2 µg/kg/min), if necessary.

Inhalation Exposure

Administer supplemental oxygen by mask to patients who have respiratory complaints. Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Formaldehyde poisoning is not known to pose additional risk during the use of bronchial or cardiac sensitizing agents.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Observe patients who are in respiratory distress for up to 12 hours and periodically repeat chest examinations and order other appropriate studies. Follow up as clinically indicated.

Skin Exposure

If formalin or high concentrations of formaldehyde vapor were in contact with the skin, chemical burns may result; treat as thermal burns.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants absorbed through the skin.

Eye Exposure

Continue irrigation for at least 15 minutes. Test visual acuity. Examine the eyes for corneal damage and treat appropriately. Immediately consult an ophthalmologist for patients who have severe corneal injuries.

Ingestion Exposure

Do not induce emesis. Give 4 to 8 ounces of water to alert patients who can swallow if not done previously. If a large dose has been ingested and the patient's condition is evaluated within 30 minutes after ingestion, consider gastric lavage and endoscopy to evaluate the extent of corrosive injury to the gastrointestinal tract. Care must be taken when placing the gastric tube because blind gastric-tube placement may further injure the chemically damaged esophagus or stomach. Extreme throat swelling may require endotracheal intubation or cricothyriodotomy. The effectiveness of activated charcoal in binding formaldehyde is unknown, but may be beneficial (if not administered previously) following lavage if it can be performed within 1 hour after ingestion (administer activated charcoal at 1 gm/kg, usual adult dose 60–90 g, child dose 25–50 g). A soda can and straw may be of assistance when offering charcoal to a child.

Because children do not ingest large amounts of corrosive materials, and because of the risk of perforation from NG intubation, lavage is discouraged in children unless intubation is performed under endoscopic guidance.

Toxic vomitus or gastric washings should be isolated (e.g., by attaching the lavage tube to isolated wall suction or another closed container).

Antidotes and Other Treatments

There is no antidote for formaldehyde. Treat patients who have metabolic acidosis with sodium bicarbonate (adult dose = 1 ampule; pediatric dose = 1 Eq/kg). Further correction of acidosis should be guided by ABG measurements.

Hemodialysis is effective in removing formic acid (formate) and methanol and in correcting severe metabolic acidosis.

If methanol poisoning from ingestion of formalin is suspected, as indicated by a serum methanol level of greater than 20 mg/dL or elevated osmolal gap, start ethanol infusion. With 10% ethanol, the loading dose is 7.5 mL/kg body weight; maintenance dose is 1.0 to 1.5 mL/kg/hour; and maintenance dose during hemodialysis is 1.5 to 2.5 mL/kg/hour. In this setting, the target blood level of ethanol is 0.1 mg/dL.

Laboratory Tests

Routine laboratory studies for all exposed patients include CBC, glucose, and electrolyte determinations. Additional studies for patients exposed to formaldehyde include urinalysis (protein,

casts, and red blood cells may be present), methanol level, osmolal gap, and ABG measurements (to monitor acidosis in severe toxicity). Chest radiography and pulse oximetry may be helpful in cases of inhalation exposure. Plasma formaldehyde levels are not useful.

Disposition and Follow-up

Consider hospitalizing patients who have evidence of systemic toxicity from any route of exposure.

Delayed Effects

Patients who have substantial ingestion exposure may develop aspiration pneumonitis or renal failure and should be admitted to an intensive care unit for observation. Corrosive gastritis, fibrosis of the stomach (shrinkage and contracture), hematemesis, or edema and ulceration of the esophagus may occur.

Patients who have inhalation exposure and who complain of chest pain, chest tightness, or cough should be observed and examined periodically for 6 to 12 hours to detect delayed-onset bronchitis, pneumonia, pulmonary edema, or respiratory failure.

Formaldehyde poisoning can cause permanent alterations of nervous system function, including problems with memory, learning, thinking, sleeping, personality changes, depression, headache, and sensory and perceptual changes.

Patient Release

Patients who are asymptomatic should be observed for 4 to 6 hours, then discharged if no symptoms occur during this period. Advise discharged patients to seek medical care promptly if symptoms develop (see the *Formaldehyde—Patient Information Sheet* below).

Follow-up

Obtain the name of the patient's primary care physician so that the hospital can send a copy of the ED visit to the patient's doctor.

Patients with symptoms of seizures, convulsions, headache, or confusion, need to be followed for permanent central nervous system dysfunction with neurobehavioral toxicity testing, with particular attention to problems with memory, personality changes, and perceptual dysfunction.

Patients with injury to the mucous membranes of the respiratory or gastrointestinal tracts should be monitored for the development of ulceration or fibrosis.

Patients who have corneal injuries should be reexamined within 24 hours.

Reporting

If a work-related incident has occurred, you may be legally required to file a report; contact your state or local health department.

Other persons may still be at risk in the setting where this incident occurred. If the incident occurred in the workplace, discussing it with company personnel may prevent future incidents. If a public health risk exists, notify your state or local health department or other responsible public agency. When appropriate, inform patients that they may request an evaluation of their workplace from OSHA or NIOSH. See Appendices III and IV for a list of agencies that may be of assistance.

Formaldehyde
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to formaldehyde or formalin.

What is formaldehyde?

Formaldehyde is a nearly colorless, highly irritating gas with a sharp odor. It dissolves easily in water and is found in formalin (a solution of formaldehyde, water, and methanol). Formaldehyde is used in the manufacture of plastics; urea-formaldehyde foam insulation; and resins used to make construction materials (e.g., plywood), paper, carpets, textiles, paint, and furniture.

What immediate health effects can result from formaldehyde exposure?

Formaldehyde can cause irritation of the eyes, nose, and throat, even at low levels for short periods. Longer exposure or higher doses can cause coughing or choking. Severe exposure can cause death from throat swelling or from chemical burns to the lungs. Direct contact with the skin, eyes, or gastrointestinal tract can cause serious burns. Drinking as little as 30 mL (about 2 tablespoons) of formalin can cause death. Formate, a formaldehyde metabolite, can cause death or serious systemic effects. Generally, the more serious the exposure to formaldehyde, the more severe the symptoms. Previously sensitized persons may develop a skin rash or breathing problems from very small exposures.

Can formaldehyde poisoning be treated?

There is no antidote for formaldehyde, but its effects can be treated, and most exposed persons get well. Patients who have had a serious exposure (with signs and symptoms such as tearing eyes, running nose, or severe or persistent coughing) may need to be hospitalized. Patients with direct exposure to very concentrated vapors or liquid or who have swallowed formalin may require intensive hospital treatment and may experience long-term effects.

Are any future health effects likely to occur?

A single small exposure from which a person recovers quickly is not likely to cause delayed or long-term effects. After a severe exposure, some symptoms may not occur for up to 18 hours. See *Follow-up Instructions* for signs and symptoms to watch for. If any of them occur, seek medical care. Long-term, repeated exposure to formaldehyde in the workplace may cause cancer of the nasal passages.

What tests can be done if a person has been exposed to formaldehyde?

Specific tests for the presence of formaldehyde in blood or urine may be available, but the results generally are not useful to the doctor. If a severe exposure has occurred, blood and urine analyses and other tests may show whether the lungs have been injured or if systemic effects are possible. If seizures or convulsions have occurred neurobehavioral toxicity testing may be necessary. Testing is not needed in every case.

Where can more information about formaldehyde be found?

More information about formaldehyde can be obtained from your regional poison control center; your state, county, or local health department; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in occupational and environmental health. If the exposure happened at work, you may wish to discuss it with your employer, the Occupational Safety and Health Administration (OSHA), or the National Institute for Occupational Safety and Health (NIOSH). Ask the person who gave you this form for help in locating these telephone numbers.

Keep this page and take it with you to your next appointment. Follow *only* the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:

- coughing, difficulty breathing or shortness of breath
- chest pain, irregular heart beats
- increased pain or a discharge from your eyes
- increased redness or pain or a pus-like discharge in the area of a skin burn or other wound
- fever
- unexplained drowsiness, fatigue, or headache
- stomach pain, vomiting, or diarrhea

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.
[ ] Call for an appointment with Dr. _____ in the practice of _____.
When you call for your appointment, please say that you were treated in the Emergency Department at _ _____ Hospital by _____ and were advised to be seen again in _____ days.
[ ] Return to the Emergency Department/ _____ Clinic on (date) _____at ___ _____ AM/PM for a follow-up examination.
[ ] Do not perform vigorous physical activities for 1 to 2 days.
[ ] You may resume everyday activities including driving and operating machinery.
[ ] Do not return to work for _____ days.
[ ] You may return to work on a limited basis. See instructions below.
[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.
[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.
[ ] Avoid taking the following medications: _____
[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: __
_____
_____
[ ] Other instructions: _____
_____
_____

- Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.

- You or your physician can get more information on the chemical by contacting: _____ _____ or _____, or by checking out the following Internet Web sites: _____; _____.

Signature of patient _____ Date _____
Signature of physician _____ Date_____

Gasoline (Mixture)
CAS 86290-81-5 and 8006-61-9; UN 1203

Synonyms include gas, petrol, casing head gasoline, motor spirit, natural gasoline, and motor fuel.

Persons exposed only to gasoline vapors do not pose significant risks of secondary contamination; however, persons whose clothing or skin is contaminated with liquid gasoline can cause secondary contamination by direct contact or through off-gassing vapors.

Gasoline is a volatile, flammable liquid. It is colorless to pale brown or pink in color with a distinctive odor. Generally, the odor of gasoline provides adequate warning of hazardous concentrations. Its vapors may travel to a source of ignition and flash back. Gasoline vapors are heavier than air and may collect in low-lying areas.

The hydrocarbons in gasoline are readily absorbed by the lungs, less readily absorbed by the gastrointestinal tract, and poorly absorbed by intact skin. Skin burns may result from prolonged contact with gasoline.

Description

Gasoline is a mixture of petroleum hydrocarbons containing straight, branched, and cycloalkanes, which contain 5 to 18 carbons, olefins (alkenes), and aromatic hydrocarbons, including benzene, toluene, and xylenes. Gasoline vapors contain about 90% alkanes and 2% aromatics (0.9% benzene).

Various additives are blended into gasolines and may influence the properties and toxicity of specific gasoline samples (Table 1). In the United States, organic lead compounds were phased out as anti-knock additives in 1997 and are no longer used in commercial gasoline.

Table 1. Gasoline Additives

Octane enhancers	methyl *t*-butyl ether (MTBE)
	t-butyl alcohol (TBA)
	ethanol
	methanol
Antioxidants	butylated methyl, ethyl and dimethyl phenols
	various other phenols and amines

Metal deactivators	disalicylidene-*N*-methyl-dipropylene-triamine *N*,*N*'-disalicylidene-1,2-ethanediamine other related amines
Ignition controllers	tri-*o*-cresylphosphate (TOCP)
Icing inhibitors	isopropyl alcohol
Detergents/dispersants	various phosphates, amines, phenols, alcohols and carboxylic acids
Corrosion inhibitors	carboxylic, phosphoric and sulfonic acids

At room temperature, gasoline is a colorless to pale brown or pink liquid with a wide range of boiling points: 90 °F to 399 °F (39 °C to 204 °C). Many of the hydrocarbons found in gasoline vaporize readily at room temperature. Gasoline is flammable at temperatures above -51 °F (-46 °C). Most of the hydrocarbons in gasoline are insoluble in water and soluble in some organic solvents.

Routes of Exposure

Inhalation

Inhalation is a common route of exposure to gasoline. Generally, gasoline's odor provides adequate warning of hazardous concentrations. The odor threshold is 0.025 ppm. Its vapors are heavier than air and may cause asphyxiation in enclosed, poorly ventilated, or low-lying areas.

Children exposed to the same levels of gasoline vapor as adults may receive larger doses because they have greater lung surface area:body weight ratios and increased minute volumes:weight ratios. In addition, they may be exposed to higher levels than adults in the same location because of their short stature and the higher levels of gasoline vapor found nearer to the ground.

Skin/Eye Contact

Gasoline vapors are mildly irritating to mucous membranes; however, gasoline splashed in the eyes can result in transient corneal injury. Repeated or prolonged skin contact with liquid gasoline can degrease the skin, causing irritation and dermatitis. First- and second-degree skin burns can occur from continuous contact with liquid gasoline for several hours. Percutaneous absorption is slow.

Ingestion

Gasoline is not as readily absorbed from the gastrointestinal tract as from the respiratory tract. In adults, about 20 to 50 g can cause severe intoxication and 350 g (12 oz.) can result in death for a 70 kg individual. As little as 10 to 15 g (less than one-half

ounce) may be fatal in children. Symptoms of intoxication by ingestion of gasoline can range from vomiting, vertigo, drowsiness and confusion to loss of consciousness, convulsions, hemorrhaging of the lungs and internal organs, and death due to circulatory failure. Ingestion can cause irritation to the gastrointestinal mucosa and can be complicated by pulmonary aspiration, resulting in chemical pneumonitis.

Sources/Uses

Gasoline is produced by the distillation, cracking, and reforming of crude oil. Various additives influence use and physical properties of the mixture. Gasoline's primary use is as a fuel for reciprocating, spark ignition, and internal combustion engines in automobiles, trucks, and light aircraft.

Standards and Guidelines

ACGIH (TLV-TWA) = 300 ppm (averaged over an 8-hour workshift)

Physical Properties

Description: Clear, pale brown or pink volatile liquid

Warning properties: Characteristic pungent odor at <l ppm; adequate warning for acute and chronic exposure

Molecular weight: Varies by composition; average molecular weight = 108 daltons

Boiling point (760 mm Hg): Varies by composition; >90 °F (>32 °C)

Freezing point: Varies by composition

Specific Gravity: 0.8 (water = 1)

Vapor pressure: Varies by composition; 773 mm Hg at 41 °C

Vapor density: 3 to 4 (air = 1)

Water solubility: Practically insoluble in water

Flammability: Flammable at temperatures >-51 °F (-46 °C)

Flammable range: 1.4% to 7.4% (concentration in air). Vapors may travel to a source of ignition and flash back.

Incompatibilities

Gasoline reacts with strong oxidizers such as peroxides, nitric acid, and perchlorates.

Health Effects

Gasoline is a mild skin, eye, and respiratory tract irritant. Ingestion of gasoline causes mild to severe irritation to the gastrointestinal mucosa; chemical pneumonitis is often severe. Systemic effects of gasoline exposure are mainly a result of CNS depression.

- **Systemic effects can occur from all routes of exposure. Exposure to low concentrations may produce flushing of the face, staggering gait, slurred speech, and mental confusion. Higher concentrations may result in unconsciousness, coma, and possible death due to respiratory failure.**
- **Gasoline vapors sensitize the myocardium which may result in ventricular fibrillation. Delayed effects may include hemorrhage of the pancreas and fatty degeneration of the liver and of the proximal convoluted tubules and glomeruli of the kidneys.**

Acute Exposure

Most adverse health effects from acute exposure to gasoline are caused by the hydrocarbon component. However, persons who have repeated or massive exposure (e.g., inhalation abuse, prolonged skin contact) to leaded gasoline may develop lead poisoning (lead is no longer added to gasoline in the United States). Immediate effects of exposure to gasoline are primarily due to pulmonary injury and CNS depression. Other systemic effects may develop over several hours. Components of gasoline probably crosses the placenta and may be excreted in breast milk.

Children do not always respond to chemicals in the same way that adults do. Different protocols for managing their care may be needed.

CNS

Acute gasoline exposure can cause transient CNS excitation followed by CNS depression. Confusion, giddiness, nausea, headache, blurred vision, dizziness, and weakness can occur. In massive exposures, rapid CNS depression, respiratory depression, seizures, loss of consciousness, coma, and death have been reported.

Respiratory

Gasoline can irritate the mucous membranes of the respiratory tract. Pulmonary congestion, edema, acute exudative tracheobronchitis, and intrapulmonary hemorrhage have been reported in severe exposures. Pulmonary aspiration of ingested gasoline may cause pneumonitis.

Exposure to certain chemicals can lead to Reactive Airway Dysfunction Syndrome (RADS), a chemically- or irritant-induced type of asthma.

Children may be more vulnerable because of relatively increased minute ventilation per kg and failure to evacuate an area promptly when exposed.

Hydrocarbon pneumonitis may be a problem in children.

Cardiovascular Gasoline vapors sensitize the myocardium to circulating epinephrine which may cause potentially fatal ventricular fibrillation.

Renal Inhalation of massive amounts of gasoline may result in fatty degeneration of the proximal convoluted tubules and glomeruli and renal failure. Ingestion of gasoline has been reported to cause oliguria, tubular necrosis, interstitial edema, hematuria, reduced creatinine clearance and elevated serum creatinine, elevated urinary protein, glucose, and hemoglobin, and elevated BUN.

Gastrointestinal Damage to the digestive tract following ingestion of gasoline may include severe esophagitis, gastritis, degeneration of the epithelium, and mucositis of the oral cavity.

Dermal Gasoline vapors can cause inflammation of the skin. Prolonged contact with liquid gasoline causes significant irritation (i.e., irritant contact dermatitis), degreasing, and burns. Redness and blisters may occur.

Ocular Eye irritation from gasoline vapors begins at about 200 ppm. Inflammation is generally slight. When splashed in the eye, gasoline may cause burning pain and transient corneal injury. Chronic exposure to gasoline may cause damage to the cornea, retina, and ciliary body.

Potential Sequelae Acute hydrocarbon-induced CNS depression generally is completely reversible after exposure ceases unless the episode has been complicated by lack of oxygen. Acute renal toxicity may persist for several weeks following ingestion of gasoline, but usually resolves with treatment. Chronic lung dysfunction may result from pulmonary aspiration.

Chronic Exposure No health effects are expected from normal use of gasoline as a fuel. Chronic, excessive exposure such as occurs in intentional gasoline abuse (sniffing) can cause irritability, tremor, nausea,

insomnia, loss of memory, drowsiness, mental dullness, confusion, seizures, muscle spasms, altered vision, hallucinations, impaired gait, inflammation of the optic nerve, dizziness, and involuntary eye movements. Some of these effects may be due to lead or other additives in gasoline (lead is no longer added to gasoline in the United States). Sudden deaths have been reported.

Chronic abuse of gasoline may cause kidney disease (i.e., renal tubular dysfunction). Nerve disorders, causing motor weakness and muscular degeneration, can also occur in gasoline abusers. Abuse of leaded gasoline has been reported to cause brain disease (i.e., lead encephalopathy) (lead is no longer added to gasoline in the United States). Behavioral and intellectual changes, including immediate and delayed visual memory and perception, psychomotor disturbances, and visuomotor learning ability, have been reported (probably involving leaded gasoline). Chronic exposure may be more serious for children because of their potential longer latency period.

Degreasing dermatitis with skin cracking and peeling results when skin has repeated or prolonged contact with gasoline.

Carcinogenicity

The International Agency for Research on Cancer has classified gasoline in Group 2B, possibly carcinogenic to humans. The classification is based on inadequate evidence of carcinogenicity in humans and limited evidence for carcinogenicity in experimental animals.

Reproductive and Developmental Effects

The hydrocarbons found in gasoline can cross the placenta. There is no direct evidence that maternal exposure to gasoline causes fetotoxic or teratogenic effects. Gasoline is not included in *Reproductive and Developmental Toxicants*, a 1991 report published by the U.S. General Accounting Office (GAO) that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences.

Special consideration regarding the exposure of pregnant women is warranted, since gasoline may be a genotoxin; thus, medical counseling is recommended for the acutely exposed pregnant woman.

Prehospital Management

Victims exposed only to gasoline vapors do not pose contamination risks to rescuers. Victims whose clothing or skin is contaminated with liquid gasoline can secondarily contaminate response personnel by direct contact or through off-gassing vapors.

Gasoline is a skin, eye, and respiratory-tract irritant and a CNS depressant in acute exposures. Pulmonary aspiration of even small amounts of ingested gasoline can cause chemical pneumonitis. Systemic effects may also include renal failure, and increased susceptibility to ventricular fibrillation.

There is no antidote for gasoline poisoning. Treatment consists of support of cardiovascular and respiratory functions.

Hot Zone

Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if rescuers have not been trained in its use, assistance should be obtained from a local or regional HAZMAT team or other properly equipped response organization.

Rescuer Protection

Gasoline vapors are mild respiratory-tract irritants that are absorbed well by inhalation. The liquid is a mild skin irritant with slow skin absorption.

Respiratory Protection: Positive-pressure, self-contained breathing apparatus (SCBA) is recommended in response situations that involve exposure to potentially unsafe levels of gasoline vapors.

Skin Protection: Chemical-protective clothing is not generally required when only vapor exposure is expected because gasoline vapors are neither irritating to skin nor absorbed well through the skin. Chemical-protective clothing is recommended when repeated or prolonged contact with liquid gasoline is anticipated because skin irritation and dermal absorption may occur.

Gasoline is highly flammable and explosive. In case of fire, SCBA and chemical-protective clothing will provide limited or no thermal protection. Any clothing that produces a static charge potential exceeding 3,000 volts can cause the ignition of gasoline-air mixtures.

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical

immobilization manually and apply a cervical collar and a backboard when feasible.

Victim Removal

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be removed on backboards or gurneys; if these are not available, carefully carry or drag victims to safety.

Consider appropriate management of chemically contaminated children, such as measures to reduce separation anxiety if a child is separated from a parent or other adult.

Decontamination Zone

Patients exposed only to gasoline vapors who have no skin or eye irritation may be transferred immediately to the Support Zone. Other patients will require decontamination as described below.

Rescuer Protection

If exposure levels are determined to be safe, decontamination may be conducted by personnel wearing a lower level of protection than that worn in the Hot Zone (described above).

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. Stabilize the cervical spine with a collar and a backboard if trauma is suspected. Administer supplemental oxygen as required. Assist ventilation with a bag-valve-mask device if necessary.

Basic Decontamination

Victims who are able may assist with their own decontamination. Remove and double-bag contaminated clothing and personal belongings.

Flush exposed skin and hair with plain water for 2 to 3 minutes, then wash with mild soap. Rinse thoroughly with water.Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Irrigate exposed or irritated eyes with plain water or saline for 15 minutes. Remove contact lenses if easily removable without additional trauma to the eye.

In cases of ingestion, **do not induce emesis or use gastric lavage** and do not administer activated charcoal. Gasoline is poorly absorbed from the stomach. Catharsis with magnesium or sodium sulfate is acceptable. If spontaneous vomiting occurs, watch for signs of pulmonary aspiration.

Consider appropriate management of chemically contaminated children at the exposure site. Also, provide reassurance to the child during decontamination, especially if separation from a parent occurs. If possible, seek assistance from a child separation expert.

Transfer to Support Zone

As soon as basic decontamination is complete, move the victim to the Support Zone.

Support Zone

Be certain that victims have been decontaminated properly (see *Decontamination Zone* above). Victims who have undergone decontamination or who have been exposed only to vapor pose no serious risks of secondary contamination to rescuers. In such cases, Support Zone personnel require no specialized protective gear.

ABC Reminders

Quickly access for a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Ensure adequate respiration and pulse. Administer supplemental oxygen as required and establish intravenous access if necessary. Place on a cardiac monitor.

Additional Decontamination

Continue irrigating exposed skin and eyes, as appropriate.

In cases of ingestion, **do not induce emesis or use gastric lavage** and do not administer activated charcoal. Gasoline is poorly absorbed from the stomach. Catharsis with magnesium or sodium sulfate is acceptable. If spontaneous vomiting occurs, watch for signs of pulmonary aspiration.

Advanced Treatment

In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, perform cricothyroidotomy if equipped and trained to do so.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. **Do not administer epinephrine or related substances** because they may induce cardiac arrhythmias.

Patients who are comatose, hypotensive, or are having seizures or cardiac arrhythmias should be treated according to advanced life support (ALS) protocols.

If evidence of shock or hypotension is observed begin fluid administration. For adults, bolus 1,000 mL/hour intravenous saline or lactated Ringer's solution if blood pressure is under 80 mm Hg; if systolic pressure is over 90 mm Hg, an infusion rate of 150 to 200 mL/hour is sufficient. For children with compromised perfusion administer a 20 mL/kg bolus of normal saline over 10 to 20 minutes, then infuse at 2 to 3 mL/kg/hour.

Transport to Medical Facility

Only decontaminated patients or patients not requiring decontamination should be transported to a medical facility. "Body bags" are not recommended.

Report to the base station and the receiving medical facility the condition of the patient, treatment given, and estimated time of arrival at the medical facility.

If gasoline has been ingested, prepare the ambulance in case the victim vomits toxic material. Have ready several towels and open plastic bags to quickly clean up and isolate vomitus.

Multi-Casualty Triage

Consult with the base station physician or the regional poison control center for advice regarding triage of multiple victims.

Patients who have evidence suggesting substantial exposure (e.g., coughing or coma) should be transported to a medical facility for evaluation.

Patients without significant symptoms may be discharged at the scene after their names, addresses, and telephone numbers are recorded. Those discharged should be advised to seek medical care promptly if symptoms develop or recur (see the *Patient Information Sheet* below).

Emergency Department Management

Patients do not pose risks of secondary contamination if they have been exposed only to gasoline vapors. However, hospital personnel in an enclosed area can be secondarily contaminated by vapors off-gassing from heavily soaked clothing or skin or from vomitus. Patients do not pose serious contamination risks after contaminated clothing is removed and the skin is thoroughly washed.

Gasoline is a mild skin, eye, and respiratory tract irritant and a CNS depressant in acute exposures. Pulmonary aspiration of even small amounts of ingested gasoline can cause chemical pneumonitis. Systemic effects may also include renal failure and increased susceptibility to ventricular fibrillation.

There is no antidote for gasoline. Treatment consists of support of respiratory and cardiovascular functions.

Decontamination Area

Patients who have been decontaminated previously and patients exposed only to gasoline vapors who have no skin or eye irritation may be transferred immediately to the Critical Care Area. All other patients will require decontamination as described below.

Be aware that use of protective equipment by the provider may cause fear in children, resulting in decreased compliance with further management efforts.

ABC Reminders

Evaluate and support airway, breathing, and circulation. In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, surgically create an airway.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. **Do not administer epinephrine or related substances** because they may induce cardiac arrhythmias.

Patients who are comatose, hypotensive, or having seizures or cardiac arrhythmias should be treated in the conventional manner.

Basic Decontamination

Patients who are able and cooperative may assist with their own decontamination. If the patient's clothing is wet with gasoline,

remove and double-bag the contaminated clothing and personal belongings.

Flush exposed skin and hair with plain water for 2 to 3 minutes (preferably under a shower), then wash with mild soap. Rinse thoroughly with water. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Irrigate exposed eyes with plain water or saline for 15 minutes. Remove contact lenses if easily removable without additional trauma to the eye. If pain or injury is evident, continue irrigation while transferring the patient to the Critical Care Area.

In cases of ingestion, **do not induce emesis or use gastric lavage** or administer activated charcoal. Gasoline is poorly absorbed through the stomach. Spontaneous vomiting may occur. If the patient is coughing or dyspneic, pulmonary aspiration may have occurred. Treat accordingly.

Critical Care Area

Be certain that appropriate decontamination has been carried out (see *Decontamination Area* above).

ABC Reminders

Evaluate and support airway, breathing, and circulation as in ABC Reminders above. Children may be more vulnerable to corrosive agents than adults because of the relatively smaller diameter of their airways. Establish intravenous access in seriously symptomatic patients if this has not been done previously. Continuously monitor cardiac rhythm.

Patients who are comatose, hypotensive, or having seizures or cardiac arrhythmias should be treated in the conventional manner.

Inhalation Exposure

Administer supplemental oxygen by mask to patients who have respiratory symptoms. Patients in respiratory distress or who have abnormal pulmonary examination will require pulse oximetry (or ABG measurements) and chest radiography.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. **Do not administer epinephrine or related substances** because they may induce cardiac arrhythmias.

Skin Exposure

If liquid gasoline comes in contact with the skin for a prolonged period, chemical burns may occur; treat as thermal burns.

Eye Exposure

Ensure that adequate eye irrigation has been completed. If eye irritation or injury is evident, test visual acuity. Examine the eyes for corneal damage and treat appropriately. Immediately consult an ophthalmologist for patients who have severe corneal injuries.

Ingestion Exposure

Do not induce emesis or use gastric lavage or administer activated charcoal. Gasoline is poorly absorbed through the stomach. Spontaneous vomiting and diarrhea may occur. If the patient is coughing or dyspneic, pulmonary aspiration may have occurred. Treat accordingly.

Toxic vomitus should be isolated in a closed container.

Antidotes and Other Treatments

There is no antidote for gasoline. Treatment is supportive.

Laboratory Tests

Routine laboratory studies for all exposed patients include CBC, glucose, and electrolyte determinations. Additional studies for patients exposed to gasoline include ECG monitoring and renal-function tests. Chest radiography and pulse oximetry (or ABG measurements) are recommended for severe inhalation exposure or if pulmonary aspiration is suspected.

Identification or measurement of hydrocarbons in blood is not clinically useful; however, such tests may be used to document exposure.

Disposition and Follow-up

Consider hospitalizing patients who have had significant oral or inhalation exposure and patients who have symptoms of chemical pneumonitis.

Delayed Effects

Patients who have ingested gasoline should be observed for at least 6 hours for signs of chemical pneumonitis. Systemic effects may develop over several hours and may include hemorrhage of the pancreas and fatty degeneration of the liver and of the proximal convoluted tubules and glomeruli of the kidneys. Acute renal toxicity may persist for several weeks following ingestion of gasoline but usually resolves with treatment.

Patient Release

Patients who are asymptomatic for 6 to 8 hours may be discharged and advised to seek medical care promptly if symptoms develop (see the *Gasoline—Patient Information* below).

Follow-up

Obtain the name of the patient's primary care physician so that the hospital can send a copy of the ED visit to the patient's doctor.

Patients who have aspirated gasoline should receive follow-up pulmonary function tests.

Acute renal toxicity may persist for several weeks following ingestion of gasoline but usually resolves with treatment.

Patients who have corneal injuries should be reexamined within 24 hours.

Reporting

If a work-related incident has occurred, you may be legally required to file a report; contact your state or local health department.

Other persons may still be at risk in the setting where this incident occurred. If the incident occurred in the workplace, discussing it with company personnel may prevent future incidents. If a public health risk exists, notify your state or local health department or other responsible public agency. When appropriate, inform patients that they may request an evaluation of their workplace from OSHA or NIOSH. See Appendices III and IV for a list of agencies that may be of assistance.

Gasoline
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to gasoline.

What is gasoline?
At room temperature, gasoline is a clear to pale brown or pink liquid that contains a mixture of hydrocarbons (from crude oil) with a variety of substances added to improve its performance as a fuel. It is used as a fuel in cars, trucks, and light aircraft.

What immediate health effects can be caused by exposure to gasoline?
Breathing gasoline vapor can cause headache, nausea, and dizziness. Extremely high levels can cause fainting and even death. Gasoline in the air can also irritate the eyes, nose, and throat. Gasoline splashed in the eyes can cause eye injury. Swallowing gasoline can cause irritation of the gastric tract and breathing difficulties. When liquid gasoline contacts the skin, it may cause redness and blisters. Generally, the longer the exposure or the greater level of exposure, the more severe the symptoms.

Can gasoline poisoning be treated?
There is no antidote for gasoline poisoning, but its effects can be treated, and most exposed persons get well. Persons who have experienced serious symptoms may need to be hospitalized.

Are any future health effects likely to occur?
A single small exposure from which a person recovers quickly is not likely to cause delayed or long-term effects. Repeated exposure to very high levels of gasoline can cause poor appetite, weakness, and even brain or kidney damage. Gasoline contains benzene and other additives that may cause future health problems after repeated, high-level exposures.

What tests can be done if a person has been exposed to gasoline?
Specific tests for the presence of gasoline in blood generally are not useful to the doctor. If a severe exposure has occurred, blood and urine analyses and other tests may show whether the nervous system, heart, kidneys, liver, or lungs have been damaged. Testing is not needed in every case.

Where can more information about gasoline be found?
More information about gasoline can be obtained from your regional poison control center; your state, county, or local health department; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in occupational and environmental health. If the exposure happened at work, you may wish to discuss it with your employer, the Occupational Safety and Health Administration (OSHA), or the National Institute for Occupational Safety and Health (NIOSH). Ask the person who gave you this form for help in locating these telephone numbers.

Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow *only* the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:

- stomach pain or vomiting
- coughing, wheezing, or shortness of breath
- confusion or fainting
- increased pain or a discharge from exposed eyes
- increased redness pain or a pus-like discharge in the area of a skin burn
- lack of or infrequent urination

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.
[ ] Call for an appointment with Dr. _____ in the practice of _____.
When you call for your appointment, please say that you were treated in the Emergency Department at _ _____ Hospital by _____ and were advised to be seen again in _____ days.
[ ] Return to the Emergency Department/ _____ Clinic on (date) _____at ___ _____ AM/PM for a follow-up examination.
[ ] Do not perform vigorous physical activities for 1 to 2 days.
[ ] You may resume everyday activities including driving and operating machinery.
[ ] Do not return to work for _____ days.
[ ] You may return to work on a limited basis. See instructions below.
[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.
[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.
[ ] Avoid taking the following medications: _____
[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: __
_____
_____
[ ] Other instructions: _____
_____
_____

- Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.

- You or your physician can get more information on the chemical by contacting: _____ _____ or _____, or by checking out the following Internet Web sites: _____; _____.

Signature of patient _____ Date _____

Signature of physician _____ Date _____

Hydrogen Chloride (HCl)
CAS 7647-01-0; UN 1050 (anhydrous), UN 1789 (solution), UN 2186 (refrigerated liquefied gas)

Synonyms for an aqueous solution of hydrogen chloride include chlorohydric acid, hydrochloric acid, and muriatic acid.

Persons exposed only to hydrogen chloride gas do not pose significant risks of secondary contamination. Persons whose clothing or skin is contaminated with hydrochloric acid can cause secondary contamination by direct contact or through off-gassing vapor.

Hydrogen chloride is a colorless, corrosive, nonflammable gas that fumes in air. It has a characteristic pungent odor. It is heavier than air and may accumulate in low-lying areas.

Hydrogen chloride is not absorbed through the skin, but when hydrogen chloride gas comes in contact with moisture, it forms hydrochloric acid, which is corrosive and can cause irritation and burns.

Description

At room temperature, hydrogen chloride is a colorless to slightly yellow gas with a pungent odor. On exposure to air, the gas forms dense white vapors due to condensation with atmospheric moisture. The vapor is corrosive, and air concentrations above 5 ppm can cause irritation.

Hydrogen chloride is available commercially as an anhydrous gas or as aqueous solutions (hydrochloric acid). Commercial concentrated hydrochloric acid contains 36% to 38% hydrogen chloride in water. Aqueous solutions generally are colorless but may be yellow due to traces of iron, chlorine, and organic impurities.

Routes of Exposure

Inhalation

Inhalation is an important route of exposure to hydrogen chloride. Its odor and highly irritating properties generally provide adequate warning for acute, high-level exposures. However, only 50% of exposed persons can perceive hydrogen chloride's odor at the OSHA permissible exposure limit (5 ppm), and **odor may not provide adequate warning in the workplace**. Hydrogen chloride vapor is heavier than air and may cause asphyxiation in enclosed, poorly ventilated, or low-lying areas.

Children exposed to the same levels of hydrogen chloride as adults may receive larger dose because they have greater lung surface area:body weight ratios and increased minute volumes:weight ratios. In addition, they may be exposed to higher levels than adults in the same location because of their short stature and the higher levels of hydrogen chloride found nearer to the ground.

Skin/Eye Contact

Hydrogen chloride is not absorbed through the skin. Direct contact with aqueous solutions of hydrogen chloride or with concentrated vapor can cause severe chemical burns.

Children are more vulnerable to toxicants affecting the skin because of their relatively larger surface area:body weight ratio.

Ingestion

Ingestion of concentrated hydrochloric acid can cause severe corrosive injury to the lips, mouth, throat, esophagus, and stomach.

Sources/Uses

Hydrogen chloride is produced commercially by any of the following reactions: heated hydrogen gas with calcium chloride, sulfuric acid with sodium chloride, sodium chloride with sulfur dioxide and steam, and hydrogen burned in chlorine. Hydrogen chloride can be formed during the combustion of many plastics. Hydrochloric acid (muriatic acid) is a component of commercial chemicals used to clean and disinfect swimming pools.

Hydrogen chloride is used for cleaning, pickling, and electroplating metals; in refining mineral ores; in petroleum well extraction; in leather tanning; and in the refining of fats, soaps, and edible oils. It is also used in producing polymers and plastics, rubber, fertilizers, dyes, dyestuffs, and pigments.

Standards and Guidelines

OSHA PEL (permissible exposure limit) = 5 ppm (ceiling)

NIOSH IDLH (immediately dangerous to life or health) = 50 ppm

AIHA ERPG-2 (emergency response planning guideline) (maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms which could impair an individual's ability to take protective action) = 20 ppm

Physical Properties

Description: Colorless-to-slightly yellow gas

Warning properties: Sharp, choking odor. Air odor threshold is 0.77 ppm, but only 50% of distracted exposed persons can perceive hydrogen chloride's odor at 5 ppm.

Molecular weight: 36.5 daltons

Boiling point (760 mm Hg): = -121 °F (-85 °C)

Freezing point: -174 °F (-114 °C)

Vapor pressure: 30,780 mm Hg at 68 °F (20 °C)

Gas density: 1.3 (air = 1)

Water solubility: 67% at 68 °F (20 °C)

Flammability: Not flammable

Incompatibilities

Hydrogen chloride is highly corrosive to most metals. It also reacts with hydroxides, amines, and alkalies.

Health Effects

- **Concentrated hydrogen chloride can be corrosive to the skin, eyes, nose, mucous membranes, and respiratory and gastrointestinal tracts.**
- **Inhalation of hydrogen chloride can lead to pulmonary edema. Ingestion can cause severe injury to the mouth, throat, esophagus, and stomach.**
- **Other effects of exposure include shock, circulatory collapse metabolic acidosis, and respiratory depression.**

Acute Exposure

Hydrogen chloride is a strong mineral acid; its corrosive and irritant properties are the primary concern in both acute and chronic exposures.

Children do not always respond to chemicals in the same way that adults do. Different protocols for managing their care may be needed.

Respiratory

Hydrogen chloride gas is intensely irritating to the mucous membranes of the nose, throat, and respiratory tract. Brief exposure to 35 ppm causes throat irritation, and levels of 50 to 100 ppm are barely tolerable for 1 hour. The greatest impact is on the upper respiratory tract; exposure to high concentrations can rapidly lead to swelling and spasm of the throat and suffocation.

Most seriously exposed persons have immediate onset of rapid breathing, blue coloring of the skin, and narrowing of the bronchioles. Patients who have massive exposures may develop an accumulation of fluid in the lungs.

Exposure to hydrogen chloride can lead to Reactive Airway Dysfunction Syndrome (RADS), a chemically- or irritant-induced type of asthma.

Children may be more vulnerable to corrosive agents than adults because of the relatively smaller diameter of their airways. Children may also be more vulnerable to gas exposure because of increased minute ventilation per kg and failure to evacuate an area promptly when exposed.

Metabolic

A rare and unusual complication of ingestion of high levels of hydrogen chloride is an increase in the concentration of chloride ions in the blood, causing an acid-base imbalance.

Because of their higher metabolic rates, children may be more vulnerable to toxicants interfering with basic metabolism.

Dermal

Deep burns of the skin and mucous membranes are caused by contact with concentrated hydrochloric acid or hydrogen chloride gas; disfiguring scars may result. Contact with less concentrated acid or with vapor or mist can cause redness of the skin and mild inflammation.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants affecting the skin.

Ocular

Exposure of the eyes to concentrated hydrogen chloride vapor or hydrochloric acid can cause corneal cell death, cataracts, and glaucoma. Exposure to dilute solutions can cause stinging pain and injuries such as ulcers of the eye surface.

Gastrointestinal

Ingesting concentrated hydrochloric acid can cause pain, difficulty swallowing, nausea, and vomiting.

Ingestion of concentrated hydrochloric acid can also cause severe corrosive injury to the mouth, throat esophagus, and stomach, with bleeding, perforation, scarring, or stricture formation as potential sequelae.

Cardiovascular

Ingestion of concentrated hydrochloric acid or massive skin exposure to either hydrochloric acid or hydrogen chloride gas may cause low blood pressure as a result of gastrointestinal bleeding or fluid displacement. After acute exposure, pulmonary function generally returns to baseline in 7 to 14 days.

Potential Sequelae

Although complete recovery is usual, symptoms and prolonged pulmonary deficits can persist. Patients may develop Reactive Airways Dysfunction Syndrome (RADS).

Patients who have ingested hydrochloric acid may experience scarring of the esophagus or stomach, which can cause narrowing, difficulty swallowing, or gastric outlet obstruction.

Chronic Exposure

Chronic or prolonged exposure to hydrogen chloride gas (above the OSHA PEL) or to mist has been associated with changes in pulmonary function, chronic inflammation of the bronchi, nasal ulceration, and symptoms resembling acute viral infection of the upper respiratory tract as well as inflammation of the skin, discoloration and erosion of dental enamel, and inflammation of the eye membrane.

Carcinogenicity

Hydrogen chloride has not been classified for carcinogenic effects.

Reproductive and Developmental Effects

The reproductive hazards of hydrogen chloride to humans are unknown. Few studies have been directed at reproductive effects in experimental animals exposed to hydrogen chloride. No data were located pertaining to maternal transfer of hydrogen chloride through the placenta or in breast milk Hydrogen chloride is not included in *Reproductive and Developmental Toxicants*, a 1991 report published by the U.S. General Accounting Office (GAO) that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences.

Prehospital Management

Victims exposed only to hydrogen chloride gas and whose skin and clothing appear dry do not pose risks of secondary contamination to rescuers. However, victims exposed to hydrochloric acid or hydrogen chloride whose clothing or skin is moist or wet can secondarily contaminate response personnel by direct contact or through off-gassing vapor.

High concentrations of hydrogen chloride can cause corrosive injury to all exposed body tissues. When inhaled, it can result in upper respiratory tract irritation, leading to laryngeal edema, laryngeal spasm, and asphyxia. Concentrated hydrochloric acid causes similar corrosive injury to the skin and, if ingested, can cause severe corrosive injury to the mouth, throat, esophagus, and stomach.

There is no antidote for hydrogen chloride poisoning. Treatment consists of support of respiratory and cardiovascular functions.

Hot Zone

Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if rescuers have not been trained in its use, assistance should be obtained from a local or regional HAZMAT team or other properly equipped response organization.

Rescuer Protection

Hydrogen chloride gas is a severe respiratory-tract and skin irritant that forms a strong acid (hydrochloric acid) on contact with water.

Respiratory Protection: Positive-pressure, self-contained breathing apparatus (SCBA) is recommended in response situations that involve exposure to potentially unsafe levels of hydrogen chloride.

Skin Protection: Chemical-protective clothing is recommended because hydrogen chloride can cause skin irritation and burns.

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible.

Victim Removal

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be removed on backboards or gurneys; if these are not available, carefully carry or drag victims to safety.

Consider appropriate management of chemically contaminated children, such as measures to reduce separation anxiety if a child is separated from a parent or other adult.

Decontamination Zone

Victims exposed only to hydrogen chloride gas who have no skin or eye irritation do not need decontamination; they may be transferred immediately to the Support Zone. All others require decontamination as described below.

Rescuer Protection

If exposure levels are determined to be safe, decontamination may be conducted by personnel wearing a lower level of protection than that worn in the Hot Zone (described above).

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. Stabilize the cervical spine with a collar and a backboard if trauma is suspected. Administer supplemental oxygen as required. Assist ventilation with a bag-valve-mask device if necessary.

Basic Decontamination

Victims who are able may assist with their own decontamination. Remove contaminated clothing while flushing exposed skin and hair with water for 3 to 5 minutes, wash thoroughly with soap and water. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate. Double-bag contaminated clothing and personal belongings.

Flush exposed or irritated eyes with tepid plain water or saline for 15 minutes. Eye irrigation should be carried out simultaneously with other basic care and transport. Remove contact lenses if easily removable without additional trauma to the eye.

In cases of ingestion, **do not induce emesis**. **Do not administer activated charcoal or attempt to neutralize stomach contents**. Victims who are conscious and able to swallow should be given 4 to 8 ounces of water or milk. (Children's dose is 2 to 4 ounces.)

Consider appropriate management of chemically contaminated children, such as measures to reduce separation anxiety if a child is separated from a parent or other adult. If possible, seek assistance from a child separation expert.

Transfer to Support Zone

As soon as basic decontamination is complete, move the victim to the Support Zone.

Support Zone

Be certain that victims have been decontaminated properly (see *Decontamination Zone* above). Victims who have undergone decontamination or who have been exposed only to gas and who have no symptoms of skin or eye irritation pose no serious risk of secondary contamination. In such cases, Support Zone personnel require no specialized protective gear.

ABC Reminders

Quickly access for a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Ensure adequate respiration and pulse. Administer supplemental oxygen as required and establish intravenous access if necessary. Place on a cardiac monitor.

Additional Decontamination

Continue irrigating exposed skin and eyes, as appropriate.

In cases of ingestion, **do not induce emesis**. **Do not administer activated charcoal or attempt to neutralize stomach contents**. Adult victims who are conscious and able to swallow should be given 4 to 8 ounces of water or milk, if it has not been given previously, to flush residual acid from the esophagus and to dilute stomach contents. Children should receive half of the adult dose.

Advanced Treatment

In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, perform cricothyroidotomy if equipped and trained to do so.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Sympathomimetic bronchodilators generally will reverse bronchospasm in patients exposed to hydrogen chloride.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Patients who are comatose, hypotensive, or are having seizures or cardiac arrhythmias should be treated according to advanced life support (ALS) protocols.

Transport to Medical Facility

Only decontaminated patients or patients not requiring decontamination should be transported to a medical facility. “Body bags” are not recommended.

Report to the base station and the receiving medical facility the condition of the patient, treatment given, and estimated time of arrival at the medical facility.

If hydrochloric acid has been ingested, prepare the ambulance in case the victim vomits toxic material. Have ready several towels and open plastic bags to quickly clean up and isolate vomitus.

Multi-Casualty Triage

Consult with the base station physician or the regional poison control center for advice regarding triage of multiple victims.

Patients with evidence of significant exposure such as skin or eye irritation, pain, or breathing difficulties should be transported to a medical facility for evaluation. Others may be discharged from the scene after their names, addresses, and telephone numbers are recorded. Those discharged should be advised to seek medical care promptly if symptoms develop (see *Patient Information Sheet* below).

Emergency Department Management

Patients exposed only to hydrogen chloride gas whose clothing and skin are dry do not pose a risk of secondary contamination. Hospital personnel can be secondarily contaminated by patients exposed to hydrochloric acid either by direct skin contact or through inhalation of vapor off-gassing from heavily soaked clothing or skin. Patients do not pose contamination risks after contaminated clothing is removed and the skin is washed.

High concentrations of hydrogen chloride causes corrosive injury to all exposed body tissues. When inhaled, it can result in upper respiratory tract irritation, leading to laryngeal edema, laryngeal spasm, and asphyxia. Concentrated hydrochloric acid causes similar corrosive injuries to exposed tissues and, if ingested, can cause severe corrosive injury to the mouth, throat, esophagus, and stomach.

There is no antidote for hydrogen chloride poisoning. Treatment consists of support of respiratory and cardiovascular functions.

Decontamination Area

Previously decontaminated patients and patients exposed only to hydrogen chloride gas who have no skin or eye irritation may be transferred immediately to the Critical Care Area. Others require decontamination as described below.

Hospital personnel should don rubber gloves, rubber aprons, and eye protection before treating patients who are wet with hydrochloric acid.

Be aware that use of protective equipment by the provider may cause fear in children, resulting in decreased compliance with further management efforts.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants affecting the skin. Also, emergency room personnel should examine children's mouths because of the frequency of hand-to-mouth activity among children.

ABC Reminders

Evaluate and support airway, breathing, and circulation. Children may be more vulnerable to corrosive agents than adults because of the smaller diameter of their airways. In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, surgically create an airway.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in

situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Hydrogen chloride poisoning is not known to pose additional risk during the use of bronchial or cardiac sensitizing agents. Sympathomimetic bronchodilators generally will reverse bronchospasm in patients exposed to hydrogen chloride.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Patients who are comatose, hypotensive, or having seizures or cardiac arrhythmias should be treated in the conventional manner.

Basic Decontamination

Patients who are able may assist with their own decontamination. Remove and double-bag contaminated clothing and personal belongings.

Flush exposed skin and hair with water for 3 to 5 minutes (preferably under a shower). Wash thoroughly with soap and water, rinse thoroughly with water. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Flush exposed eyes with plain water or saline for at least 15 minutes. Remove contact lenses if easily removable without additional trauma to the eye. Continue irrigation while transporting the patient to the Critical Care Area.

In cases of ingestion, **do not induce emesis**. **Do not administer activated charcoal or attempt to neutralize stomach contents**. If it has not been given previously, administer 4 to 8 ounces of water or milk to adults to flush residual acid from the esophagus and to dilute stomach contents. (Children's dose is 2 to 4 ounces.)

Critical Care Area

Be certain that appropriate decontamination has been carried out (see *Decontamination Area* above).

ABC Reminders

Evaluate and support airway, breathing, and circulation as in *ABC Reminders* above. Children may be more vulnerable to corrosive agents than adults because of the relatively smaller diameter of their airways. Establish intravenous access in seriously ill patients if this has not been done previously. Continuously monitor cardiac rhythm.

Patients who are comatose, hypotensive, or have seizures or cardiac arrhythmias should be treated in the conventional manner.

Inhalation Exposure

Administer supplemental oxygen by mask to patients who have respiratory symptoms. Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Sympathomimetic bronchodilators generally will reverse bronchospasm in patients exposed to hydrogen chloride.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Observe patients for at least 24 hours, repeating appropriate tests and chest examinations as needed. Follow-up as clinically indicated.

Some authorities recommend treatment with high doses of corticosteroids for patients who have high-dose exposures, but the value of this treatment is questionable and unsupported by clinical studies.

Skin Exposure

If the skin was in contact with concentrated hydrochloric acid or hydrogen chloride gas or mists, chemical burns may occur, treat as thermal burns.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants affecting the skin.

Eye Exposure

Continue irrigating for at least 15 minutes or until the pH of the conjunctival fluid has returned to normal. Test visual acuity. Examine eyes for corneal damage and treat appropriately. Immediately consult an ophthalmologist for patients who have corneal injuries.

Ingestion Exposure

Do not induce emesis. **Do not administer activated charcoal or attempt to neutralize stomach contents**. Immediate dilution with 4 to 8 ounces of water or milk may be beneficial (pediatric dose 2 to 4 ounces) for alert patients who can swallow.

Consider endoscopy to evaluate the extent of gastrointestinal tract injury. Extreme throat swelling may require endotracheal intubation or cricothyroidotomy. Gastric lavage is useful in certain circumstances to remove caustic material and prepare for endoscopic examination. Consider gastric lavage with a small nasogastric tube if: (1) a large dose has been ingested; (2) the patient's condition is evaluated within 30 minutes; (3) the patient has oral lesions or persistent esophageal discomfort; and (4) the lavage can be administered within 1 hour of ingestion. Care must be taken when placing the gastric tube because blind gastric-tube placement may further injure the chemically damaged esophagus or stomach.

Because children do not ingest large amounts of corrosive materials, and because of the risk of perforation from NG intubation, lavage is discouraged in children unless performed under endoscopic guidance.

Toxic vomitus or gastric washings should be isolated (e.g., by attaching the lavage tube to isolated wall suction or another closed container).

The use of corticosteroids to prevent acid-induced strictures is questionable and unsupported by clinical studies.

Antidotes and Other Treatments

There is no antidote for hydrogen chloride poisoning.

Laboratory Tests

The diagnosis of acute hydrogen chloride toxicity is primarily clinical, based on symptoms of the corrosive action of the gas or acid. Routine laboratory studies for all exposed patients include CBC, glucose, and electrolyte determinations. Monitor acid-base status in patients who have ingested hydrochloric acid. If respiratory-tract irritation is present, monitor with chest radiography and pulse oximetry (or ABG measurements).

There is no biologic test specific for systemically absorbed hydrogen chloride.

Disposition and Follow-up

Patients who develop serious signs or symptoms of hydrogen chloride exposure should be hospitalized and observed closely for 4 to 6 hours or until asymptomatic.

Delayed Effects

Delayed effects are unlikely in patients who have minor symptoms that resolve quickly. However, symptoms can be delayed for 1 to 2 days.

Patient Release

Patients who have had minor exposure and who are asymptomatic 4 to 6 hours after exposure may be discharged and advised to seek medical care promptly if symptoms develop (see the *Hydrogen Chloride—Patient Information Sheet* below).

Follow-up

Obtain the name of the patient's primary care physician so that the hospital can send a copy of the ED visit to the patient's doctor.

Patients who have inhaled significant amounts of hydrogen chloride should be monitored with pulmonary function tests. Patients should also be monitored for the development of Reactive Airway Dysfunction Syndrome (RADS), a chemically- or irritant-induced type of asthma. About 2 to 4 weeks after an ingestion, consider follow-up esophagoscopy and an upper gastrointestinal tract series to evaluate secondary scarring or stricture formation.

Patients who have skin or corneal injury should be re-examined within 24 hours.

Reporting

If a work-related incident has occurred, you may be legally required to file a report; contact your state or local health department.

Other persons may still be at risk in the setting where this incident occurred. If the incident occurred in the workplace, discussing it with company personnel may prevent future incidents. If a public health risk exists, notify your state or local health department or other responsible public agency. When appropriate, inform patients that they may request an evaluation of their workplace from OSHA or NIOSH. See Appendices III and IV for a list of agencies that may be of assistance.

Hydrogen Chloride
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to hydrogen chloride gas or hydrochloric acid solution.

What are hydrogen chloride and hydrochloric acid?
Hydrogen chloride is a colorless to slightly yellow gas with a sharp, irritating odor. It forms a dense white vapor when it comes in contact with air. When hydrogen chloride dissolves in water, it forms hydrochloric acid also known as muriatic acid. Both hydrogen chloride and hydrochloric acid are corrosive and may cause burns on contact. Hydrogen chloride is not flammable.

What immediate health effects can be caused by exposure to these chemicals?
Hydrogen chloride gas can irritate the lungs, causing a cough and shortness of breath. Breathing high levels of the gas or vapor can lead to a build-up of fluid in the lungs, which may cause death. Because hydrochloric acid is corrosive, it can cause eye damage, even blindness, if splashed in the eyes. Skin contact can cause severe burns. Ingestion of concentrated hydrochloric acid can cause severe injury to the mouth, throat, esophagus and stomach. Generally, the more serious the exposure, the more severe the symptoms.

Can hydrogen chloride or hydrochloric acid overexposure be treated?
There is no antidote for poisoning due to these substances, but their effects can be treated and most exposed persons get well. People who have had serious exposures may need to be hospitalized.

Are any future health effects likely to occur?
A single, small exposure from which a person recovers quickly is not likely to cause delayed or long-term effects. Patients who breath a large amount of hydrogen chloride may develop permanent lung injury. If hydrochloric acid was swallowed, a patient may permanently have trouble swallowing.

What tests can be done if a person has been exposed to hydrogen chloride?
Specific tests for the presence of hydrogen chloride in blood or urine generally are not useful to the doctor. If a severe exposure has occurred, blood and urine analyses and other tests may show whether the lungs or stomach has been injured. Testing is not needed in every case.

Where can more information about hydrogen chloride and hydrochloric acid be found?
More information about hydrogen chloride and hydrochloric acid can be obtained from your regional poison control center; your state, county, or local health department; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in occupational and environmental health. If the exposure happened at work, you may wish to discuss it with your employer, the Occupational Safety and Health Administration (OSHA), or the National Institute for Occupational Safety and Health (NIOSH). Ask the person who gave you this form for help in locating these telephone numbers.

Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow *only* the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:

- coughing or wheezing
- difficulty breathing, shortness of breath, or chest pain
- stomach pain or vomiting
- increased pain or a discharge from exposed eyes
- increased redness or pain or a pus-like discharge in the area of a skin burn

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.
[ ] Call for an appointment with Dr. _____ in the practice of _____. When you call for your appointment, please say that you were treated in the Emergency Department at _ _____ Hospital by _____ and were advised to be seen again in _____ days.
[ ] Return to the Emergency Department/ _____ Clinic on (date) _____at ___ _____ AM/PM for a follow-up examination.
[ ] Do not perform vigorous physical activities for 1 to 2 days.
[ ] You may resume everyday activities including driving and operating machinery.
[ ] Do not return to work for _____ days.
[ ] You may return to work on a limited basis. See instructions below.
[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.
[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.
[ ] Avoid taking the following medications: _____
[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: __ _____
_____
[ ] Other instructions: _____
_____
_____

- Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.

- You or your physician can get more information on the chemical by contacting: _____ _____ or _____, or by checking out the following Internet Web sites: _____; _____.

Signature of patient _____ Date _____

Signature of physician _____ Date _____

Hydrogen Cyanide (HCN)
CAS 74-90-8; UN 1051

Synonyms include formonitrile. Aqueous solutions are referred to as hydrocyanic acid and prussic acid.

Persons whose clothing or skin is contaminated with cyanide-containing solutions can secondarily contaminate response personnel by direct contact or through off-gassing vapor.

Hydrogen cyanide is a colorless or pale-blue liquid at room temperature. It is very volatile, readily producing flammable and toxic concentrations at room temperature. Hydrogen cyanide gas mixes well with air, and explosive mixtures are easily formed.

- **Hydrogen cyanide has a distinctive bitter almond odor, but some individuals cannot detect it and consequently, it may not provide adequate warning of hazardous concentrations.**

Hydrogen cyanide is absorbed well by inhalation and can produce death within minutes. Substantial absorption can occur through intact skin if vapor concentration is high or with direct contact with solutions, especially at high ambient temperatures and relative humidity. Exposure by any route may cause systemic effects.

Description

At temperatures below 78 °F, hydrogen cyanide is a colorless or pale-blue liquid (hydrocyanic acid); at higher temperatures, it is a colorless gas. Hydrogen cyanide is very volatile, producing potentially lethal concentrations at room temperature. The vapor is flammable and potentially explosive. Hydrogen cyanide has a faint, bitter almond odor and a bitter, burning taste. It is soluble in water and is often used as a 96% aqueous solution.

Routes of Exposure

Inhalation

Hydrogen cyanide is readily absorbed from the lungs; symptoms of poisoning begin within seconds to minutes. The odor of hydrogen cyanide is detectable at 2–10 ppm (OSHA PEL = 10 ppm), but **does not provide adequate warning of hazardous concentrations**. Perception of the odor is a genetic trait (20% to 40% of the general population cannot detect hydrogen cyanide); also, rapid olfactory fatigue can occur. Hydrogen cyanide is lighter than air.

Children exposed to the same levels of hydrogen cyanide as adults may receive larger doses because they have greater lung surface area:body weight ratios and increased minute volumes:weight ratios.

Skin/Eye Contact

Exposure to hydrogen cyanide can cause skin and eye irritation. More importantly, skin or eye absorption is rapid and contributes to systemic poisoning. After skin exposure, onset of symptoms may be immediate or delayed for 30 to 60 minutes. Most cases of toxicity from dermal exposure have been from industrial accidents involving partial immersion in liquid cyanide or cyanide solutions or from contact with molten cyanide salts, resulting in large surface-area burns.

Children are more vulnerable to toxicants absorbed through the skin because of their relatively larger surface area:body weight ratio.

Ingestion

Ingestion of hydrogen cyanide solutions or cyanide salts can be rapidly fatal.

Sources/Uses

Hydrogen cyanide is manufactured by oxidation of ammonia-methane mixtures under controlled conditions and by the catalytic decomposition of formamide. It may be generated by treating cyanide salts with acid, and it is a combustion by-product of nitrogen-containing materials such as wool, silk, and plastics. It is also produced by enzymatic hydrolysis of nitriles and related chemicals. Hydrogen cyanide gas is a by-product of coke-oven and blast-furnace operations.

Hydrogen cyanide is used in fumigating; electroplating; mining; and in producing synthetic fibers, plastics, dyes, and pesticides. It also is used as an intermediate in chemical syntheses.

Standards and Guidelines

OSHA PEL (permissible exposure limit) (ceiling) = 10 ppm (skin) (averaged over 15 minutes)

NIOSH IDLH (immediately dangerous to life or health) = 50 ppm

AIHA ERPG-2 (emergency response planning guideline) (maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms which could impair an individual's ability to take protective action) = 10 ppm

Physical Properties

Description: Colorless gas or colorless or pale-blue liquid

Warning properties: Almond odor at >l ppm; inadequate warning for acute or chronic exposure

Molecular weight: 27.03 daltons

Boiling point (760 mm Hg): 78 °F (25.6 °C)

Freezing point: 8 °F (-13.4 °C)

Specific gravity: 0.69 (water = 1)

Vapor pressure: 630 mm Hg at 68 °F (20 °C)

Gas density: 0.94 (air = 1)

Water solubility: Miscible with water

Flammability: Flammable at temperatures > 0 °F (-18 °C)

Flammable range: 5.6% to 40% (concentration in air)

Incompatibilities

Hydrogen cyanide reacts with amines, oxidizers, acids, sodium hydroxide, calcium hydroxide, sodium carbonate, caustic substances, and ammonia. Hydrogen cyanide may polymerize at 122 °F to 140 °F.

Health Effects

Hydrogen cyanide is highly toxic by all routes of exposure and may cause abrupt onset of profound CNS, cardiovascular, and respiratory effects, leading to death within minutes.

- **Exposure to lower concentrations of hydrogen cyanide may produce eye irritation, headache, confusion, nausea, and vomiting followed in some cases by coma and death.**

Hydrogen cyanide acts as a cellular asphyxiant. By binding to mitochondrial cytochrome oxidase, it prevents the utilization of oxygen in cellular metabolism. The CNS and myocardium are particularly sensitive to the toxic effects of cyanide.

Acute Exposure

In humans, cyanide combines with the ferric ion in mitochondrial cytochrome oxidase, preventing electron transport in the cytochrome system and bringing oxidative phosphorylation and ATP production to a halt. The inhibition of oxidative metabolism puts increased demands on anaerobic glycolysis, which results in lactic acid production and may produce severe acid-base imbalance. The CNS is particularly sensitive to the toxic effects of cyanide, and exposure to hydrogen cyanide generally produces symptoms within a short period of time.

Children do not always respond to chemicals in the same way that adults do. Different protocols for managing their care may be needed.

CNS

CNS signs and symptoms usually develop rapidly. Initial symptoms are nonspecific and include excitement, dizziness, nausea, vomiting, headache, and weakness. As poisoning progresses, drowsiness, tetanic spasm, lockjaw, convulsions, hallucinations, loss of consciousness, and coma may occur.

Cardiovascular

Abnormal heartbeat can occur in cases of severe poisoning. Slow heartbeat, intractable low blood pressure, and death may result. High blood pressure and a rapid heartbeat may be early, transient findings.

Respiratory

After systemic poisoning begins, victims may complain of shortness of breath and chest tightness. Pulmonary findings may include rapid breathing and increased depth of respirations. As poisoning progresses, respirations become slow and gasping; a bluish skin color may or may not be present. Accumulation of fluid in the lungs may develop.

Children may be more vulnerable to gas exposure because of relatively increased minute ventilation per kg and failure to evacuate an area promptly when exposed.

Metabolic

An anion-gap, metabolic acidosis occurs in severe poisoning from increased blood levels of lactic acid.

Because of their higher metabolic rates, children may be more vulnerable to toxicants interfering with basic metabolism.

Dermal

Dermal absorption can occur, leading to systemic toxicity. Absorption occurs more readily at high ambient temperature and relative humidity.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants absorbed through the skin.

Ocular

When splashed in the eye, hydrogen cyanide can cause eye irritation and swelling. Eye contact with cyanide salts has produced systemic symptoms in experimental animals.

Potential Sequelae

Survivors of severe exposure may suffer brain damage due to a direct action on neurons, or to lack of oxygen, or possibly due to insufficient blood circulation. Cases of neurologic sequelae such as personality changes, memory deficits, disturbances in voluntary muscle movements, and the appearance of involuntary movements (i.e., extrapyramidal syndromes) have been reported.

Chronic Exposure

Chronically exposed workers may complain of headache, eye irritation, easy fatigue, chest discomfort, palpitations, loss of appetite, and nosebleeds.

Chronic exposure may be more serious for children because of their potential longer life span.

Carcinogenicity

Hydrogen cyanide has not been classified for carcinogenic effects, and no carcinogenic effects have been reported for hydrogen cyanide.

Reproductive and Developmental Effects

No reproductive or developmental effects of hydrogen cyanide have been reported in experimental animals or humans. Hydrogen cyanide is not included in *Reproductive and Developmental Toxicants,* a 1991 report published by the U.S. General Accounting Office (GAO) that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences. Increased levels of thiocyanate in

the umbilical cords of fetuses whose mothers smoked compared to those whose mothers were non-smokers suggests that thiocyanate, and possibly also cyanide, can cross the placenta. No data were located pertaining to hydrogen cyanide in breast milk.

Prehospital Management

Victims exposed only to hydrogen cyanide gas do not pose secondary contamination risks to rescuers, but do not attempt resuscitation without a barrier. Victims whose clothing or skin is contaminated with hydrogen cyanide liquid or solution can secondarily contaminate response personnel by direct contact or through off-gassing vapor. Avoid dermal contact with cyanide-contaminated victims or with gastric contents of victims who may have ingested cyanide-containing materials.

Hydrogen cyanide poisoning is marked by abrupt onset of profound toxic effects that may include syncope, seizures, coma, gasping respirations, and cardiovascular collapse, causing death within minutes. These effects can occur from all routes of exposure.

Victims exposed to hydrogen cyanide require supportive care and rapid administration of specific antidotes.

Hot Zone

Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if rescuers have not been trained in its use, assistance should be obtained from a local or regional HAZMAT team or other properly equipped response organization.

Rescuer Protection

Hydrogen cyanide is a highly toxic systemic poison that is absorbed well by inhalation and through the skin.

Respiratory Protection: Positive-pressure, self-contained breathing apparatus (SCBA) is recommended in response situations that involve exposure to potentially unsafe levels of hydrogen cyanide.

Skin Protection: Chemical-protective clothing is recommended because both hydrogen cyanide vapor and liquid can be absorbed through the skin to produce systemic toxicity.

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible.

Victim Removal

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be removed on backboards or gurneys; if these are not available, carefully carry or drag victims to safety.

Consider appropriate management of chemically contaminated children, such as measures to reduce separation anxiety if a child is separated from a parent or other adult.

Decontamination Zone

Patients exposed only to hydrogen cyanide gas who have no eye irritation do not need decontamination. They may be transferred immediately to the Support Zone. Other patients will require decontamination as described below.

Rescuer Protection

If exposure levels are determined to be safe, decontamination may be conducted by personnel wearing a lower level of protection than that worn in the Hot Zone (described above). **However, do not attempt resuscitation without a barrier.**

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. Stabilize the cervical spine with a collar and a backboard if trauma is suspected. Administer supplemental oxygen as required. Assist ventilation with a bag-valve-mask device if necessary.

Basic Decontamination

Speed is critical. For symptomatic victims, provide treatment with 100% oxygen and specific antidotes as needed. Treatment should be given simultaneously with decontamination procedures. (For treatment, see *ABC Reminders*, *Advanced Treatment*, and *Antidotes* below).

Victims who are able may assist with their own decontamination. Rapidly remove contaminated clothing while flushing exposed skin and hair with plain water for 2 to 3 minutes, then wash twice with mild soap. Rinse thoroughly with water. Double-bag contaminated clothing and personal belongings. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Irrigate exposed or irritated eyes with plain water or saline for 5 minutes. Continue eye irrigation during other basic care or transport. Remove contact lenses if easily removable without additional trauma to the eye.

In cases of ingestion, **do not induce emesis**. If the victim is alert, asymptomatic, and has a gag reflex, administer a slurry of activated charcoal (administer at 1 gm/kg, usual adult dose 60–90 g, child dose 25–50 g). A soda can and a straw may be of assistance when offering charcoal to a child. **If the victim is symptomatic, immediately institute emergency life support measures including the use of the cyanide antidote kit *(*see *Antidotes* below).**

Consider appropriate management of chemically contaminated children, such as measures to reduce separation anxiety if a child is separated from a parent or other adult. If possible, seek assistance from a child separation expert.

Transfer to Support Zone

As soon as basic decontamination is complete, move the victim to the Support Zone.

Support Zone

Be certain that victims have been decontaminated properly (see *Decontamination Zone* above). Victims who have been decontaminated or who have been exposed only to vapor generally pose no serious risks of secondary contamination to rescuers. In such cases, Support Zone personnel require no specialized protective gear.

ABC Reminders

Quickly access for a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Ensure adequate respiration and pulse. Administer supplemental oxygen as required and establish intravenous access if necessary. Place on a cardiac monitor.

Patients who rapidly regain consciousness and who have no other signs or symptoms may not require antidotal treatment. Those who remain comatose or develop shock should be treated promptly with the antidotes in the cyanide antidote kit (see *Antidotes* below).

Additional Decontamination

Continue irrigating exposed skin and eyes, as appropriate.

In cases of ingestion, **do not induce emesis**. If activated charcoal has not been administered previously, and the victim is alert, asymptomatic, and has a gag reflex, administer a slurry of activated charcoal (administer at 1 gm/kg, usual adult dose 60–90 g, child dose 25–50 g). A soda can and a straw may be of assistance when offering charcoal to a child. **If the patient is symptomatic, immediately institute emergency life support measures, including the use of a cyanide antidote kit *(*see *Antidotes* below).**

Advanced Treatment

In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, perform cricothyroidotomy if equipped and trained to do so.

Patients who are in shock or have seizures should be treated according to advanced life support (ALS) protocols. These patients or those who have arrhythmias may be seriously

acidotic; consider giving, under medical supervision, each patient 1 mEq/kg intravenous sodium bicarbonate.

Antidotes

When possible, treatment with cyanide antidotes should be given under medical supervision to unconscious victims who have known or strongly suspected cyanide poisoning. Cyanide antidotes—amyl nitrite perles and intravenous infusions of sodium nitrite and sodium thiosulfate—are packaged in the cyanide antidote kit.

Amyl nitrite perles should be broken onto a gauze pad and held under the nose, over the Ambu-valve intake, or placed under the lip of the face mask. Inhale for 30 seconds every minute and use a new perle every 3 minutes if sodium nitrite infusions will be delayed.

If the patient has not responded to oxygen and amyl nitrite treatment, infuse sodium nitrite intravenously as soon as possible. The usual adult dose is 10 mL of a 3% solution (300 mg) infused over **absolutely no less than 5 minutes**; the average pediatric dose is 0.12 to 0.33 mL/kg body weight up to 10 mL infused as above. Monitor blood pressure during sodium nitrite administration, and slow the rate of infusion if hypotension develops.

Next, infuse sodium thiosulfate intravenously. The usual adult dose is 50 mL of a 25% solution (12.5 g) infused over 10 to 20 minutes; the average pediatric dose is 1.65 mL/kg of a 25% solution. Repeat one-half of the initial dose 30 minutes later if there is an inadequate clinical response.

Transport to Medical Facility

Only decontaminated patients or patients not requiring decontamination should be transported to a medical facility. “Body bags” are not recommended.

Report to the base station and the receiving medical facility the condition of the patient, treatment given, and estimated time of arrival at the medical facility.

If a cyanide-containing solution has been ingested, prepare the ambulance in case the victim vomits toxic material. Have ready several towels and open plastic bags to quickly clean up and isolate vomitus.

Multi-Casualty Triage

Consult with the base station physician or the regional poison control center for advice regarding triage of multiple victims.

Patients with evidence of significant hydrogen cyanide exposure, and all patients who have hydrogen cyanide ingestion should be transported to a medical facility for evaluation.

Patients who have only brief inhalation exposure and mild or transient symptoms may be discharged from the scene after their names, addresses, and telephone numbers are recorded. They should be advised to seek medical care promptly if symptoms develop or recur (see *Patient Information Sheet* below).

Emergency Department Management

Hospital personnel in an enclosed area can be secondarily contaminated by vapor off-gassing from heavily soaked clothing or skin, or from toxic vomitus. Avoid dermal contact with cyanide-contaminated patients or with gastric contents of patients who may have ingested cyanide-containing materials, Patients do not pose secondary contamination risks after contaminated clothing is removed and the skin is washed.

Hydrogen cyanide poisoning is marked by abrupt onset of profound toxic effects that may include syncope, seizures, coma, gasping respirations, and cardiovascular collapse, causing death within minutes.

Patients exposed to hydrogen cyanide can survive with supportive care and rapid administration of specific antidotes.

Decontamination Area

Previously decontaminated patients and patients exposed only to hydrogen cyanide gas who have no skin or eye irritation may be transferred immediately to the Critical Care Area. Other patients require decontamination as described below.

ED personnel should don butyl rubber gloves and aprons before treating patients who have been exposed to hydrogen cyanide liquid or solutions. (Hydrogen cyanide readily penetrates most rubbers and barrier fabrics or creams, but butyl rubber provides good skin protection for a short period of time.)

Be aware that use of protective equipment by the provider may cause fear in children, resulting in decreased compliance with further management efforts.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants absorbed through the skin. Also, emergency room personnel should examine children's mouths because of the frequency of hand-to-mouth activity among children.

ABC Reminders

Evaluate and support airway, breathing, and circulation. In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, surgically create an airway.

Patients who are comatose, hypotensive, or have seizures or cardiac dysrhythmias should be treated in the conventional manner. If not previously administered, give sodium bicarbonate

intravenously to these patients. Further bicarbonate therapy should be guided by ABG measurements.

Basic Decontamination

Patients who are able may assist with their own decontamination.

Speed is critical. If the patient is symptomatic, immediately institute emergency life support measures, including the use of the cyanide antidote kit (see *Antidotes and Other Treatments* below).

If the patient's clothing is wet with hydrogen cyanide solution, quickly remove contaminated clothing while flushing exposed skin and hair with plain water for 2 to 3 minutes (preferably under a shower), then wash twice with mild soap. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Rinse thoroughly with water. Double-bag contaminated clothing and personal belongings.

Irrigate exposed eyes for at least 5 minutes. Remove contact lenses if easily removable without additional trauma to the eye. Continue irrigation while transporting the patient to the Critical Care Area.

In cases of ingestion, **do not induce emesis**. If activated charcoal has not been administered previously, and the victim is alert, asymptomatic, and has a gag reflex, administer a slurry of activated charcoal (administer at 1 gm/kg, usual adult dose 60–90 g, child dose 25–50 g). A soda can and a straw may be of assistance when offering charcoal to a child. Consider gastric lavage if the patient is conscious and it can be performed shortly after ingestion. Because cyanide absorption from the gut is rapid, the effectiveness of activated charcoal will depend on how quickly after ingestion it can be administered. Isolate gastric washings and vomitus; they may off-gas hydrogen cyanide.

Critical Care Area

Be certain that appropriate decontamination has been carried out (see *Decontamination Area* above).

ABC Reminders

Evaluate and support airway, breathing, and circulation as in *ABC Reminders* above. Establish intravenous access in seriously ill patients if this has not been done previously. Continuously monitor cardiac rhythm.

Patients who are in shock or have seizures should be treated according to ALS protocols. These patients or those who have

dysrhythmias may be seriously acidotic; consider giving 1 mEq/kg intravenous sodium bicarbonate.

Inhalation Exposure

Inhalation is the primary route of exposure to hydrogen cyanide. Refer to *Antidotes and Other Treatments* below for appropriate clinical treatment of systemic effects.

Skin Exposure

If the skin contacted hydrogen cyanide liquid or cyanide solutions, chemical burns may occur; treat as thermal burns. Watch for signs or symptoms of systemic toxicity, which may be delayed in onset for up to 1 hour.

Eye Exposure

Continue irrigation for at least 15 minutes. Test visual acuity. Examine the eyes for corneal damage and treat appropriately. Immediately consult an ophthamologist for patients who have corneal injuries.

Ingestion Exposure

Do not induce emesis.

If the victim is symptomatic, immediately institute emergency life support measures including the use of a cyanide antidote kit *(*see *Antidotes and Other Treatments* below). If the victim is alert, asymptomatic, has a gag reflex, and it has not been done previously, perform gastric lavage and give activated charcoal as soon as possible. Because cyanide absorption from the gut is rapid, the usefulness of activated charcoal will depend on how quickly after ingestion it can be administered.

Administer a slurry of activated charcoal at 1 gm/kg (usual adult dose 60–90 g, child dose 25–50 g). A soda can and a straw may be of assistance when offering charcoal to a child.

Toxic vomitus or gastric washings should be isolated (e.g., by attaching the lavage tube to isolated wall suction or another closed container).

Antidotes and Other Treatments

Patients who have signs or symptoms of significant systemic toxicity should be evaluated for antidotal treatment. In the United States, antidotes for cyanide include amyl nitrite perles and intravenous infusions of sodium nitrite and sodium thiosulfate, which are packaged in the cyanide antidote kit.

If one dose of the antidotes from the kit has been administered previously by prehospital personnel and inadequate clinical response has occurred, a second dose of one-half the initial amounts may be given 30 minutes after the initial dose. Further

doses should be guided by the patient's clinical condition and not by the percentage of methemoglobin induced. The usual methods of monitoring methemoglobin levels are unreliable in cases of cyanide poisoning and may seriously underestimate the levels of inactive hemoglobin.

Amyl nitrite perles should be broken onto a gauze pad and held under the nose, over the Ambu-valve intake, or placed under the lip of the face mask. Inhale for 30 seconds every minute and use a new perle every 3 minutes if sodium nitrite infusions will be delayed.

If the patient has not responded to oxygen and amyl nitrite treatment, infuse sodium nitrite intravenously as soon as possible. The usual adult dose is 10 mL of a 3% solution (300 mg) infused over **absolutely no less than 5 minutes**; the average pediatric dose is 0.12 to 0.33 mL/kg body weight up to 10 mL infused as above. Monitor blood pressure during sodium nitrite administration, and slow the rate of infusion if hypotension develops.

Next, infuse sodium thiosulfate intravenously. The usual adult dose is 50 mL of a 25% solution (12.5 g) infused over 10 to 20 minutes; the average pediatric dose is 1.65 mL/kg of a 25% solution. Repeat one-half of the initial dose 30 minutes later if there is an inadequate clinical response.

Amyl nitrite and sodium nitrite oxidize the ferrous iron of hemoglobin to methemoglobin. Methemoglobin levels should not exceed 20%. Repeat treatment with nitrite and thiosulfate as required.

The efficacy of hyperbaric oxygen in cyanide poisoning is unproven. It has been reported to be useful in severe cases of smoke inhalation combined with exposure to hydrogen cyanide and carbon monoxide.

Laboratory Tests

The diagnosis of acute cyanide toxicity is primarily a clinical one (based on rapid onset of CNS toxicity and cardiorespiratory collapse). Laboratory testing is useful for monitoring the patient and evaluating complications. Routine laboratory studies for all exposed patients include CBC, blood glucose, and electrolyte determinations. Additional studies for patients exposed to hydrogen cyanide include ECG monitoring, determinations of serum lactate, chest radiography, and pulse oximetry (or ABG measurements).

In severe poisonings, venous blood is oxygenated and has a bright red color. Elevated venous PO_2 and venous percent O_2 saturation occurs, narrowing the gap between arterial and central venous PO_2 or percent O_2 saturation.

After treatment with nitrites, serum methemoglobin levels may be monitored. However, the usual methods of monitoring methemoglobin levels are unreliable in cases of cyanide poisoning and may seriously underestimate the levels of inactive hemoglobin. Alternative methods exist, but may not be available. Whole blood cyanide tests generally require several hours and cannot be used to guide emergency treatment. However, blood cyanide levels may be useful in documenting exposure.

Disposition and Follow-up

Consider hospitalizing patients who have histories of significant exposure and are symptomatic. Whenever infusions from the cyanide antidote kit are used, the patient should be admitted to the intensive care unit.

Delayed Effects

Patients who have ingested hydrogen cyanide solutions or patients who have direct skin or eye contact should be observed in the Emergency Department for at least 4 to 6 hours.

Patient Release

Patients who remain asymptomatic 4 to 6 hours after exposure may be discharged with instructions to seek medical care promptly if symptoms develop (see the *Hydrogen Cyanide—Patient Information Sheet* below).

Follow-up

Obtain the name of the patient's primary care physician so that the hospital can send a copy of the ED visit to the patient's doctor.

Survivors of a serious exposure should be evaluated for ischemic damage to the brain and heart. Patients who have serious systemic cyanide poisoning may be at risk for CNS sequelae including Parkinsonian-like syndromes; they should be monitored for several weeks to months.

Patients who have corneal injuries should be reexamined within 24 hours.

Reporting

If a work-related incident has occurred, you may be legally required to file a report; contact your state or local health department.

Other persons may still be at risk in the setting where this incident occurred. If the incident occurred in the workplace, discussing it with company personnel may prevent future incidents. If a public health risk exists, notify your state or local health department or other public agency. When appropriate, inform patients that they may request an evaluation of their workplace from OSHA or NIOSH. See Appendices III and IV for a list of agencies that may be of assistance.

Hydrogen Cyanide
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to hydrogen cyanide.

What is hydrogen cyanide?
At room temperature, hydrogen cyanide is a volatile, colorless-to-blue liquid (also called hydrocyanic acid). It rapidly becomes a gas that can produce death in minutes if breathed. Hydrogen cyanide is used in making fibers, plastics, dyes, pesticides, and other chemicals, and as a fumigant to kill rats. It is also used in electroplating metals and in developing photographic film.

What immediate health effects can be caused by exposure to hydrogen cyanide?
Breathing small amounts of hydrogen cyanide may cause headache, dizziness, weakness, nausea, and vomiting. Larger amounts may cause gasping, irregular heartbeats, seizures, fainting, and even rapid death. Generally, the more serious the exposure, the more severe the symptoms. Similar symptoms may be produced when solutions of hydrogen cyanide are ingested or come in contact with the skin.

Can hydrogen cyanide poisoning be treated?
The treatment for cyanide poisoning includes breathing pure oxygen, and in the case of serious symptoms, treatment with specific cyanide antidotes. Persons with serious symptoms will need to be hospitalized.

Are any future health effects likely to occur?
A single small exposure from which a person recovers quickly is not likely to cause delayed or long-term effects. After a serious exposure, a patient may have brain or heart damage.

What tests can be done if a person has been exposed to hydrogen cyanide?
Specific tests for the presence of cyanide in blood and urine generally are not useful to the doctor. If a severe exposure has occurred, blood and urine analyses and other tests may show whether the brain or heart has been injured. Testing is not needed in every case.

Where can more information about hydrogen cyanide be found?
More information about hydrogen cyanide can be obtained from your regional poison control center; your state, county, or local health department; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in occupational and environmental health. If the exposure happened at work, you may wish to discuss it with your employer, the Occupational Safety and Health Administration (OSHA), or the National Institute for Occupational Safety and Health (NIOSH). Ask the person who gave you this form for help in locating these telephone numbers.

Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow *only* the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:

- difficulty breathing, shortness of breath, or chest pain
- confusion or fainting
- increased pain or a discharge from your eyes
- increased redness, pain, or a pus-like discharge in the area of a skin burn

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.
[ ] Call for an appointment with Dr. _____ in the practice of _____. When you call for your appointment, please say that you were treated in the Emergency Department at _ _____ Hospital by _____ and were advised to be seen again in _____ days.
[ ] Return to the Emergency Department/ _____ Clinic on (date) _____at ___ _____ AM/PM for a follow-up examination.
[ ] Do not perform vigorous physical activities for 1 to 2 days.
[ ] You may resume everyday activities including driving and operating machinery.
[ ] Do not return to work for _____ days.
[ ] You may return to work on a limited basis. See instructions below.
[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.
[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.
[ ] Avoid taking the following medications: _____
[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: __ _____
_____
[ ] Other instructions: _____
_____
_____

- Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.

- You or your physician can get more information on the chemical by contacting: _____ _____ or _____, or by checking out the following Internet Web sites: _____; _____.

Signature of patient _____ Date _____

Signature of physician _____ Date _____

Hydrogen Fluoride (HF)
CAS 7664-39-3; UN 1052 (anhydrous), UN 1790 (solution)

Synonyms include hydrogen fluoride, fluoric acid, hydrofluoride, hydrofluoric acid, and fluorine monohydride.

Victims exposed only to hydrogen fluoride vapor do not pose substantial risks of secondary contamination; however, victims whose clothing or skin is contaminated with hydrogen fluoride liquid or solution can secondarily contaminate response personnel by direct contact or through off-gassing vapor.

Hydrofluoric acid is a serious systemic poison. It is highly corrosive. Its severe and sometimes delayed health effects are due to deep tissue penetration by the fluoride ion. The surface area of the burn is not predictive of its effects.

Most hydrogen fluoride exposures occur by inhalation of the gas and dermal contact with hydrofluoric acid.

Description

Hydrogen fluoride is a colorless, fuming liquid or gas with a strong, irritating odor. It is usually shipped in steel cylinders as a compressed gas. Hydrogen fluoride readily dissolves in water to form colorless hydrofluoric acid solutions; dilute solutions are visibly indistinguishable from water. It is present in a variety of over-the-counter products at concentrations of 6% to 12%.

Although hydrofluoric acid is weak compared with most other mineral acids, it can produce serious health effects by any route of exposure. These effects are due to the fluoride ion's aggressive, destructive penetration of tissues.

Routes of Exposure

Inhalation

Inhalation hazards result not only from exposure to hydrogen fluoride gas, but also from fumes arising from concentrated hydrogen fluoride liquid. Hydrogen fluoride gas is lighter than air. Even fairly low airborne concentrations of hydrogen fluoride produce rapid onset of eye, nose, and throat irritation. Hydrogen fluoride has a strong irritating odor that is discernable at concentrations of about 0.04 ppm, which is considerably less than the OSHA PEL of 3 ppm. Therefore, odor generally provides adequate warning of hazardous concentrations.

Children exposed to the same levels of hydrogen fluoride as adults may receive larger doses because they have greater lung surface area:body weight ratios and increased minute volumes:weight ratios. Children may also be more vulnerable to

corrosive agents than adults because of the relatively smaller diameter of their airways.

Skin/Eye Contact

Most hydrogen fluoride exposures occur by cutaneous contact with the aqueous solution. The fluoride ion, which penetrates tissues deeply, can cause both local cellular destruction and systemic toxicity and is readily absorbed through both intact and damaged skin. Hydrogen fluoride is irritating to the skin, eyes, and mucous membranes.

Children are more vulnerable to toxicants absorbed through the skin because of their relatively larger surface area:body weight ratio.

Ingestion

Ingestion of even a small amount of hydrofluoric acid is likely to produce systemic effects and may be fatal.

Sources/Uses

Hydrogen fluoride is primarily an industrial raw material. It is produced commercially by action of sulfuric acid on the mineral fluorspar. Hydrogen fluoride is used in separating uranium isotopes, as a cracking catalyst in oil refineries, and for etching glass and enamel, removing rust, and cleaning brass and crystal. It also is used in manufacturing silicon semiconductor chips and as a laboratory reagent. Some consumer products that may contain hydrogen fluoride include automotive cleaning products (e.g., for aluminum and chrome), rust inhibitors, rust removers (e.g., for ceramic tubs, sinks, and fabrics), and water-spot removers.

Standards and Guidelines

OSHA PEL (permissible exposure limit) = 3 ppm (averaged over an 8 hour work shift)

NIOSH IDLH (immediately dangerous to life or health) = 30 ppm

AIHA ERPG-2 (emergency response planning guideline) (maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms which could impair an individual's ability to take protective action) = 20 ppm

Physical Properties

Description: Colorless gas or fuming liquid; weak solutions have the appearance of water.

Warning properties: Disagreeable, pungent odor at 0.04 ppm; irritation of eyes and throat at 3 ppm.

Molecular weight: 20.0 daltons

Boiling point (760 mm Hg): 68 ° (20 °C)

Freezing point: -118 ° (-83 °)

Specific gravity: 1 for liquid at 67 °F (20 °C) (water = 1)

Vapor pressure (68 °F): 783 mm Hg

Gas density: 0.7 (air = 1)

Water solubility: Miscible with water with release of heat

Flammability: Nonflammable

Incompatibilities

Hydrogen fluoride reacts with metals and water or steam. It will attack glass and concrete.

Health Effects

Hydrogen fluoride is irritating to the skin, eyes, and mucous membranes, and inhalation may cause respiratory irritation or hemorrhage. Systemic effects can occur from all routes of exposure and may include nausea, vomiting, gastric pain, or cardiac arrhythmia. Symptoms may be delayed for several days, especially in the case of exposure to dilute solutions of hydrogen fluoride (less than 20%).

- **Hydrofluoric acid is corrosive and also causes destruction of deep tissues when fluoride ions penetrate the skin. Absorption of substantial amounts of hydrogen fluoride by any route may be fatal.**

  The systemic effects of hydrogen fluoride are due to increased fluoride concentrations in the body which can change the levels of calcium, magnesium, and potassium in the blood.

- **Hypocalcemia can cause tetany, decreased myocardial contractility, and possible cardiovascular collapse while hyperkalemia has been suggested to cause ventricular fibrillation leading to death.**

Acute Exposure

The toxic effects of hydrogen fluoride are due primarily to the fluoride ion, which is able to penetrate tissues and bind intracellular calcium and magnesium. This results in cell destruction and local bone demineralization. Systemic deficiency of calcium and magnesium and excess of potassium can occur. Hypocalcemia can cause tetany, decreased myocardial contractility, and possible cardiovascular collapse, while hyperkalemia has been suggested to cause ventricular fibrillation leading to death. The adverse action of the fluoride ion may progress for several days before symptoms appear.

Children do not always respond to chemicals in the same way that adults do. Different protocols for managing their care may be needed.

Respiratory

Inhaled hydrogen fluoride mist or vapor initially affects the nose, throat, and eyes. Mild clinical effects include mucous-membrane irritation and inflammation, cough, and narrowing of the bronchi. Severe clinical effects include almost immediate narrowing and swelling of the throat, causing upper airway obstruction. Lung injury may evolve rapidly or may be delayed in onset for 12 to 36 hours. Accumulation of fluid in the lungs, constriction of the bronchi, and partial or complete lung collapse can occur. Pulmonary effects can result even from splashes on the skin.

Children may be more vulnerable to corrosive agents than adults because of the relatively smaller diameter of their airways.

Children may be more vulnerable to gas exposure because of relatively increased minute ventilation per kg and failure to evacuate an area promptly when exposed.

Dermal

Depending on the concentration and duration of exposure, skin contact may produce pain, redness of the skin, and deep, slow-healing burns.

Acid concentrations of more than 50% (including anhydrous hydrogen fluoride) cause immediate severe, throbbing pain and a whitish discoloration of the skin, which usually forms blisters. Hydrogen fluoride solutions from 20% to 50% may produce pain and swelling, which may be delayed up to 8 hours. Hydrogen fluoride solutions of less than 20% cause almost no immediate pain on contact but may cause delayed serious injury 12 to 24 hours later.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants absorbed through the skin.

Ocular

Mild effects of hydrogen fluoride exposure include rapid onset of eye irritation. More severe effects, which may result from even minor hydrofluoric acid splashes, include sloughing of the surface of the eye, swelling of various structures of the eye, and cell death due to lack of blood supply. Potentially permanent clouding of the eye surface may develop immediately or after several days.

Gastrointestinal

Ingestion of hydrofluoric acid may cause corrosive injury to the mouth, throat, and esophagus. Inflammation of the stomach with bleeding occurs commonly. Nausea, vomiting, diarrhea, and abdominal pain may occur. Systemic effects are likely. An acid-base imbalance can occur after acute ingestion. Pulmonary aspiration may lead to respiratory complications.

Electrolyte

Exposure by any route may result in systemic effects, namely, low levels of calcium and magnesium and high levels of potassium in the blood. Low blood pressure, irregular heartbeat, involuntary muscle contractions, seizures, and death may ensue.

Potential Sequelae

Survivors of severe inhalation injury may suffer residual chronic lung disease. Healing of skin burns caused by concentrated hydrogen fluoride may be prolonged, and extensive scarring may result. Fingertip injuries are troublesome with persistent pain, bone loss, and nail-bed injury. After eye exposure, prolonged or permanent visual defects, blindness, or total eye destruction may occur. Hydrogen fluoride ingestion may damage the esophagus and stomach progressively for weeks. Persistent narrowing of the esophagus may result.

Chronic Exposure

Repeated ingestion of more than 6 mg of fluoride per day may result in mottling of the teeth in developing children, accumulation of fluoride in the bone, and hardening of the bone in adults and children. Long-term hydrogen fluoride exposure has been reported to damage the kidneys and liver.

Chronic exposure may be more serious for children because of their potential longer latency period.

Carcinogenicity

Hydrogen fluoride has not been classified for carcinogenic effects.

Reproductive and Developmental Effects

Hydrogen fluoride is not included in *Reproductive and Developmental Toxicants,* a 1991 report published by the U.S. General Accounting Office (GAO) that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences. Fluoride crosses the placenta, and at low doses is thought to be essential for normal fetal development in humans. It is rarely excreted in breast milk. There have been rare cases of mottling of deciduous teeth in infants born to mothers who had high daily intakes of fluoride during pregnancy; skeletal abnormalities are considered unlikely. No reproductive effects due to hydrogen fluoride are known.

Prehospital Management

Victims exposed only to hydrogen fluoride gas or vapor do not pose substantial risks of secondary contamination to rescuers. However, victims whose clothing or skin is contaminated with hydrogen fluoride liquid, solution, or condensed vapor can secondarily contaminate response personnel by direct contact or through off-gassing vapor.

Hydrogen fluoride is irritating to the skin, eyes, and mucous membranes. It is a corrosive chemical that can cause immediate or delayed onset of deep, penetrating injury. Systemic effects can occur from all routes of exposure and include pulmonary edema, nausea, vomiting, gastric pain, and cardiac arrhythmia. Absorption of fluoride ions can cause hypocalcemia, hypomagnesemia, and hyperkalemia, which can result in cardiac arrest.

Rapid decontamination is critical. Calcium-containing gels, solutions, and medications are used to neutralize the effects of hydrogen fluoride. Patients may require support of respiratory and cardiovascular functions.

Hot Zone

Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if rescuers have not been trained to use it, assistance should be obtained from a local or regional HAZMAT team or other properly equipped response organization.

Rescuer Protection

Hydrogen fluoride is corrosive to the respiratory tract and skin and is a serious systemic poison.

Respiratory Protection: Positive-pressure, self-contained breathing apparatus (SCBA) is recommended in response situations that involve exposure to potentially unsafe levels of hydrogen fluoride.

Skin Protection: Chemical-protective clothing is recommended because skin exposure to either vapor or liquid may cause severe burns and systemic toxicity.

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible.

Victim Removal

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be

removed on backboards or gurneys; if these are not available, carefully carry or drag victims to safety.

Consider appropriate management of chemically contaminated children, such as measures to reduce separation anxiety if a child is separated from a parent or other adult.

Decontamination Zone

Victims exposed only to hydrogen fluoride gas or vapor who have no skin or eye irritation do not need decontamination. They may be transferred immediately to the Support Zone. Other patients will require decontamination as described below.

Rescuer Protection

If exposure levels are determined to be safe, decontamination may be conducted by personnel wearing a lower level of protection than that worn in the Hot Zone (described above).

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. Stabilize the cervical spine with a collar and a backboard if trauma is suspected. Administer supplemental oxygen as required. Assist ventilation with a bag-valve-mask device if necessary.

Basic Decontamination

Rapid decontamination is critical. Victims who are able may assist with their own decontamination. Quickly remove and double-bag contaminated clothing while flushing exposed skin and hair with plain water or saline for at least 30 minutes. Cover exposed skin with a calcium-containing slurry or gel (2.5 g calcium gluconate in 100 mL of water-soluble lubricant, such as K-Y Jelly, or 1 ampule of 10% calcium gluconate per ounce of K-Y Jelly).

Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Irrigate exposed or irritated eyes with plain water or saline for at least 20 minutes. Remove contact lenses if easily removable without additional trauma to the eye. Continue irrigation during other decontamination procedures. Use of ophthalmic anesthetic eyedrops will increase patient comfort and efficiency of irrigation.

In case of hydrofluoric acid ingestion, **do not induce emesis**. Do not administer activated charcoal. Victims who are conscious and able to swallow should be given 4 to 8 ounces of water or milk. If available, also give 2 to 4 ounces of an antacid

containing magnesium (e.g., Maalox, milk of magnesia) or calcium (e.g., Tums).

Consider appropriate management of chemically contaminated children, such as measures to reduce separation anxiety if a child is separated from a parent or other adult. If possible, seek assistance from a child separation expert.

Transfer to Support Zone

As soon as basic decontamination is complete, move the victim to the Support Zone.

Support Zone

Be certain that victims have been decontaminated properly (see *Decontamination* Zone above). Victims who have undergone decontamination or have been exposed only to vapor generally pose no serious risks of secondary contamination. In such cases, Support Zone personnel require no specialized protective gear.

ABC Reminders

Quickly access for a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Ensure adequate respiration and pulse. Administer supplemental oxygen as required and establish intravenous access if necessary. Place on a cardiac monitor. Monitor ECG for prolonged Q-T interval or QRS duration.

Additional Decontamination

Continue flushing exposed skin for 15 minutes. **Do not inject or use calcium chloride** for treating skin burns. It will cause extreme pain and may further injure tissues.

Treat the burned areas with calcium gluconate gel (2.5 g in 100 mL water-soluble lubricant, such as K-Y Jelly, or 1 ampule of 10% calcium gluconate per ounce of K-Y Jelly). Initially, the health care provider should wear rubber or latex gloves to prevent secondary contamination. Continue this procedure until pain is relieved or more definitive care is rendered.

If the eyes are still irritated, continue irrigating with water or saline. Remove contact lenses if present and easily removable without additional trauma. Continue irrigating the eyes with saline during transport. Use of ophthalmic anesthetic eyedrops will increase patient comfort and efficiency of irrigation.

In cases of ingestion, **do not induce emesis**. Do not administer activated charcoal. Victims who are conscious and able to swallow should be given 4 to 8 ounces of water or milk. If available, also give 2 to 4 ounces of an antacid containing

magnesium (e.g., Maalox, milk of magnesia) or calcium (e.g., Tums).

Advanced Treatment

In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, perform cricothyroidotomy if equipped and trained to do so.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Hydrogen cyanide poisoning is not known to pose additional risk during the use of bronchial or cardiac sensitizing agents.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Patients who are comatose, hypotensive, or are having seizures or cardiac arrhythmias should be treated according to advanced life support (ALS) protocols.

Hypocalcemia (manifested by tetany and dysrhythmias) is probable after ingestion of even small amounts of hydrogen fluoride. With medical consultation, treat hypocalcemia with intravenous injections of a 10% solution of calcium gluconate.

For inhalation victims, 2.5% calcium gluconate (2.5 g of calcium gluconate in 100 mL of water or 25 mL of 10% calcium gluconate diluted to 100 mL with water) administered by nebulizer with oxygen has been recommended, but the success of this therapy has not been demonstrated.

Transport to Medical Facility

Only decontaminated patients or patients not requiring decontamination should be transported to a medical facility. “Body bags” are not recommended.

Report to the base station and the receiving medical facility the condition of the patient, treatment given, and estimated time of arrival at the medical facility.

If hydrofluoric acid has been ingested, prepare the ambulance in case the victim vomits toxic material. Have ready several towels and open plastic bags to quickly clean up and isolate vomitus.

Multi-Casualty Triage

Consult with the base station physician or regional poison control center for advice regarding triage of multiple victims.

Persons who have had only minor or brief exposure to hydrogen fluoride gas or vapor and are initially asymptomatic are not likely to develop complications. After their names, addresses, and telephone numbers are recorded, patients may be released from the scene with follow-up instructions (see *Patient Information Sheet* below).

Inhalation Exposure

Immediately transport to a medical facility those patients who have inhaled hydrogen fluoride and have upper respiratory irritation or other acute symptoms.

Skin/Eye Contact

All persons who have eye exposure or serious skin exposure (i.e., fingertip exposure or skin exposure greater than the total surface area of the palm) or any evidence of burns (e.g., erythema, pain, or blisters) should be transported to a hospital as soon as possible. Continue skin and eye irrigation or treatment during transport. Patients who have had even mild skin or eye contact with hydrogen fluoride should be brought to the attention of a physician as soon as possible because they may have delayed pain and systemic complications.

Ingestion Exposure

In cases of ingestion, patients should be transported to a hospital without delay. Watch patients carefully because systemic effects are likely to occur.

Emergency Department Management

Patients exposed only to hydrogen fluoride gas or vapor do not pose substantial risks of secondary contamination to personnel outside the Hot Zone. However, patients whose clothing or skin is contaminated with hydrogen fluoride liquid or solution can secondarily contaminate personnel by direct contact or through off-gassing vapor.

Hydrogen fluoride is a corrosive chemical that can cause deep, penetrating injury. Absorption of fluoride ions can result in hypocalcemia and cardiac arrest. Hypocalcemia should be considered a risk in all instances of inhalation or ingestion and whenever skin burns exceed 25 square inches (an area about the size of the palm).

Because of hydrogen fluoride's rapid skin penetration and the serious toxicity of the fluoride ion, rapid decontamination is critical. Calcium-containing gels, solutions, and medications can be used to neutralize the fluoride ion. The intense pain of hydrogen fluoride burns should not be suppressed with local anesthetics because the degree of pain is an indicator of treatment efficacy. Treatment may also include support of respiratory and cardiovascular functions.

Decontamination Area

Previously decontaminated patients and patients exposed only to hydrogen fluoride gas or vapor who have no skin or eye irritation may be transferred immediately to the Critical Care Area. Other patients will require decontamination as described below.

Because coming in contact with hydrogen fluoride-soaked clothing or skin can cause burns, ED personnel should don chemical resistant jumpsuits (e.g., of Tyvek or Saranex) or butyl rubber aprons, multiple layers of latex gloves, and eye protection.

Be aware that use of protective equipment by the provider may cause fear in children, resulting in decreased compliance with further management efforts.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants absorbed through the skin. Also, emergency room personnel should examine children's mouths because of the frequency of hand-to-mouth activity among children.

ABC Reminders

Evaluate and support airway, breathing, and circulation. In cases of respiratory compromise secure airway and respiration via

endotracheal intubation. If not possible, surgically create an airway.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Hydrogen cyanide poisoning is not known to pose additional risk during the use of bronchial or cardiac sensitizing agents.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Patients who are comatose, hypotensive, or are having seizures or cardiac arrhythmias should be treated in the conventional manner.

Basic Decontamination

Rapid skin decontamination is critical. Patients who are able may assist with their own decontamination. If the patient's clothing is wet with hydrogen fluoride, remove and double-bag the clothing while flushing the skin with water (preferably under a shower). Flush exposed skin for at least 20 minutes. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Flush exposed eyes with plain water or saline for at least 20 minutes. Remove contact lenses if present and easily removable without additional trauma to the eye. Continue irrigation while transporting the patient to the Critical Care Area. An ophthalmic anesthetic, such as 0.5% tetracaine, may be necessary to alleviate blepharospasm, and lid retractors may be required to allow adequate irrigation under the eyelids.

In cases of ingestion, **do not induce emesis**. Do not administer activated charcoal. If it has not been given previously and the patient is alert and able to swallow, administer 4 to 8 ounces of water. (More information is provided in *Ingestion Exposure* under *Critical Care Area* below.)

Critical Care Area

Be certain that appropriate decontamination has been carried out (see *Decontamination Area* above).

ABC Reminders

Evaluate and support airway, breathing, and circulation as in *ABC Reminders* above. Children may be more vulnerable to corrosive agents than adults because of the relatively smaller diameter of their airways. Establish intravenous access in seriously ill patients if this has not already been done.

Patients who are comatose, hypotensive, or are having seizures or cardiac arrhythmias should be treated in the conventional manner.

Monitor heart, renal, and liver functions. Hypocalcemia may cause prolonged Q-T interval and cardiac rhythm abnormalities.

Inhalation Exposure

Calcium gluconate (2.5 grams of calcium gluconate in 100 mL of water or 25 mL of 10% calcium gluconate diluted to 100 mL with water) may be administered with oxygen by nebulizer to victims who have severe respiratory distress.

Pulmonary edema or edema of the upper airway may occur. Observe the patient for at least 24 hours and monitor with repeated chest examinations, blood gas determinations, and other appropriate tests. Follow up as clinically indicated.

Skin Contact

A burn specialist or plastic surgeon should be consulted early in the treatment of fluoride burns.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants absorbed through the skin.

If blisters have formed, they should be opened and drained and debrided of necrotic tissue before treatment; early debridement may facilitate healing.

Do not inject calcium chloride to treat skin burns. It will cause extreme pain and may further injure tissues.

Treat the burned area with calcium gluconate gel (2.5 grams in 100 mL water-soluble lubricant, such as K-Y Jelly) until the pain is relieved. If used as definitive treatment, the gel should be applied 4 to 6 times daily for 3 to 4 days. Initially, health care providers should wear rubber gloves to protect their fingers from secondary contamination. If some relief of pain is not obtained within 30 to 60 minutes, consider calcium gluconate injections.

Subungual (under the nail) burns often do not respond to immersion treatment. The treatments for hand burns require expert assistance; consult a poison center, medical toxicologist, or hand surgeon. Care must be used because multiple injections into the fingers can lead to pressure necrosis. It will be necessary to split or remove the nail.

Large burns or deeply penetrating burns (i.e., from delayed treatment or exposure to hydrogen fluoride concentrations greater than 50%) may require injections of sterile aqueous calcium gluconate into and around the burned area. The recommended dose is to inject up to 0.5 mL of 10% calcium gluconate solution per cm^2 of affected skin surface using a small-gauge needle (#30). No local infiltration of anesthetic should be used, but in the case of severe burns, regional or general anesthesia may be considered. Injection may not be feasible in the case of burns to the fingers; in such cases, intra-arterial infusion should be considered.

Intra-arterial calcium gluconate has been found to be effective for the treatment of burned digits and upper extremities. The radial artery has been preferentially used, with the brachial artery used if there is incomplete anastomotic flow between the radial and ulnar circulations. The initial dosage is 10 mL of 10% calcium gluconate diluted with 40 mL D_5W given intra-arterially over 4 hours. If pain is unrelieved, 20% concentrations have been used. After the first dose, the infusion can be stopped, but the line should be maintained so that further doses can be infused if pain recurs. Once the patient has been pain-free for 4 hours, the catheter can be removed. Although anesthesia can be used, it is not recommended since it invalidates the pain relief which is a titration endpoint for effective treatment.

Eye Contact

Immediate consultation with an ophthalmologist is indicated.

Do not use oils, salves, or ointments for injured eyes. Do not use the gel form of calcium gluconate in eyes, as described for skin treatment.

Irrigate exposed eyes with 1 to 2 L of plain water or saline. Administering drops of a 1% aqueous solution of calcium gluconate (50 mL of 10% solution in 450 mL of sterile saline) has also been suggested as a possible therapy. After irrigation, the pH of the eye should be checked and a complete ophthalmic examination should be carried out.

A topical anesthetic can minimize the tendency for eyelid closure and facilitate irrigation. One or two drops of proparacaine or tetracaine will usually provide rapid-onset ocular anesthesia for 20 minutes to an hour. If exposure was minor, perform visual acuity testing. Examine the eyes for corneal damage and treat appropriately.

Ingestion Exposure

Do not give emetics and do not administer activated charcoal. If the patient is conscious and alert, and treatment has not been administered previously, immediately give 4 to 12 ounces of water to dilute the acid. Orally administer a one-time dose of several ounces of Mylanta, Maalox, or milk of magnesia; the magnesium in these products may act chemically to bind the fluoride in the stomach. Do not give sodium bicarbonate to neutralize acid because it can cause burns.

Consider endoscopy to evaluate the extent of gastrointestinal-tract injury. Extreme throat swelling may require endotracheal intubation or cricothyroidotomy. Gastric lavage is useful in certain circumstances to remove caustic material and prepare for endoscopic examination. Consider gastric lavage with a small nasogastric tube if: (1) a large dose has been ingested; (2) the patient's condition is evaluated within 30 minutes; (3) the patient has oral lesions or persistent esophageal discomfort; and (4) the lavage can be administered within 1 hour of ingestion. Care must be taken when placing the gastric tube because blind gastric-tube placement may further injure the chemically damaged esophagus or stomach.

Because children do not ingest large amounts of corrosive materials, and because of the risk of perforation from NG intubation, lavage is discouraged in children unless performed under endoscopic guidance.

Toxic vomitus or gastric washings should be isolated (e.g., by attaching the lavage tube to isolated wall suction or another closed container).

Systemic Toxicity

Treat hypocalcemia using intravenous 10% calcium gluconate infusions with doses of 0.1 to 0.2 mL/kg up to 10 mL. Infusions can be repeated until serum calcium, ECG, or symptoms improve. Calcium levels should be checked hourly. Treat hypomagnesemia with 2 to 4 mL of 50% of magnesium sulfate intravenously over 40 minutes.

Laboratory Tests

Routine laboratory studies for all exposed patients include CBC, glucose, and electrolyte determinations. Patients exposed to hydrogen fluoride should also have serum calcium, potassium, and magnesium levels monitored. Chest radiography and pulse oximetry (or ABG measurements) may be useful for patients exposed through inhalation.

Disposition and Follow-up

Patients in whom treatment fails to diminish pain and those who have respiratory distress, ingestion exposure, fingertip or eye burns, or substantial skin burns should be admitted to an intensive care unit and watched carefully for 24 hours. (Substantial skin burns are those covering an area greater than the palm of a hand, and causing skin change, or producing pain within 1 hour of exposure.) ECG monitoring may help determine treatment need and effectiveness.

Patient Release

Patients who have eye exposure who have no signs of irritation after treatment do not require hospitalization.

Patients in the ED who have burns covering less than an area equivalent to the palm of the hand and who have normal serum calcium levels who have responded to treatment can be discharged for outpatient follow-up after remaining stable for at least 6 hours. They should be advised to seek medical care promptly if pain recurs (see the *Hydrogen Fluoride—Patient Information Sheet).*

Follow-up

Obtain the name of the patient's primary care physician so that the hospital can send a copy of the ED visit to the patient's doctor.

Survivors of a serious exposure should be evaluated for damage to the lungs and heart. Patients who have serious systemic hydrogen fluoride poisoning may be at risk for respiratory sequelae and should be monitored for several weeks to months. Healing of skin burns may be prolonged and eye exposure can lead to permanent damage. Ingestion may produce progressive damage to the stomach and esophagus for weeks after exposure and may result in persistent narrowing of the esophagus.

Patients who have corneal injuries should be reexamined within 24 hours.

Reporting

If a work-related incident has occurred, you may be legally required to file a report; contact your state or local health department.

Other persons may still be at risk in the setting where this incident occurred. If the incident occurred in the workplace, discussing it with company personnel may prevent future incidents. If a public health risk exists, notify your state or local health department or other responsible public agency. When appropriate, inform patients that they may request an evaluation of their workplace from OSHA or NIOSH. See Appendices III and IV for a list of agencies that may be of assistance.

Hydrogen Fluoride
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to hydrogen fluoride gas or hydrofluoric acid solution or vapor.

What is hydrogen fluoride?
Hydrogen fluoride is a colorless, highly irritating gas with a pungent odor. It dissolves easily in water to form hydrofluoric acid. Consumer products that contain hydrogen fluoride include rust removers, water-spot removers, and chrome cleaners.

What immediate health effects can be caused by exposure to hydrogen fluoride?
Most poisonings occur when hydrogen fluoride gets on the skin or in the eyes. Concentrated hydrogen fluoride solutions can cause severe, deep, and disfiguring burns. Absorption of the chemical into the body can cause the heart to beat irregularly, leading to death. Exposure to dilute solutions (less than 20% concentration) may cause few or no symptoms at first, but may cause severe pain later. Drinking hydrofluoric acid can cause severe burns to the throat and stomach and even death. Injury can also occur from breathing hydrogen fluoride gas or the vapor from concentrated hydrogen fluoride solutions. Breathing high concentrations of hydrogen fluoride vapor can cause rapid death from throat swelling or from chemical burns to the lungs.

Can hydrogen fluoride poisoning be treated?
Patients who have experienced serious symptoms, such as severe or persistent coughing or skin or eye burns, may need to be hospitalized. Calcium- or magnesium-containing medicines may be used to treat the skin, and doctors may inject calcium-containing medicines into burned areas or into the blood. If hydrofluoric acid is swallowed, a solution containing calcium or magnesium may be given.

Are any future health effects likely to occur?
A single small exposure from which a person recovers quickly is not likely to cause delayed or long-term effects. After a severe exposure, you may not notice any symptoms for up to 36 hours. Scarring may result from skin contact with hydrogen fluoride.

What tests can be done if a person has been exposed to hydrogen fluoride?
The doctor may order blood tests, urine tests, chest x-ray, and heart monitoring to see whether damage has been done to the heart, lungs, or other organs. Testing is not needed in every case. If hydrogen fluoride contacts the eyes, the doctor may put a special dye into the eyes and examine them with a magnifying device.

Where can more information about hydrogen fluoride be found?
More information about hydrogen fluoride or hydrofluoric acid can be obtained from your regional poison control center; your state, county, or local health department; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in occupational and environmental health. If the exposure happened at work, you may wish to discuss it with your employer, the Occupational Safety and Health Administration (OSHA) or the National Institute for Occupational Safety and Health (NIOSH). Ask the person who gave you this form for help in locating these telephone numbers.

Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow *only* the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:

- difficulty breathing, shortness of breath or wheezing
- hoarseness, high-pitched voice, or difficulty speaking
- chest pain or tightness
- any skin changes, discharge, or increased pain where skin is burned
- stomach pain, vomiting, or diarrhea
- increased pain or a discharge from exposed eyes

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.
[ ] Call for an appointment with Dr. _____ in the practice of _____.
When you call for your appointment, please say that you were treated in the Emergency Department at _ _____ Hospital by _____ and were advised to be seen again in _____ days.
[ ] Return to the Emergency Department/ _____ Clinic on (date) _____at ___ _____ AM/PM for a follow-up examination.
[ ] Do not perform vigorous physical activities for 1 to 2 days.
[ ] You may resume everyday activities including driving and operating machinery.
[ ] Do not return to work for _____ days.
[ ] You may return to work on a limited basis. See instructions below.
[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.
[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.
[ ] Avoid taking the following medications: _____
[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: __
_____
_____
[ ] Other instructions: _____
_____
_____

- Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.

- You or your physician can get more information on the chemical by contacting: _____ _____ or _____, or by checking out the following Internet Web sites: _____; _____.

Signature of patient _____ Date _____

Signature of physician _____ Date _____

Hydrogen Peroxide (H_2O_2)
CAS 7722-84-1; UN 2984 (8%-20%), UN 2014 (20%-52%), UN 2015 (>52%)

Synonyms include dihydrogen dioxide, hydrogen dioxide, hydroperoxide, and peroxide.

Persons exposed only to hydrogen peroxide gas do not pose risks of secondary contamination to personnel outside the Hot Zone. However, persons whose clothing or skin is contaminated with concentrated hydrogen peroxide solution can secondarily contaminate personnel by direct contact or through off-gassing vapor.

Hydrogen peroxide is a clear, colorless, noncombustible liquid. It is a powerful oxidizing agent; when it comes in contact with organic material, spontaneous combustion can occur. Odor does not provide a warning of hazardous concentrations.

Description

Pure hydrogen peroxide is a crystalline solid below 12 °F and a colorless liquid with a bitter taste above 12 °F. It is almost always used as an aqueous solution, which is available in dilute form (3% to 10%) for household use and in concentrated form (greater than 30%) for industrial use. Hydrogen peroxide is unstable, decomposing readily to oxygen and water with release of heat. Commercial peroxide products contain a stabilizer (usually acetanilide) to slow the rate of spontaneous decomposition.

Hydrogen peroxide is nonflammable, but it is a powerful oxidizing agent that can cause spontaneous combustion when it comes in contact with organic material.

Routes of Exposure

Inhalation

Inhalation of vapors, mists, or aerosols from concentrated solutions of hydrogen peroxide can cause significant morbidity. Because it is nearly odorless and nonirritating except at high concentrations, persons may not be aware of its presence. No odor threshold was located for hydrogen peroxide (the OSHA PEL is 1 ppm). **Detection of odor does not provide adequate warning of hazardous concentrations**. Hydrogen peroxide vapor is heavier than air and may cause asphyxiation in enclosed, poorly ventilated, or low-lying areas.

Children exposed to the same levels of hydrogen peroxide vapor as adults may receive larger doses because they have greater lung surface area:body weight ratios and increased minute volumes:weight ratios. In addition, they may be exposed to higher levels than adults in the same location because of their

short stature and the higher levels of hydrogen peroxide vapor found nearer to the ground. Children may be more vulnerable to corrosive agents than adults because of the smaller diameter of their airways.

Skin/Eye Contact

Hydrogen peroxide is poorly absorbed through intact skin. When used for household disinfectant purposes (3% to 5%), it is mildly irritating to the skin and mucous membranes. At a concentration of 10%, which is found in some hair-bleaching solutions, it is strongly irritating and may be corrosive.

Children are more vulnerable to toxicants affecting the skin because of their relatively larger surface area:body weight ratio.

Ingestion

If ingested, solutions of hydrogen peroxide up to concentrations of 9% are generally nontoxic; however, even a 3% solution is mildly irritating to mucosal tissue and may cause vomiting and diarrhea. Ingestion of industrial-strength solutions (10%) causes systemic toxicity and has been associated with fatalities.

Sources/Uses

In industry, hydrogen peroxide is used as a bleach for textiles and paper, as a component of rocket fuels, and as a reagent for producing foam rubber and organic chemicals. In the home, dilute hydrogen peroxide solutions are used as disinfectants, deodorants, and hair-bleaching agents.

Standards and Guidelines

OSHA PEL (permissible exposure limit): 1 ppm (averaged over an 8-hour workshift)

NIOSH IDLH (immediately dangerous to life or health) = 75 ppm

AIHA ERPG-2 (emergency response planning guideline) (maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms which could impair an individual's ability to take protective action) = 50 ppm

Physical Properties

Description: Colorless liquid at room temperature; used commonly in aqueous solution.

Warning properties: Odor is inadequate as index of exposure

Molecular weight: 34.0 daltons

Boiling point (760 mm Hg): 286 °F (141 °C)

Freezing point: 12 °F (-11.1 °C)

Specific gravity: 1.39 at 68 °F (20 °C) (water = 1)

Vapor pressure: 5 mm Hg at 86 °F (30 °C)

Gas density: 1.2 (air = 1) (heavier than air)

Water solubility: Miscible with water

Flammability: Nonflammable, but a powerful oxidizer and may ignite any organic matter with which it comes in contact

Incompatibilities

Hydrogen peroxide reacts with oxidizable materials, iron, copper, brass, bronze, chromium, zinc, lead, manganese, and silver. Contact with organic materials may result in spontaneous combustion.

Health Effects

Hydrogen peroxide is corrosive to skin, eyes, and mucous membranes at high concentrations (>10%); lower concentrations may cause irritation.

Other effects occur from inhalation or ingestion and may include gas embolism, gastric irritation, gastric distension and emesis, an accumulation of fluid in the lungs, unconsciousness, and respiratory arrest.

Symptoms become more severe as the concentration of hydrogen peroxide increases.

Acute Exposure

The systemic effects of hydrogen peroxide result from its interaction with catalase in the tissues with the liberation of oxygen and water as it decomposes. One milliliter of 3% hydrogen peroxide liberates 10 mL of oxygen. When the amount of oxygen evolved exceeds the maximum blood solubility, venous embolism occurs. Intravascular oxygen embolism may also occur. Ingestion of dilute solutions (3–10%) produces mild gastrointestinal irritation, gastric distension and emesis, and on rare occasions, gastrointestinal erosions or embolism. Ingestion of 10–20% solutions produces similar symptoms, but exposed tissues may also be burned. Ingestion of 20–40% produces the symptoms described for lower concentrations, but may also induce rapid loss of consciousness followed by respiratory arrest.

Children do not always respond to chemicals in the same way that adults do. Different protocols for managing their care may be needed.

Respiratory

Vapors, mists, or aerosols of hydrogen peroxide can cause upper airway irritation, inflammation of the nose, hoarseness, shortness of breath, and a sensation of burning or tightness in the chest. Exposure to high concentrations can result in severe mucosal congestion of the trachea and bronchi and delayed accumulation of fluid in the lungs.

Children may be more vulnerable to corrosive agents than adults because of the relatively smaller diameter of their airways.

Children may be more vulnerable because of relatively increased minute ventilation per kg and failure to evacuate an area promptly when exposed.

CNS

Inhalation or ingestion of high concentrations of hydrogen peroxide may result in seizures, cerebral infarction, or cerebral

embolism. The ensuing damage to the CNS may cause permanent neurological deficits or death.

Dermal

Prolonged exposure to concentrated vapor or to dilute solutions can cause irritation and temporary bleaching of skin and hair. Contact with concentrated solutions can cause severe skin burns with blisters.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants affecting the skin.

Ocular

Exposure to concentrated vapor, mist, or aerosol can cause stinging pain and tearing. Solutions that are 5% or greater can cause injury to the eye surface if splashed in the eye (sometimes with delayed effects).

Gastrointestinal

Ingestion of household solutions (3%) usually causes mild mucosal irritation and vomiting. Gastric distention due to liberation of oxygen in the stomach may occur, but hollow-organ rupture is uncommon when dilute solutions are ingested.

Ingestion of concentrated solutions (10%) can cause extreme irritation, inflammation, and burns of the alimentary tract can occur, and hollow-organ distention and rupture is a significant danger. Hydrogen peroxide enemas have caused colonic rupture, intestinal gangrene with gas bubbles, and acute ulcerative colitis.

Potential Sequelae

Survivors of severe inhalation injury may sustain permanent lung damage. Severe eye exposures may result in ulceration of the eye and blindness. Permanent neurological deficits have also been reported.

Chronic Exposure

Because hydrogen peroxide is rapidly decomposed in the body, it is unlikely to cause chronic toxicity. However, repeated exposures to hydrogen peroxide vapor may cause chronic irritation of the respiratory tract and partial or complete lung collapse. Repeated contact with vapor or solution may result in bleaching of skin and hair.

Chronic exposure may be more serious for children because of their potential longer latency period.

Carcinogenicity

The International Agency for Research on Cancer (IARC) has determined that hydrogen peroxide is not classifiable as to its carcinogenicity to humans.

Developmental and Reproductive Effects

Hydrogen peroxide is not included in *Reproductive and Developmental Toxicants*, a 1991 report published by the U.S. General Accounting Office (GAO) that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences. No reports were located on the developmental or reproductive effects of hydrogen peroxide in humans.

Prehospital Management

- **Victims exposed only to hydrogen peroxide vapor do not pose substantial risks of secondary contamination to personnel outside the Hot Zone. Victims whose clothing or skin is contaminated with concentrated hydrogen peroxide solution can secondarily contaminate personnel by direct contact or through off-gassing vapor.**
- **Hydrogen peroxide is corrosive to skin, eyes, and mucous membranes at high concentrations (>10%); lower concentrations may cause irritation. Symptoms become more severe as the concentration of hydrogen peroxide increases.**
- **Other effects occur from inhalation or ingestion and may include gas embolism, gastric irritation, gastric distension, gastric rupture and emesis, an accumulation of fluid in the lungs, unconsciousness, and respiratory arrest.**
- **There is no antidote for hydrogen peroxide. Treatment consists of support of respiratory and cardiovascular functions.**

Hot Zone

Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if rescuers have not been trained in its use, assistance should be obtained from a local or regional HAZMAT team or other properly equipped response organization.

Rescuer Protection

Hydrogen peroxide vapor is a severe respiratory tract irritant. Hydrogen peroxide solutions are corrosive at high concentrations (>10%); lower concentrations may cause irritation.

Respiratory Protection: Positive-pressure, self-contained breathing apparatus (SCBA) is recommended in response situations that involve exposure to potentially unsafe levels of hydrogen peroxide.

Skin Protection: Chemical-protective clothing is recommended for concentrations greater than 10% because hydrogen peroxide can cause skin irritation and burns.

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible.

Victim Removal

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be

removed on backboards or gurneys; if these are not available, carefully carry or drag victims to safety.

Consider appropriate management of chemically contaminated children, such as measures to reduce separation anxiety if a child is separated from a parent or other adult.

Decontamination Zone

Patients exposed only to hydrogen peroxide vapor who have no skin or eye irritation may be transferred immediately to the Support Zone. Other patients will require decontamination as described below.

Rescuer Protection

If exposure levels are determined to be safe, decontamination may be conducted by personnel wearing a lower level of protection than that worn in the Hot Zone (described above).

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. Stabilize the cervical spine with a collar and a backboard if trauma is suspected. Administer supplemental oxygen as required. Assist ventilation with a bag-valve-mask device if necessary.

Basic Decontamination

Victims who are able may assist with their own decontamination. Remove contaminated clothing while flushing exposed areas. Double-bag contaminated clothing and personal belongings.

Flush liquid-exposed skin and hair with plain water for at least 5 minutes. Wash exposed area extremely thoroughly with soap and water.Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Flush exposed or irritated eyes with copious amounts of plain water or saline for at least 15 minutes. Remove contact lenses if easily removable without additional trauma to the eye. If a corrosive material is suspected or if pain or injury is evident, continue irrigation while transferring the victim to the Support Zone.

In cases of ingestion, **do not induce emesis.** Victims who are conscious and able to swallow should be given 4 to 8 ounces of milk or water. If the victim is symptomatic, delay decontamination until other emergency measures have been instituted. Activated charcoal has not been shown to absorb hydrogen peroxide and will interfere with endoscopy which will be necessary to assess tissue damage.

Consider appropriate management of chemically contaminated children at the exposure site. Provide reassurance to the child during decontamination, especially if separation from a parent occurs.

Transfer to Support Zone

As soon as basic decontamination is complete, move the victim to the Support Zone.

Support Zone

Be certain that victims have been decontaminated properly (see *Decontamination Zone* above). Victims who have undergone decontamination or who have been exposed only to vapor pose no serious risks of secondary contamination. In such cases, Support Zone personnel require no specialized protective gear.

ABC Reminders

Quickly access for a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Ensure adequate respiration and pulse. Administer supplemental oxygen as required and establish intravenous access if necessary. Place on a cardiac monitor.

Additional Decontamination

Continue irrigating exposed skin and eyes, as appropriate.

In cases of ingestion, **do not induce emesis.** Victims who are conscious and able to swallow should be given 4 to 8 ounces of milk or water. If the victim is symptomatic, delay decontamination until other emergency measures have been instituted. Activated charcoal has not been shown to absorb hydrogen peroxide and will interfere with endoscopy which will be necessary to assess tissue damage.

Advanced Treatment

In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, perform cricothyroidotomy if equipped and trained to do so.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Hydrogen peroxide poisoning is not known to pose additional risk during the use of bronchial or cardiac sensitizing agents.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Patients who are comatose, hypotensive, or are having seizures or cardiac arrhythmias should be treated according to advanced life support (ALS) protocols.

Transport to Medical Facility

Only decontaminated patients or patients not requiring decontamination should be transported to a medical facility. "Body bags" are not recommended.

Report to the base station and the receiving medical facility the condition of the patient, treatment given, and estimated time of arrival at the medical facility.

If a chemical has been ingested, prepare the ambulance in case the victim vomits toxic material. Have ready several towels and open plastic bags to quickly clean up and isolate vomitus.

Multi-Casualty Wage

Consult with the base station physician or the regional poison control center for advice regarding triage of multiple victims.

Patients who have obvious injury, such as severe wheezing, dyspnea, or skin or eye burns, should be transported immediately to a medical facility for evaluation. Patients who have ingested hydrogen peroxide solutions (except minor ingestions of household strength solutions (3% to 5%) should also be transported for medical evaluation.

Persons who have no eye, skin, or throat irritation or who have mild or transient symptoms are unlikely to develop severe complications. They may be discharged at the scene after their names, addresses, and telephone numbers are recorded. Those discharged should be advised to seek medical care promptly if symptoms of toxicity develop (see *Patient Information Sheet* below).

Emergency Department Management

Hospital personnel can be secondarily contaminated by direct contact or from vapor off-gassing from heavily soaked clothing or from the vomitus of victims who have ingested hydrogen peroxide. Patients do not pose contamination risks after contaminated clothing is removed and the skin is thoroughly washed.

Hydrogen peroxide is corrosive to skin, eyes, and mucous membranes at high concentrations (>10%); lower concentrations may cause irritation. Symptoms become more severe as the concentration of hydrogen peroxide increases.

Other effects occur from inhalation or ingestion and may include gas embolism, gastric irritation, gastric distension, gastric rupture and emesis, an accumulation of fluid in the lungs, unconsciousness, and respiratory arrest.

There is no antidote for hydrogen peroxide poisoning. Treatment consists of support of respiratory and cardiovascular functions.

Decontamination Area

Previously decontaminated patients and patients exposed only to hydrogen peroxide vapor who have no skin or eye irritation may be transferred immediately to the Critical Care Area. Other patients will require decontamination as described below.

Be aware that use of protective equipment by the provider may cause fear in children, resulting in decreased compliance with further management efforts.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants affecting the skin. Also, emergency room personnel should examine children's mouths because of the frequency of hand-to-mouth activity among children.

ABC Reminders

Evaluate and support airway, breathing, and circulation. Children may be more vulnerable to corrosive agents than adults because of the smaller diameter of their airways. In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, surgically create an airway.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of

cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Hydrogen peroxide poisoning is not known to pose additional risk during the use of bronchial or cardiac sensitizing agents.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Patients who are comatose, hypotensive, or have seizures or ventricular arrhythmias should be treated in the conventional manner.

Basic Decontamination

Patients who are able may assist with their own decontamination.

Because concentrated hydrogen peroxide can cause burns, ED staff should don chemical resistant jumpsuits (e.g., of Tyvek or Saranax) or butyl rubber aprons, rubber gloves, and eye protection if the patient's clothing or skin is wet with hydrogen peroxide. After the patient has been decontaminated, no special protective clothing or equipment is required for ED personnel.

Quickly remove contaminated clothing while flushing the exposed skin with water (preferably under a shower). Double-bag the contaminated clothing and personal belongings. Wash skin thoroughly with soap and water.Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Irrigate exposed or irritated eyes with copious amounts of plain water or saline for at least 15 minutes. Remove contact lenses if easily removable without additional trauma to the eye. If a corrosive material is present or if pain or injury is evident, continue irrigation while transporting the patient to the Critical Care Area.

In cases of ingestion, **do not induce emesis.** Victims who are conscious and able to swallow should be given 4 to 8 ounces of milk or water if this has not been done already. If the victim is symptomatic, delay decontamination until other emergency measures have been instituted. Activated charcoal has not been shown to absorb hydrogen peroxide and will interfere with endoscopy which will be necessary to assess tissue damage.

Critical Care Area

Be certain that appropriate decontamination has been carried out (see *Decontamination Area* above).

ABC Reminders

Evaluate and support airway, breathing, and circulation as in *ABC Reminders* above. Children may be more vulnerable to corrosive agents than adults because of the relatively smaller diameter of their airways. Establish intravenous access in seriously ill patients if this has not been done previously. Continuously monitor cardiac rhythm.

Patients who are comatose, hypotensive, or have seizures or cardiac arrhythmias should be treated in the conventional manner.

Inhalation Exposure

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Hydrogen peroxide poisoning is not known to pose additional risk during the use of bronchial or cardiac sensitizing agents.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Skin Exposure

If concentrated hydrogen peroxide solution was in contact with the skin, chemical burns may result; treat as thermal burns.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants affecting the skin.

Eye Exposure

Continue irrigation for at least 15 minutes. Test visual acuity. Examine the eyes for corneal damage and treat appropriately. Immediately consult an ophthalmologist for patients who have corneal injuries.

Ingestion Exposure

Do not induce emesis. Victims who are conscious and able to swallow should be given 4 to 8 ounces of milk or water if this has not been done already. If the victim is symptomatic, delay decontamination until other emergency measures have been instituted. Activated charcoal has not been shown to absorb

hydrogen peroxide and will interfere with endoscopy which will be necessary to assess tissue damage.

Consider endoscopy to evaluate the extent of gastrointestinal tract injury. Extreme throat swelling may require endotracheal intubation or cricothyroidotomy. Gastric lavage is useful in certain circumstances to remove caustic material and prepare for endoscopic examination. Consider gastric lavage with a small nasogastric tube if: (1) a large dose has been ingested; (2) the patient's condition is evaluated within 30 minutes; (3) the patient has oral lesions or persistent esophageal discomfort; and (4) the lavage can be administered within 1 hour of ingestion. Care must be taken when placing the gastric tube because blind gastric-tube placement may further injure the chemically damaged esophagus or stomach.

Because children do not ingest large amounts of corrosive materials, and because of the risk of perforation from NG intubation, lavage is discouraged in children unless performed under endoscopic guidance.

Toxic vomitus or gastric washings should be isolated (e.g., by attaching the lavage tube to isolated wall suction or another closed container).

Large ingestions may produce gastritis from hydrogen peroxide decomposition, which releases large volumes of oxygen and causes gastric distention. Gently place a small nasogastric tube to relieve distention or to perform lavage on an obtunded patient. Most ingestions of dilute hydrogen peroxide are benign, and mild irritation is self-limited.

Antidotes and Other Treatments

There is no antidote for hydrogen peroxide poisoning. Enhanced elimination methods are neither necessary nor effective. Hyperbaric oxygen has been used in severe embolization cases, but there are no controlled studies of the efficacy of this treatment. Careful aspiration of air through a central venous line may be attempted for patients in extremis.

Laboratory Tests

The diagnosis of acute hydrogen peroxide toxicity is primarily clinical based on eye and skin irritation or burns, white foam from the mouth, and gastric irritation. Routine laboratory studies for all exposed patients include CRC, glucose, and electrolyte determinations. For patients exposed through inhalation, useful studies include chest radiography, pulse oximetry (or ABG measurements), spirometry, and peak flow measurements. A radiograph of the abdomen and chest is advised if there are

symptoms, or if a high concentration is ingested to detect intravascular oxygen embolization. Ingestion of hydrogen peroxide can be assessed by adding 1 drop of 15% titanium chloride to an acidified mixture of equal parts of gastric contents and ethyl ether. A yellow to deep orange coloration of the aqueous layer indicates the formation of H_2TiO_4 which is an indication of ingested peroxide.

Disposition and Follow-up

Consider hospitalizing symptomatic patients who have histories of substantial inhalation exposure and patients who have ingested a concentrated solution of hydrogen peroxide.

Delayed Effects

Patients who have complaints of chest pain, chest tightness, or cough should be observed for 24 to 72 hours and reexamined periodically to detect delayed-onset pulmonary edema or respiratory failure.

Patient Release

Patients who remain asymptomatic for 4 to 6 hours may be discharged with instructions to seek medical care promptly if symptoms develop (see the *Hydrogen Peroxide—Patient Information Sheet* below).

Follow-up

Obtain the name of the patient's primary care physician so that the hospital can send a copy of the ED visit to the patient's doctor.

Patients who have corneal injuries or severe skin burns should be reexamined within 24 hours.

Reporting

If a work-related incident has occurred, you may be legally required to file a report; contact your state or local health department.

Other persons may still be at risk in the setting where this incident occurred. If the incident occurred in the workplace, discussing it with company personnel may prevent future incidents. If a public health risk exists, notify your state or local health department or other responsible public agency. When appropriate, inform patients that they may request an evaluation of their workplace from OSHA or NIOSH. See Appendices III and IV for a list of agencies that may be of assistance.

Hydrogen Peroxide
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to hydrogen peroxide.

What is hydrogen peroxide?
Hydrogen peroxide is used widely in industry to bleach cloth and paper and to manufacture other chemicals. It is also an ingredient of some rocket fuels. Hydrogen peroxide is found in dilute form (3% to 10%) in the home and in concentrated form (30% or greater) in industry. In the home, 3% solutions of hydrogen peroxide are used as disinfectants for cuts and scrapes, and slightly more concentrated solutions (10%) are used in hair bleaches. Dilute solutions have almost no odor, but stronger solutions have a sharp odor. Hydrogen peroxide is not flammable, but concentrated solutions may cause combustion of organic materials.

What immediate health effects can result from hydrogen peroxide exposure?
Depending on the concentration, breathing hydrogen peroxide vapor can cause eye and throat irritation, coughing, and breathing difficulty. Serious eye or skin burns and bleaching of the hair may result from contact with hydrogen peroxide solutions. Drinking a concentrated hydrogen peroxide solution can cause vomiting and severe burns of the throat and stomach. Generally, the more serious the exposure, the more severe the symptoms.

Can hydrogen peroxide poisoning be treated?
There is no proven antidote for hydrogen peroxide poisoning, but its effects can be treated, and most persons get well. Persons who have experienced serious symptoms may need to be hospitalized.

Are any future health effects likely to occur?
A single small exposure from which a person recovers quickly is not likely to cause delayed or long-term effects. After a severe exposure, a person may not notice any symptoms for up to 24 hours, but may develop lung damage.

What tests can be done if a person has been exposed?
There are no specific blood and urine tests that can show whether a person has been exposed to hydrogen peroxide. However, blood tests and a chest x-ray may be used to evaluate lung injury. Testing is not needed in every case.

Where can more information about hydrogen peroxide be obtained?
More information about hydrogen peroxide can be obtained from your regional poison control center; your state, county, or local health department; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in occupational and environmental health. If the exposure happened at work, you may wish to discuss it with your employer, the Occupational Safety and Health, Administration (OSHA), or the National Institute for Occupational Safety and Health (NIOSH). Ask the person who gave you this form for help in locating these telephone numbers.

Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow *only* the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:

- coughing, difficulty breathing or shortness of breath
- wheezing, chest pain or tightness
- increased redness or pain or a pus-like discharge from injured skin, eyes, or other wound
- stomach pain or vomiting

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.
[ ] Call for an appointment with Dr. _____ in the practice of _____.
When you call for your appointment, please say that you were treated in the Emergency Department at _ _____ Hospital by _____ and were advised to be seen again in _____ days.
[ ] Return to the Emergency Department/ _____ Clinic on (date) _____at ___ _____ AM/PM for a follow-up examination.
[ ] Do not perform vigorous physical activities for 1 to 2 days.
[ ] You may resume everyday activities including driving and operating machinery.
[ ] Do not return to work for _____ days.
[ ] You may return to work on a limited basis. See instructions below.
[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.
[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.
[ ] Avoid taking the following medications: _____
[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: __
_____
_____
[ ] Other instructions: _____
_____
_____

- Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.

- You or your physician can get more information on the chemical by contacting: _____ _____ or _____, or by checking out the following Internet Web sites: _____; _____.

Signature of patient _____ Date _____

Signature of physician _____ Date _____

Hydrogen Sulfide (H_2S)
CAS 7783-0604; UN 1053

Synonyms include dihydrogen sulfide, sulfur hydride, sulfurated hydrogen, hydrosulfuric acid, "sewer gas," "swamp gas," hepatic acid, sour gas, and "stink damp."

Persons exposed to hydrogen sulfide pose no serious risks of secondary contamination to personnel outside the Hot Zone. However, fatalities have occurred to rescuers entering the hot zone.

Hydrogen sulfide is a colorless, highly flammable and explosive gas produced naturally by decaying organic matter and by certain industrial processes. Hydrogen sulfide has a characteristic rotten-egg odor; however, olfactory fatigue may occur and consequently it may not provide adequate warning of hazardous concentrations.

Hydrogen sulfide is well absorbed through the lungs; cutaneous absorption is minimal. Exposure by any route can cause systemic effects.

Description

Hydrogen sulfide is a colorless, flammable, highly toxic gas. It is shipped as a liquefied, compressed gas. It has a characteristic rotten-egg odor that is detectable at concentrations as low as 0.5 ppb.

Routes of Exposure

Inhalation

Inhalation is the major route of hydrogen sulfide exposure. The gas is rapidly absorbed by the lungs. The odor threshold (0.5 ppb) is much lower than the OSHA ceiling (20 ppm). However, although its strong odor is readily identified, olfactory fatigue occurs at high concentrations and at continuous low concentrations. For this reason, **odor is not a reliable indicator of hydrogen sulfide's presence and may not provide adequate warning of hazardous concentrations.** Hydrogen sulfide is slightly heavier than air and may accumulate in enclosed, poorly ventilated, and low-lying areas.

Children exposed to the same levels of hydrogen sulfide as adults may receive larger doses because they have greater lung surface area:body weight ratios and increased minute volumes:weight ratios. In addition, they may be exposed to higher levels than adults in the same location because of their short stature and the higher levels of hydrogen sulfide found nearer to the ground. Children may be more vulnerable to corrosive agents than adults because of the relatively smaller diameter of their airways.

Skin/Eye Contact

Prolonged exposure to hydrogen sulfide, even at relatively low levels, may result in painful dermatitis and burning eyes. Direct contact with the liquefied gas can cause frostbite. Absorption through intact skin is minimal.

Ingestion

Because hydrogen sulfide is a gas at room temperature, ingestion is unlikely to occur.

Sources/Uses

Hydrogen sulfide is produced naturally by decaying organic matter and is released from sewage sludge, liquid manure, sulfur hot springs, and natural gas. It is a by-product of many industrial processes including petroleum refining, tanning, mining, wood-pulp processing, rayon manufacturing, sugar-beet processing, and hot-asphalt paving. Hydrogen sulfide is used to produce elemental sulfur, sulfuric acid, and heavy water for nuclear reactors.

Standards and Guidelines

OSHA ceiling = 20 ppm

OSHA maximum peak = 50 ppm (10 minutes, once, no other exposure)

NIOSH IDLH (immediately dangerous to life or health) = 100 ppm

AIHA ERPC-2 (emergency response planning guideline) (maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms which could impair an individual's ability to take protective action) = 30 ppm.

Physical Properties

Description: Colorless gas with odor of rotten eggs

Warning properties: Not dependable; characteristic rotten-egg odor detectable at about 0.5 ppb, but olfactory nerve fatigue occurs in 2 to 15 minutes at concentrations over 100 ppm

Molecular weight: 34.1 daltons

Boiling point (760 mm Hg): -77 °F (-60.3 °C)

Vapor pressure: >760 mm Hg at 68 °F (20 °C)

Gas density: 1.2 (air = 1)

Water solubility: Slightly water soluble (0.4% at 68 °F [20 °C])

Flammability: Highly flammable and explosive between 4% and 45% (concentration in air); may travel to a source of ignition and flash back. Burns to produce a toxic gas, sulfur dioxide.

Incompatibilities

Hydrogen sulfide reacts with strong oxidizers, strong nitric acid, and metals.

Health Effects

Hydrogen sulfide is a mucous membrane and respiratory tract irritant; pulmonary edema, which may be immediate or delayed, can occur after exposure to high concentrations.

- **Symptoms of acute exposure include nausea, headaches, delirium, disturbed equilibrium, tremors, convulsions, and skin and eye irritation.**
- **Inhalation of high concentrations of hydrogen sulfide can produce extremely rapid unconsciousness and death. Exposure to the liquified gas can cause frostbite injury.**

Acute Exposure

Hydrogen sulfide's can cause inhibition of the cytochrome oxidase enzyme system resulting in lack of oxygen use in the cells. Anaerobic metabolism causes accumulation of lactic acid leading to an acid-base imbalance. The nervous system and cardiac tissues are particularly vulnerable to the disruption of oxidative metabolism and death is often the result of respiratory arrest. Hydrogen sulfide also irritates skin, eyes, mucous membranes, and the respiratory tract. Pulmonary effects may not be apparent for up to 72 hours after exposure.

Children do not always respond to chemicals in the same way that adults do. Different protocols for managing their care may be needed.

CNS

CNS injury is immediate and significant after exposure to hydrogen sulfide. At high concentrations, only a few breaths can lead to immediate loss of consciousness, coma, respiratory paralysis, seizures, and death. CNS stimulation may precede CNS depression. Stimulation manifests as excitation, rapid breathing, and headache; depression manifests as impaired gait, dizziness, and coma, possibly progressing to respiratory paralysis and death. In addition, decreased ability to smell hydrogen sulfide occurs at concentrations greater than 100 ppm.

Respiratory

Inhaled hydrogen sulfide initially affects the nose and throat. Low concentrations (50 ppm) can rapidly produce irritation of the nose, throat, and lower respiratory tract. Pulmonary manifestations include cough, shortness of breath, and bronchial or lung hemorrhage. Higher concentrations can provoke bronchitis and cause accumulation of fluid in the lungs, which may be immediate or delayed for up to 72 hours. Lack of oxygen may result in blue skin color.

Children may be more vulnerable to corrosive agents than adults because of the relatively smaller diameter of their airways. Children may also be more vulnerable to gas exposure because of increased minute ventilation per kg and failure to evacuate an area promptly when exposed.

Cardiovascular High-dose exposures may cause insufficient cardiac output, irregular heartbeat, and conduction abnormalities.

Renal Transient renal effects include blood, casts, and protein in the urine. Renal failure as a direct result of hydrogen sulfide toxicity has not been described, although it may occur secondary to cardiovascular compromise.

Gastrointestinal Symptoms may include nausea and vomiting.

Dermal Prolonged or massive exposure may cause burning, itching, redness, and painful inflammation of the skin. Exposure to the liquified gas can cause frostbite injury.

Ocular Eye irritation may result in inflammation (i.e., keratoconjunctivitis) and clouding of the eye surface. Symptoms include blurred vision, sensitivity to light, and spasmodic blinking or involuntary closing of the eyelid.

Potential Sequelae Inflammation of the bronchi can be a late development. Survivors of severe exposure may develop psychological disturbances and permanent damage to the brain and heart. The cornea may be permanently scarred.

Chronic Exposure Hydrogen sulfide does not accumulate in the body. Nevertheless, repeated or prolonged exposure has been reported to cause low blood pressure, headache, nausea, loss of appetite, weight loss, ataxia, eye-membrane inflammation, and chronic cough. Neurologic symptoms, including psychological disorders, have been associated with chronic exposure. Chronic exposure may be more serious for children because of their potential longer latency period.

Carcinogenicity Hydrogen sulfide has not been classified for carcinogenic effects.

Reproductive and Developmental Effects

There is some evidence to suggest that exposure to hydrogen sulfide may be associated with an increased risk of spontaneous abortion. No information was located pertaining to placental transfer of hydrogen sulfide or to excretion of hydrogen sulfide in breast milk. There are no studies of developmental effects in humans exposed to hydrogen sulfide. However, results from animal studies suggest that hydrogen sulfide may be a developmental neurotoxicant. Hydrogen sulfide is not listed in TERIS or in *Shepard's Catalog of Teratogenic Agents.* It is also not included in *Reproductive and Developmental Toxicants,* a 1991 report published by the U.S. General Accounting Office (GAO) that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences.

Prehospital Management

Victims exposed only to hydrogen sulfide gas do not pose substantial risks of secondary contamination to personnel outside the Hot Zone. However, personnel could be secondarily contaminated by contacting or breathing vapors from clothing heavily soaked with hydrogen sulfide-containing solution.

Hydrogen sulfide is a highly toxic gas that can produce extremely rapid CNS and respiratory depression. It is also an irritant affecting skin and mucous membranes.

There is no proven antidote for hydrogen sulfide poisoning. Treatment generally consists of support of respiratory and cardiovascular functions.

Hot Zone

Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if prehospital staff have not been trained in its use, assistance should be obtained from a local or regional HAZMAT team or other properly equipped response organization.

Rescuer Protection

Hydrogen sulfide is an extremely rapidly acting, highly toxic gas. Fatalities have occurred to rescuers entering the hot zone.

Respiratory Protection: Positive-pressure, self-contained breathing apparatus (SCBA) is recommended in response situations that involve exposure to potentially unsafe levels of hydrogen sulfide.

Skin Protection: Chemical-protective clothing is not generally required because hydrogen sulfide gas is not absorbed through the skin, and skin irritation is rare. Direct contact with the liquefied gas can cause frostbite.

Rescuers should have a safety line during rescue operations because of the extremely rapid toxic action of hydrogen sulfide.

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible.

Victim Removal

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be removed on backboards or gurneys; if these are not available, carefully carry or drag victims to safety.

Consider appropriate management of chemically contaminated children, such as measures to reduce separation anxiety if a child is separated from a parent or other adult.

Decontamination Zone

Patients exposed only to hydrogen sulfide gas who have no skin or eye irritation do not need decontamination. They may be transferred immediately to the Support Zone. Other patients will require decontamination as described below.

Rescuer Protection

If exposure levels are determined to be safe, decontamination may be conducted by personnel wearing a lower level of protection than that worn in the Hot Zone (described above).

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. Stabilize the cervical spine with a collar and a backboard if trauma is suspected. Administer supplemental oxygen as required. Assist ventilation with a bag-valve-mask device if necessary.

Basic Decontamination

Victims who are able may assist with their own decontamination. Remove and double-bag contaminated clothing.

Handle frostbitten skin and eyes with caution. Wrap the affected part gently in blankets. Let the circulation reestablish itself naturally. Encourage the victim to exercise the affected part while it is being warmed.

Flush exposed skin and hair with water for 3 to 5 minutes. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Do not irrigate frostbitten eyes. Otherwise, irrigate exposed or irritated eyes with plain water or saline for at least 5 minutes. Eye irrigation may be carried out simultaneously with other basic care and transport. Remove contact lenses if easily removable without additional trauma to the eye. If a corrosive material is suspected or if pain or injury is evident, continue irrigation while transferring the victim to the support zone.

Consider appropriate management of chemically contaminated children, such as measures to reduce separation anxiety if a child is separated from a parent or other adult. If possible, seek assistance from a child separation expert.

Transfer to Support Zone

As soon as basic decontamination is complete, move the victim to the Support Zone.

Support Zone

Be certain that victims have been properly decontaminated (see *Decontamination Zone* above). Victims who have undergone decontamination or who have been exposed only to hydrogen sulfide gas pose no serious risks of secondary contamination. In such cases, Support Zone personnel require no specialized protective gear.

ABC Reminders

Quickly access for a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Ensure adequate respiration and pulse. Administer supplemental oxygen as required and establish intravenous access if necessary. Place on a cardiac monitor.

Additional Decontamination

Continue irrigating exposed skin and eyes, as appropriate.

Advanced Treatment

In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, perform cricothyroidotomy if equipped and trained to do so.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Hydrogen sulfide poisoning is not known to pose additional risk during the use of bronchial or cardiac sensitizing agents.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Patients who are comatose, hypotensive, or are having seizures or cardiac arrhythmias should be treated according to advanced life support (ALS) protocols.

If frostbite is present, treat by rewarming in a water bath at a temperature of 102 to 108 °F (40 to 42 °C) for 20 to 30 minutes and continue until a flush has returned to the affected area.

Nitrite therapy (found in the cyanide antidote kit) has been suggested as a therapy for hydrogen sulfide exposure. Amyl nitrite is given by inhalation (for 30 seconds every minute until an intravenous line is established) followed by intravenous sodium nitrite (**300 mg over absolutely no less than 5 minutes**). This may aid recovery by forming sulfmethemoglobin, thus removing sulfide from combination in tissue. It is not necessary to use the sodium thiosulfate component of the cyanide antidote kit. The antidotal efficacy of nitrite therapy is controversial, but is currently recommended if it can be started shortly after exposure. However, there is only anecdotal evidence that nitrite therapy is effective, and victims of hydrogen sulfide poisoning have survived without sequelae after supportive care alone. The usefulness of nitrite therapy given beyond the first few minutes after exposure is questionable. Nitrite therapy should not be allowed to interfere with the establishment of adequate ventilation and oxygenation.

Transport to Medical Facility

Only decontaminated patients or patients not requiring decontamination should be transported to a medical facility. “Body bags” are not recommended.

Report to the base station and the receiving medical facility the condition of the patient, treatment given, and estimated time of arrival at the medical facility.

Multi-Casualty Triage

Consult with the base station physician or regional poison control center for further advice regarding triage of multiple victims.

Patients with evidence of significant exposure (e.g., breathing difficulties, unconsciousness, seizures, or collapse) should be transported to a medical facility for evaluation. Patients who have minor or transient irritation of the eyes or throat may be discharged from the scene after their names, addresses, and telephone numbers are recorded. They should be advised to seek medical care promptly if symptoms develop or recur (see *Patient Information Sheet* below).

Emergency Department Management

Hospital personnel away from the scene are not at risk of secondary contamination from patients exposed only to hydrogen sulfide gas; however, personnel can be secondarily contaminated by contacting or breathing vapors from clothing heavily soaked with hydrogen sulfide-containing solution.

Hydrogen sulfide is a very rapidly acting, highly toxic gas that can produce rapid CNS and respiratory depression. It is also an irritant affecting skin and mucous membranes.

There is no proven antidote for hydrogen sulfide poisoning. Treatment generally consists of support of respiratory and cardiovascular functions.

Decontamination Area

Patients who have been decontaminated previously and patients exposed only to hydrogen sulfide gas who have no skin or eye irritation may be transferred immediately to the Critical Care Area. Other patients require decontamination as described below.

Be aware that use of protective equipment by the provider may cause fear in children, resulting in decreased compliance with further management efforts.

ABC Reminders

Evaluate and support airway, breathing, and circulation. Children may be more vulnerable to corrosive agents than adults because of the smaller diameter of their airways. In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, surgically create an airway.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Hydrogen sulfide poisoning is not known to pose additional risk during the use of bronchial or cardiac sensitizing agents.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine

solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Patients who are comatose, hypotensive, or have seizures or ventricular arrhythmias should be treated in the conventional manner.

Nitrite therapy (found in the cyanide antidote kit) has been suggested as a therapy for hydrogen sulfide exposure. Amyl nitrite is given by inhalation (for 30 seconds every minute until an intravenous line is established) followed by intravenous sodium nitrite (**300 mg over absolutely no less than 5 minutes**). This may aid recovery by forming sulfmethemoglobin, thus removing sulfide from combination in tissue. It is not necessary to use the sodium thiosulfate component of the cyanide antidote kit. The antidotal efficacy of nitrite therapy is controversial, but is currently recommended if it can be started shortly after exposure. The usefulness of nitrite therapy given beyond the first few minutes after exposure is questionable. There is only anecdotal evidence that nitrite therapy is effective, and victims of hydrogen sulfide poisoning have survived without sequelae after supportive care alone. Nitrite therapy should not be allowed to interfere with the establishment of adequate ventilation and oxygenation.

Basic Decontamination

Patients who are able may assist with their own decontamination. Remove and double-bag contaminated clothing and personal belongings,

Handle frostbitten skin and eyes with caution. Place frostbitten skin in warm water, about 108 °F (42 °C). Let the circulation reestablish itself naturally. Encourage the victim to exercise the affected part while it is being warmed.

Flush exposed skin and hair with plain water for 5 minutes, preferably under a shower. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Do not irrigate frostbitten eyes. Otherwise, irrigate exposed eyes for at least 5 minutes. Remove contact lenses if easily removable without additional trauma to the eye. An ophthalmic anesthetic may be necessary to alleviate blepharospasm, and lid retractors may be required to allow adequate irrigation under the eyelids. Continue irrigation while transporting the patient to the Critical Care Area.

Critical Care Area

Be certain that appropriate decontamination has been carried out (see *Decontamination Area* above).

ABC Reminders

Evaluate and support airway, breathing, and circulation as in *ABC Reminders* above. Children may be more vulnerable to corrosive agents than adults because of the smaller diameter of their airways. Establish intravenous access in seriously symptomatic patients. Continuously monitor cardiac rhythm.

Patients who are comatose, hypotensive, or have seizures or cardiac arrhythmias should be treated in the conventional manner.

Inhalation Exposure

Administer supplemental oxygen by mask to patients who have respiratory symptoms. Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Hydrogen sulfide poisoning is not known to pose additional risk during the use of bronchial or cardiac sensitizing agents.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Observe patients for 24 hours, repeating appropriate tests and chest examinations as needed. Follow-up as clinically indicated.

Skin Exposure

If concentrated hydrogen sulfide was in contact with the skin, chemical burns may result; treat as thermal burns. If the liquefied compressed gas is released and contacts the skin, frostbite may result. If a victim has frostbite, treat by rewarming affected areas in a water bath at a temperature of 102 to 108 °F (40 to 42 °C) for 20 to 30 minutes and continue until a flush has returned to the affected area.

Eye Exposure

Continue irrigation for at least 5 minutes. Test visual acuity. Examine the eyes for corneal damage and treat appropriately. Immediately consult an ophthalmologist for patients who have severe corneal injuries.

Antidotes and Other Treatments

Nitrite therapy (found in the cyanide antidote kit) has been suggested as a therapy for hydrogen sulfide exposure. Amyl nitrite is given by inhalation (for 30 seconds every minute until an intravenous line is established) followed by intravenous sodium nitrite (**300 mg over absolutely no less than 5 minutes**). This may aid recovery by forming sulfmethemoglobin, thus removing sulfide from combination in tissue. It is not necessary to use the sodium thiosulfate component of the cyanide antidote kit. The antidotal efficacy of nitrite therapy is controversial, but is currently recommended if it can be started shortly after exposure. The usefulness of nitrite therapy given beyond the first few minutes after exposure is questionable. There is only anecdotal evidence that nitrite therapy is effective, and victims of hydrogen sulfide poisoning have survived without sequelae after supportive care alone. Nitrite therapy should not be allowed to interfere with the establishment of adequate ventilation and oxygenation.

Hyperbaric oxygen therapy is controversial and based on anecdotal evidence. It may be effective for patients with persistent coma in whom other treatments are unsuccessful.

Laboratory Tests

Routine laboratory studies for all symptomatic exposed patients include CBC, blood glucose, and electrolyte determinations. Additional studies for patients exposed to hydrogen sulfide include ECG monitoring and renal-function tests. Chest radiography and pulse oximetry (or ABG measurements) may be helpful in cases of inhalation exposure. If nitrites are used, check methemoglobin levels.

Disposition and Follow-up

Delayed Effects

Patients who are unconscious or hypotensive should be observed closely for complications including post-hypoxic encephalopathy. Because pulmonary edema may be delayed in onset, patients seriously exposed by inhalation should be monitored for 24 hours. If pulmonary edema is suspected, admit patients to an intensive care unit.

Patient Release

Asymptomatic patients who have no evidence of pulmonary edema or CNS or respiratory compromise and no signs of eye irritation may be discharged after 4 to 6 hours of observation with instructions to seek medical care promptly if symptoms develop (see the *Hydrogen Sulfide—Patient Information Sheet* below).

Follow-up

Obtain the name of the patient's primary care physician so that the hospital can send a copy of the ED visit to the patient's doctor.

Patients exposed to hydrogen sulfide should be monitored for heart and brain injuries, including evaluation for neurologic deficits.

Patients who have skin or corneal injury should be re-examined within 24 hours.

Reporting

If a work-related incident has occurred, you may be legally required to file a report; contact your state or local health department.

Other persons may still be at risk in the setting where this incident occurred. If the incident occurred in the workplace, discussing it with company personnel may prevent future incidents. If a public health risk exists, notify your state or local health department or other responsible public agency. When appropriate, inform patients that they may request an evaluation of their workplace from OSHA or NIOSH. See Appendices III and IV for a list of agencies that may be of assistance.

Hydrogen Sulfide
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to hydrogen sulfide.

What is hydrogen sulfide?
Hydrogen sulfide is an extremely rapidly acting, highly toxic, colorless gas with a rotten-egg odor. It is produced naturally by decaying organic matter and is released from sewage sludge, liquid manure, sulfur hot springs, and natural gas. It is used in several industries and is a by-product of many industrial processes such as oil refining, mining, and rayon manufacturing.

What immediate health effects can result from hydrogen sulfide exposure?
Even in small amounts, hydrogen sulfide has a strong rotten-egg odor. However, with continued exposure and at high levels, the poison may deaden a person's sense of smell. If the rotten egg odor is no longer noticeable, it may not necessarily mean that exposure has stopped.

After a serious exposure, symptoms usually begin immediately. At low levels, hydrogen sulfide causes irritation of the eyes, nose, and throat. Moderate levels can cause headache, dizziness, nausea, and vomiting, as well as coughing and difficulty in breathing. Higher levels can cause shock, convulsions, coma, and death. Generally, the more serious the exposure, the more severe the symptoms.

Can hydrogen sulfide poisoning be treated?
There is no proven antidote for hydrogen sulfide poisoning, but the effects of hydrogen sulfide can be treated and some exposed persons get well. Persons who have had serious exposures may need to be hospitalized.

Are any future health effects likely to occur?
A single small exposure from which a person recovers quickly is not likely to cause delayed or long-term effects. Moderate exposure can cause residual damage and a serious exposure that causes coma or convulsions may damage the brain and heart.

What tests can be done if a person has been exposed to hydrogen sulfide?
Specific tests for the presence of hydrogen sulfide in blood and urine generally are not useful to the doctor. If a severe exposure has occurred, blood and urine analyses and other tests may show whether the brain, nerves, heart, or kidneys have been injured. If hydrogen sulfide was inhaled, blood tests and a chest x-ray may be necessary to determine if the lungs have been injured. Testing is not needed in every case.

Where can more information about hydrogen sulfide be found?
More information about hydrogen sulfide can be obtained from your regional poison control center; your state, county, or local health department; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in occupational and environmental health. If the exposure happened at work, you may wish to discuss it with your employer, the Occupational Safety and Health Administration (OSHA), or the National Institute for Occupational Safety and Health (NIOSH). Ask the person who gave you this form for help in locating these telephone numbers.

Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow *only* the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:

- coughing, wheezing, difficulty breathing, or shortness of breath
- chest pain or tightness
- stomach pain, or vomiting
- headache
- increased redness or pain or a pus-like discharge in the area of a skin burn

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.
[ ] Call for an appointment with Dr. _____ in the practice of _____. When you call for your appointment, please say that you were treated in the Emergency Department at _ _____ Hospital by _____ and were advised to be seen again in _____ days.
[ ] Return to the Emergency Department/ _____ Clinic on (date) _____at ___ _____ AM/PM for a follow-up examination.
[ ] Do not perform vigorous physical activities for 1 to 2 days.
[ ] You may resume everyday activities including driving and operating machinery.
[ ] Do not return to work for _____ days.
[ ] You may return to work on a limited basis. See instructions below.
[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.
[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.
[ ] Avoid taking the following medications: _____
[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: __ _____
_____
[ ] Other instructions: _____
_____
_____

- Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.

- You or your physician can get more information on the chemical by contacting: _____ _____ or _____, or by checking out the following Internet Web sites: _____; _____.

Signature of patient _____ Date _____

Signature of physician _____ Date _____

Malathion ($C_{10}H_{19}O_6PS_2$)
CAS 121-75-5; UN 2783

Synonyms include S-[1,2-Di(ethoxycarbonyl)ethyl]O,O-dimethyl-phosphorothioate, diethyl (dimethoxyphosphinothioylthio) succinate, and a variety of trade names such as Cekumal, Cythion, Fosfothion, Fyfafon, Malixol, Maltox, Sadophos, and Zithiol.

- **Persons whose skin or clothing is contaminated with liquid or powdered malathion can cause secondary contamination by direct contact.**
- **Malathion is an organophosphate pesticide. At room temperature, it is a combustible yellow to deep brown liquid that may be difficult to ignite. In commercial products, malathion is usually dissolved in hydrocarbon solvents such as toluene or xylene, which are flammable. Malathion has a garlic-like odor, which does not provide adequate warning of hazardous concentrations.**
- **Because malathion has a low vapor pressure, significant inhalation is unlikely at ordinary temperatures. However, the hydrocarbon solvents in commercial preparations can be inhaled. Malathion is rapidly absorbed by ingestion and through intact skin and the eyes, resulting in acute systemic toxicity.**

Description

At room temperature, malathion is a yellow to deep brown liquid with an odor of garlic. It is a solid below 37 °F. It is often dissolved in a hydrocarbon solvent before use. Malathion itself is not volatile. It is slightly soluble in water, soluble in alcohols and aromatic solvents, and of limited solubility in petroleum oils. The premium grade can maintain its biological activity unchanged for approximately 2 years if stored unopened in a cool, shaded, and well aired place at 68–86 °F.

Routes of Exposure

Inhalation

Inhalation is not a significant route of exposure to malathion at ordinary temperatures because of its low volatility, but toxic effects can occur after inhalation of malathion sprays or dusts. The hydrocarbon solvents (most commonly toluene and xylene) used to dissolve malathion are more volatile than malathion itself, and toxicity can result from inhalation of solvent vapor as well. The odor threshold of malathion is very close (13.5 mg/m^3) to the OSHA PEL (15 mg/m^3) and **may not provide adequate warning of hazardous concentrations**.

Children exposed to the same levels of malathion as adults may receive a larger dose because they have greater lung surface area:body weight ratios and higher minute volume:weight ratios.

Skin/Eye Contact

Dermal exposure constitutes a major route of exposure during and following malathion application to fields and following aerial spraying for pest control and residential use. Malathion is irritating to the skin and eyes, and is readily absorbed through intact skin, contributing to systemic toxicity.

Because of their relatively larger surface area:weight ratio, children are more vulnerable to toxicants absorbed through the skin.

Ingestion

Malathion residues are often detected in foods but this level of exposure is not of concern. Acute toxic effects, including rapidly fatal systemic poisoning, can result from ingestion of high amounts of malathion.

Sources/Uses

Malathion is produced by the reaction of phosphorus pentasulfide with methanol in toluene to produce an intermediate, dimethylphosphorodithioic acid. The intermediate is isolated and then reacted with either diethylfumarate or diethylmaleate. Malathion is widely used as an agricultural insecticide. It is used to kill insects on agricultural crops, on stored products, on golf courses, and in home gardens. It also used to kill mosquitoes and fruit flies in large outdoor areas. In addition, it is used to kill fleas on pets and to treat head lice on humans.

Standards and Guidelines

OSHA PEL (permissible exposure limit) = 15 mg/m^3 (skin) (averaged over an 8-hour workshift)

NIOSH REL-TWA (recommended exposure limit) = 10 mg/m^3 (skin)

NIOSH IDLH (immediately dangerous to life or health) = 250 mg/m^3

Physical Properties

Description: Yellow to deep brown liquid at room temperature

Warning properties: Garlic odor at 13.5 mg/m^3; inadequate warning for acute and chronic exposures. May produce skin irritation

Molecular weight: 330.36 daltons

Boiling point: (0.7 torr): 156-157 °C

Freezing point: 37.2 °F (2.9 °C)

Specific gravity: 1.23 (water = 1)

Vapor pressure: 5 x 10^{-6} mm Hg at 25 °C

Water solubility: 145 mg/L at 20 °C

Flammability: >325 °F

Incompatibilities Malathion reacts with strong oxidizers, magnesium and alkaline pesticides.

Health Effects

- **Systemic malathion toxicity due to excess cholinergic stimulation may result from all routes of exposure. Symptoms include abdominal cramps, vomiting, diarrhea, pinpoint pupils and blurred vision, excessive sweating, salivation and lacrimation, wheezing, excessive tracheobronchial secretions, agitation, seizures, bradycardia or tachycardia, muscle twitching and weakness, and urinary and fecal incontinence. Seizures are much more common in children than in adults.**
- **Death results from loss of consciousness, coma, excessive bronchial secretions, respiratory depression and cardiac irregularity.**
- **Commercial malathion products often contain impurities and hydrocarbon solvents, such as xylene or toluene, which themselves can cause toxicity.**
- **Toxicity of malathion depends on metabolic activation; thus, symptoms may appear from a few minutes to a few hours after exposure.**

Acute Exposure

Malathion, like all organophosphate pesticides, inhibits acetylcholinesterase and alters cholinergic synaptic transmission at neuroeffector junctions (muscarinic effects), at skeletal myoneural junctions and autonomic ganglia (nicotinic effects), and in the central nervous system. Inhibition occurs when malaoxon, a metabolite of malathion, binds to acetylcholinesterase; thus, symptoms may be delayed after exposure. Signs and symptoms of poisoning vary according to age, dose, and concentration. Most systemic effects are secondary to inhibition of acetylcholinesterase.

Muscarinic effects include pinpoint pupils; blurred vision; hypersecretion by salivary, lacrimal, sweat, and bronchial glands; narrowing of the bronchi; nausea, vomiting, diarrhea, and crampy abdominal pains; urinary and fecal incontinence; and slow heart rate.

Nicotinic effects include muscle twitching, cramping, and weakness. Nicotinic stimulation can obscure certain muscarinic effects and produce rapid heart rate and high blood pressure.

CNS

CNS effects are often the earliest manifestations of poisoning in adults and constitute the major signs and symptoms in children. CNS effects include irritability, nervousness, giddiness, fatigue, lethargy, impairment of memory, confusion, slurred speech, visual disturbance, depression, impaired gait, convulsions, loss of consciousness, coma, and respiratory depression.

High exposure to malathion may cause an effect termed intermediate syndrome that manifests 1 to 4 days after intoxication and is characterized by paralysis of respiratory, cranial motor, neck flexor, and proximal limb muscles. This effect is thought to be the result of inadequate oxime treatment.

Peripheral Neurologic

Peripheral neurologic effects include muscle twitching and weakness due to inhibition of acetylcholinesterase at neuromuscular junctions.

Respiratory

Respiratory failure is the most common cause of death due to malathion poisoning. Narrowing of the bronchi and markedly increased bronchial secretions can occur. Respiratory failure results from respiratory depression coupled with paralysis of the respiratory muscles and progressive airway obstruction from bronchorrhea. In addition, pulmonary aspiration of the hydrocarbon solvents found in many commercial preparations can cause inflammation of the lungs.

Children may be more vulnerable because of relatively higher minute ventilation per kg and failure to evacuate an area promptly when exposed.

Cardiovascular

Most exposure victims experience bradycardia, but pulse rate may be increased initially and tachycardia is more common in very severe poisoning. Irregular heartbeat may occur.

Gastrointestinal

Nausea, vomiting, abdominal cramps, diarrhea, and fecal incontinence are common manifestations, regardless of the exposure route. These are generally the earliest symptoms to occur.

Dermal

Malathion is has been reported to cause skin irritation and sensitization. Because it is readily absorbed through the skin, skin contact can result in systemic poisoning.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants absorbed through the skin.

Ocular/Ophthalmic

Systemic poisoning typically causes pinpoint pupils and spasm of the muscle of visual accommodation (i.e., ciliary muscle) leading to blurred vision and aching pain in the eye. However, organophosphate poisoning may still be present without pinpoint pupils, and dilation of the pupils may even be noted occasionally. Eye irritation, if it occurs, is most likely caused by the hydrocarbon solvents used in commercial pesticide preparations.

Potential Sequelae

Complete recovery generally occurs within 10 days unless severe lack of oxygen has caused residual brain damage. CNS effects such as confusion, fatigue, irritability, nervousness, and impairment of memory can occasionally last for several weeks. There is no evidence that malathion induces delayed neurotoxicity.

Chronic Exposure

Persistent weakness and impaired memory have been reported to occur from low-level exposures to some organophosphates in the absence of acute cholinergic effects, but there is no reliable information on adverse health effects of chronic exposure to malathion.

Carcinogenicity

The International Agency for Research on Cancer has determined that malathion is unclassifiable as to its carcinogenicity to humans. In animals, malathion induced liver carcinogenicity at doses that were considered excessive.

Reproductive and Developmental Effects

Studies have been reported in which malathion induced transient testicular effects in rodents. Results from studies addressing reproductive or developmental effects in humans are inconclusive. Malathion is not included in *Reproductive and Developmental Toxicants,* a 1991 report published by the U.S. General Accounting Office (GAO) that lists 30 other chemicals of concern because of widely acknowledged reproductive and developmental consequences.

Prehospital Management

- **Malathion is highly contaminating. Victims whose skin or clothing is contaminated with liquid or powdered malathion can secondarily contaminate response personnel by direct contact or evaporation of solvent vapor. Clothing and leather goods (e.g., belts or shoes) cannot be reliably decontaminated; they should be incinerated.**
- **Systemic effects of malathion poisoning can occur from all routes of exposure. Symptoms of malathion poisoning can include headache, nausea, vomiting, abdominal cramps, diarrhea, generalized muscle weakness and twitching, slurred speech, pinpoint pupils, excessive secretions, and shortness of breath.**
- **Severely poisoned patients may develop seizures, skeletal-muscle paralysis, cardiac arrhythmias, and respiratory failure, or may become comatose.**
- **Commercial malathion products often contain hydrocarbon solvents, such as xylene or toluene, which themselves can cause toxicity. Treatment for breathing the solvent is fresh air.**
- **Treatment for malathion poisoning consists of thorough decontamination, cardiorespiratory support, and administration of the antidotes atropine and pralidoxime. In cases of severe poisoning, diazepam should also be administered. Antidotes should be administered as prevention even if the diagnosis is in doubt.**

Hot Zone

Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if rescuers have not been trained in its use, assistance should be obtained from a local or regional HAZMAT team or other properly equipped response organization.

Rescuer Protection

Malathion is a systemic poison that is absorbed well by all routes of exposure.

Respiratory Protection: Positive-pressure, self-contained breathing apparatus (SCBA) is recommended in response situations that involve exposure to potentially unsafe levels of malathion as may occur in large spills or contamination in confined spaces.

Skin Protection: Chemical-protective clothing is recommended because malathion is rapidly absorbed through the skin and may cause systemic poisoning.

ABC Reminders

Quickly establish a patent airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible.

Victim Removal

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be removed on backboards or gurneys; if these are not available, carefully carry or drag victims to safety.

Consider appropriate management in victims with chemically-induced acute disorders, especially children who may suffer separation anxiety if separated from a parent or other adult.

Decontamination Zone

All victims suspected of malathion ingestion, or substantial exposure to aerosolized malathion, or who have skin or eye exposure to liquid or powdered malathion require thorough decontamination as described below.

Rescuer Protection

If exposure levels are determined to be safe, decontamination may be conducted by personnel wearing a lower level of protection than that worn in the Hot Zone (described above).

ABC Reminders

Quickly establish a patent airway, ensure adequate respiration and pulse. Stabilize the cervical spine with a collar and a backboard if trauma is suspected. Administer supplemental oxygen as required. Assist ventilation with a bag-valve-mask device if necessary.

Basic Decontamination

Rapid and thorough decontamination is critical, but must proceed concurrently with supportive and antidotal measures.

Victims who are able may assist with their own decontamination. Quickly remove and double-bag contaminated clothing and personal belongings. Clothing (especially leather items) is extremely difficult to decontaminate; in most cases, contaminated clothing should be incinerated as directed by hazardous materials experts.

Victims should be washed repeatedly with copious amounts of soap and water. Rescuers should wear rubber gloves as vinyl gloves provide no protection against skin absorption. It is important to observe the patient closely for sudden appearance of symptoms. It is important to thoroughly clean hair, fingernails, and skin folds. Use caution to avoid hypothermia when decontaminating victims, particularly children or the elderly. Use blankets or warmers after decontamination as needed.

Irrigate exposed or irritated eyes with plain water or saline for 15 minutes. Remove contact lenses if easily removable without additional trauma to the eye. If pain or injury is evident, continue irrigation while transferring the victim to the Support Zone.

In cases of ingestion, **do not induce emesis**. If the victim is alert and asymptomatic, administer a slurry of activated charcoal at a dose of 1 g/kg (infant, child, and adult dose). A soda can and straw may be of assistance when offering charcoal to a child.

Consider appropriate management of chemically contaminated children at the exposure site. Provide reassurance to the child during decontamination, especially if separation from a parent occurs.

Transfer to Support Zone

As soon as basic decontamination is complete, move the victim to the Support Zone.

Support Zone

Be certain that victims have been decontaminated properly (see *Decontamination Zone* above). Victims who have undergone decontamination or have been exposed only to vapor generally pose no serious risks of secondary contamination to rescuers. However, the Support Zone team should wear disposable aprons or gowns and rubber gloves for protection.

ABC Reminders

Quickly establish a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Ensure adequate respiration and pulse. Administer supplemental oxygen as required and establish intravenous access if necessary. Place on a cardiac monitor, if available. Airway suctioning may be required for excessive bronchial secretions.

Additional Decontamination

Continue irrigating exposed skin and eyes, as appropriate.

In cases of ingestion, **do not induce emesis**. If the victim is alert and asymptomatic, administer a slurry of activated charcoal if it has not already been given at a dose of 1 g/kg (infant, child, and adult dose). A soda can and straw may be of assistance when offering charcoal to a child.

Advanced Treatment

Treat cases of respiratory compromise, coma, or excessive pulmonary secretions with respiratory support using protocols and techniques available and within the scope of training. Some cases

may necessitate procedures such as endotracheal intubation or cricothyrotomy by properly trained and equipped personnel.

When possible, atropine (see *Antidotes*, below) should be given under medical supervision to all symptomatic patients who have known or strongly suspected malathion poisoning.

Patients who are comatose, hypotensive, or having seizures or cardiac arrhythmias should be treated according to advanced life support (ALS) protocols.

Antidotes

Two antidotes are administered to treat organophosphate poisoning. Atropine is a competitive antagonist of acetylcholine at muscarinic receptors and is used to control the excessive bronchial secretions which are often responsible for death. Pralidoxime relieves both the nicotinic and muscarine effects of organophosphate poisoning by regenerating acetylcholinesterase and can reduce both the bronchial secretions and the muscle weakness associated with poisoning.

The initial intravenous dose of atropine in adults should be determined by the severity of symptoms: An initial adult dose of 1.0 to 2.0 mg or pediatric dose of 0.01 mg/kg (minimum 0.01 mg) should be administered intravenously. If intravenous access cannot be established, atropine may also be given intramuscularly, subcutaneously or via endotracheal tube. Doses should be repeated every 15 minutes until excessive secretions and sweating have been controlled. Once bronchial secretion has been controlled, atropine administration should be repeated whenever the secretions begin to recur. In seriously poisoned patients, very large doses may be required. Alterations of pulse rate and pupillary size should not be used as indicators of treatment adequacy.

Pralidoxime should be administered as early in poisoning as possible as its efficacy may diminish when given more than 24 to 36 hours after exposure. Doses are as follows: adult 1.0 g; pediatric 25 to 50 mg/kg. The drug should be administered intravenously over 30 to 60 minutes, but in a life-threatening situation, one-half of the total dose can be given per minute for a total administration time of 2 minutes. Treatment should begin to take effect within 40 minutes with a reduction in symptoms and the amount of atropine necessary to control bronchial secretion. The initial dose can be repeated in 1 hour and then every 8 to 12 hours until the patient is clinically well and no longer requires atropine. If intravenous access cannot be established, pralidoxime may also be given intramuscularly.

Early administration of diazepam in addition to the combined atropine and pralidoxime treatment may help prevent the onset of seizures and potential brain and cardiac morphologic damage following high-level organophosphate poisoning.

Transport to Medical Facility

Only decontaminated patients or patients not requiring decontamination should be transported to a medical facility. "Body bags" are not recommended.

Report to the base station and the receiving medical facility the condition of the patient, treatment given, and estimated time of arrival at the medical facility. Severely ill patients should be taken to a medical facility immediately.

If malathion has been ingested, prepare the ambulance in case the victim vomits toxic material. Have ready several towels and open plastic bags to quickly clean up and isolate vomitus.

Multi-Casualty Triage

Consult with the base station physician or the regional poison control center for advice regarding triage of multiple victims.

Patients with evidence of significant exposure, such as nausea or excessive sweating, and all persons who have ingested malathion should be transported to a medical facility for evaluation. Others may be discharged at the scene after their names, addresses, and telephone numbers are recorded. It is very important to ensure that individuals have been completely decontaminated before discharge; otherwise life-threatening symptoms may occur in the absence of assistance. Those discharged should be advised to seek medical care promptly if symptoms develop (see *Patient Information Sheet* below).

Emergency Department Management

- **Malathion is highly contaminating. Patients whose skin or clothing is contaminated with liquid or powdered malathion can secondarily contaminate hospital personnel by direct contact or off-gassing of solvent vapor from clothing, skin, or vomitus. Clothing and leather goods (e.g., belts or shoes) cannot be reliably decontaminated; they should be incinerated.**
- **Systemic malathion toxicity due to excess cholinergic stimulation may be expressed in symptoms such as headache, nausea, vomiting, abdominal cramps, diarrhea, generalized muscle weakness and twitching, slurred speech, pinpoint pupils, excessive secretions, and shortness of breath.**
- **Severely poisoned patients may develop seizures, skeletal-muscle paralysis, cardiac arrhythmias and respiratory failure, or may become comatose.**
- **Commercial malathion products often contain hydrocarbon solvents such as xylene or toluene, which themselves can cause toxicity.**
- **Treatment consists of thorough decontamination, cardiorespiratory support, and administration of the antidotes atropine and pralidoxime. Antidotes should be administered as prevention even if the diagnosis is in doubt.**

Decontamination Area

Unless decontaminated previously, all patients suspected of skin or eye contact with liquid or powdered malathion require decontamination immediately. If a solvent such as xylene or toluene is involved, decontamination should take place outdoors or with proper ventilation.

Health care personnel should don butyl rubber aprons and butyl rubber gloves. If butyl rubber items are not available, limited protection will be provided by two layers of latex gloves and a waterproof apron or chemical-resistant jumpsuit. Wash hands frequently during decontamination and promptly dispose of latex gloves. Personnel who come in contact with malathion secondarily should undergo decontamination.

Be aware that use of protective equipment by the provider may cause anxiety, particularly in children, resulting in decreased compliance with further management efforts.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants absorbed through the skin. Also emergency room personnel should examine children's mouths because of the frequency of hand-to-mouth activity among children.

ABC Reminders

Evaluate and support airway, breathing, and circulation. In cases of respiratory compromise, coma, or to facilitate tracheal suctioning, secure airway and respiration via endotracheal intubation. If not possible, surgically create an airway. Suctioning may be required for excessive bronchial secretions.

Patients who are comatose, hypotensive, or have seizures or ventricular arrhythmias should be treated in the conventional manner.

Basic Decontamination

Patients who are able may assist with their own decontamination. Remove and double-bag contaminated clothing and personal belongings. Dispose of contaminated clothing and leather goods (e.g., belts, wallets, and shoes); they should be incinerated as directed by hazardous materials experts.

Victims should be washed repeatedly with copious amounts of soap and water. Rescuers should wear rubber gloves as vinyl gloves provide no protection against skin absorption. It is important to observe the patient closely for sudden appearance of symptoms. It is important to thoroughly clean hair, fingernails, and skin folds. Use caution to avoid hypothermia when decontaminating victims, particularly children or the elderly. Use blankets or warmers after decontamination as needed.

Flush exposed eyes with plain water or saline for 15 minutes. Remove contact lenses if easily removable without additional trauma to the eye. Continue irrigation during transport to the Critical Care Area.

In cases of ingestion, **do not induce emesis**. If the victim is alert and asymptomatic, administer a slurry of activated charcoal if it has not already been given at a dose of 1 g/kg (infant, child, and adult dose). A soda can and straw may be of assistance when offering charcoal to a child.

Critical Care Area

Be certain that appropriate decontamination has been carried out (see *Decontamination Area* above).

ABC Reminders

Evaluate and support airway, breathing, and circulation as in ABC Reminders above. Establish intravenous access in seriously ill patients. Continuously monitor cardiac rhythm.

Patients who are comatose, hypotensive, or have seizures or cardiac arrhythmias should be treated in the conventional manner.

Inhalation Exposure

Administer supplemental oxygen by mask to patients who have respiratory symptoms. Refer to *Antidotes and Other Treatments* below for appropriate clinical treatment.

Skin Exposure

Malathion may irritate the skin and dermal exposure produces systemic toxicity. Thorough washing of the skin, as described in *Basic Decontamination* above, should be performed and may need to be repeated. Unexplained, persistent symptoms may indicate inadequate decontamination.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants absorbed through the skin.

Eye Exposure

Continue irrigation for at least 15 minutes. Test visual acuity. Examine the eyes for cornea1 damage and treat appropriately. Immediately consult an ophthalmologist for patients who have severe corneal injuries.

Ingestion

Do not induce emesis. If the victim is alert and asymptomatic, administer a slurry of activated charcoal if it has not already been given at a dose of 1 g/kg (infant, child, and adult dose). A soda can and straw may be of assistance when offering charcoal to a child.

Gastric lavage is useful in certain circumstances to remove toxic material. Consider gastric lavage with a small nasogastric tube if: (1) a large dose has been ingested; (2) the patient's condition is evaluated within 30 minutes; (3) the patient has oral lesions or persistent esophageal discomfort; and (4) the lavage can be administered within one hour of ingestion. Care must be taken when placing the gastric tube because blind gastric-tube placement may further injure the chemically damaged esophagus or stomach.

Because children do not ingest large amounts of toxic materials, and because of the risk of perforation from NG intubation, lavage is discouraged in children unless performed under endoscopic guidance.

Toxic vomitus or gastric washings should be isolated, e.g., by attaching the lavage tube to isolated wall suction or another closed container.

Antidotes and Other Treatments

All patients who have signs or symptoms of systemic toxicity require antidotal treatment. In the United States, primary antidotal treatment for malathion poisoning involves administration of atropine. In addition, pralidoxime (2-PAM) is indicated for seriously poisoned patients.

Atropine is a competitive antagonist of acetylcholine at muscarinic receptors and is used to control the excessive bronchial secretions which are often responsible for death. Pralidoxime relieves both the nicotinic and muscarine effects of organophosphate poisoning by regenerating acetylcholinesterase and can reduce both the bronchial secretions and the muscle weakness associated with poisoning.

The initial intravenous dose of atropine in adults should be determined by the severity of symptoms: An initial adult dose of 1.0 to 2.0 mg or pediatric dose of 0.01 mg/kg (minimum 0.01 mg) should be administered intravenously. If intravenous access cannot be established, atropine may also be given intramuscularly, subcutaneously, or via endotracheal tube. Doses should be repeated every 15 minutes until excessive secretions and sweating have been controlled. Once bronchial secretion has been controlled, atropine administration should be repeated whenever the secretions begin to recur. In seriously poisoned patients, very large doses may be required. Alterations of pulse rate and pupillary size should not be used as indicators of treatment adequacy.

Pralidoxime should be administered as early in poisoning as possible as its efficacy may diminish when given more than 24 to 36 hours after exposure. Doses are as follows: adult 1.0 g; pediatric 25 to 50 mg/kg. The drug should be administered intravenously over 30 to 60 minutes, but in a life-threatening situation, one-half of the total dose can be given per minute for a total administration time of 2 minutes. Treatment should begin to take effect within 40 minutes with a reduction in symptoms and the amount of atropine necessary to control bronchial secretion. The initial dose can be repeated in 1 hour and then every 8 to 12 hours until the patient is clinically well and no longer requires atropine. If intravenous access cannot be established, pralidoxime may also be given intramuscularly.

Early administration of diazepam in addition to the combined atropine and pralidoxime treatment may help prevent the onset of seizures and potential brain and cardiac morphologic damage following high-level organophosphate poisoning. Treat patients in seizure with a benzodiazepine such as diazepam or lorazepam.

Avoid other acetylcholinesterase inhibitors (e.g., physostigmine and edrophonium chloride), and do not use depolarizing neuromuscular blockers such as succinylcholine for rapid sequence intubation. The paralyzing effects of succinylcholine are likely to be prolonged because it will not be metabolized normally.

Non-depolarizing neuromuscular blockers (e.g., pancuronium and vecuronium) may be less effective because of unsuccessful competition with acetylcholinesterase for the motor end-plate receptors.

Laboratory Tests

The diagnosis of acute malathion toxicity is primarily clinical and is based on the combination of nausea, excessive sweating and salivation, miosis, and muscle weakness. Routine laboratory studies for all exposed patients include CBC, glucose, and electrolyte determinations. A chest radiograph is useful to examine for hydrocarbon aspiration and non-cardiogenic pulmonary edema. Symptomatic and asymptomatic patients suspected of significant exposure should have determinations of plasma and red blood cell (RBC) cholinesterase activity. Symptoms of acute poisoning are usually present when more than 50% of RBC cholinesterase activity is inhibited. However, these tests are not always readily available and are more useful in diagnosis and follow-up. Blood and urine analyses for the presence of malathion or its metabolite may indicate recent exposure to malathion. High levels in the blood or urine may be indicative of potential for brain, heart, lung, and nerve damage.

Disposition and Follow-up

Patients with life threatening illness must be hospitalized, also consider hospitalizing patients who have a suspected serious exposure and are symptomatic.

Delayed Effects

Skin absorption can cause delayed or recurrent symptoms. Contaminated clothing and leather items (e.g., shoes, wallets, and belts) should not be reused, even if they have been washed.

Aspiration of commercial malathion preparations that contain hydrocarbon solvents can result in chemical pneumonitis.

Chronic neurologic symptoms have been reported for some patients exposed to some organophosphates, but not specifically for malathion.

Patient Release

Patients who remain asymptomatic for 4 to 6 hours after exposure may be discharged with instructions to seek medical care promptly if symptoms develop (see *Malathion—Patient Information Sheet* below).

Follow-up

Obtain the name of the patient's primary care physician so that the hospital can send a copy of the ED visit to the patient's doctor.

Patients who have severe exposure should be evaluated for persistent CNS sequelae.

Patients who have been acutely poisoned should be advised to avoid further organophosphate exposure until sequential RBC cholinesterase levels have stabilized in the normal range, a process that may take 3 to 4 months after severe poisoning.

Patients who have corneal injuries or severe skin burns should be reexamined within 24 hours.

Reporting

If a work-related incident has occurred, you may be legally required to file a report; contact your state or local health department.

Other persons may still be at risk in the setting where this incident occurred. If the incident occurred in the workplace, discussing it with company personnel may prevent future incidents. If a public health risk exists, notify your state or local health department or other responsible public agency. When appropriate, inform patients that they may request an evaluation of their workplace from OSHA or NIOSH. See Appendix III for a list of agencies that may be of assistance.

Malathion
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to malathion.

What is malathion?
Malathion is an organophosphate pesticide. It is a yellow to deep brown liquid with an odor like garlic. It is widely used to kill insects on agricultural crops, on stored products, on golf courses, and in home gardens. It also used to kill mosquitoes and fruit flies in large outdoor areas. In addition, it is used to kill fleas on pets and to treat head lice on humans, and by farmers as a pesticide on fruits, vegetables, nuts, and grains. Commercial pesticides often contain a hydrocarbon solvent, which itself can cause illness.

What immediate health effects can be caused by exposure to malathion?
Malathion can cause nausea, vomiting, stomach cramps, and diarrhea, as well as confusion, blurred vision, sweating, muscle twitching, irregular heartbeat, convulsions, and death. Symptoms occur when malathion is inhaled, swallowed, or absorbed through the skin. Breathing the solvent used to dissolve the pesticide may cause dizziness, headache, and nausea. Generally, the more serious the exposure, the more severe the symptoms.

Can malathion poisoning be treated?
For minor exposures (for example, breathing the pesticide solvent), the only treatment needed is fresh air. For serious malathion poisoning, thorough washing of all exposed skin, removal and burning of exposed clothing, and hospitalization and administration of an antidote may be needed.

Are any future health effects likely to occur?
A single small exposure from which a person recovers quickly is not likely to cause delayed or long-term effects. After a serious exposure, a patient may feel ill for several weeks.

What tests can be done if a person has been exposed to malathion?
Specific tests for the presence of malathion or its breakdown product in blood and urine generally are not useful to the doctor. If a severe exposure has occurred, blood and urine analyses and other tests may show whether damage has been done to the brain, heart, lungs, and nerves. Testing is not needed in every case.

Where can more information about malathion be found?
More information about malathion can be obtained from your regional poison control center; your state, county, or local health department; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in occupational and environmental health. If the exposure happened at work, you may wish to discuss it with your employer, the Occupational Safety and Health Administration (OSHA), or the National Institute for Occupational Safety and Health (NIOSH). Ask the person who gave you this form for help in locating these telephone numbers.

Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow *only* the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:

- irritability, confusion, or fatigue
- coughing, wheezing, or shortness of breath
- nausea, vomiting, cramps, or diarrhea
- muscle weakness or twitching
- blurred vision

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.

[ ] Call for an appointment with Dr. _____ in the practice of _____. When you call for your appointment, please say that you were treated in the Emergency Department at _____ Hospital by _____ and were advised to be seen again in _____ days.

[ ] Return to the Emergency Department/ _____ Clinic on (date) _____at _ _____ AM/PM for a follow-up examination.

[ ] Do not perform vigorous physical activities for 1 to 2 days.

[ ] You may resume everyday activities including driving and operating machinery.

[ ] Do not return to work for _____ days.

[ ] You may return to work on a limited basis. See instructions below.

[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.

[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.

[ ] Avoid taking the following medications: _____

[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: __
_____
_____

[ ] Other instructions: _____
_____
_____

- Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.

- You or your physician can get more information on the chemical by contacting: _____ _____ or _____, or by checking out the following Internet Web sites: _____; _____.

Signature of patient _____ Date _____

Signature of physician _____ Date _____

Methyl Bromide (CH_3Br)
CAS 74-83-9; UN 1062

Synonyms include bromomethane, monobromomethane, isobrome, and methyl fume.

Persons exposed only to methyl bromide gas do not pose substantial risks of secondary contamination; however, some methyl bromide may permeate clothing. Persons whose clothing or skin is contaminated with liquid methyl bromide (temperatures less than 38.5 °F) can secondarily contaminate others by direct contact or through off-gassing vapor.

A gas at room temperature, methyl bromide readily penetrates skin, cloth, and other protective materials such as rubber and leather. It is nonflammable and toxic at low concentrations.

Methyl bromide is odorless and odor provides no warning of hazardous concentrations. However, because methyl bromide is odorless and nonirritating, a lacrimator (an agent that irritates the eyes and causes tearing), most commonly chloropicrin, is often added as a warning agent.

- **Methyl bromide is absorbed well by the lungs and to some degree through intact skin. Oral exposure is rare because methyl bromide is a gas at room temperature, but it may be absorbed by the gastrointestinal tract. Exposure by any route can cause systemic effects.**

Description

Methyl bromide is a colorless gas at room temperature and a liquid below 38.5 °F (3.6 °C) or when compressed. It is usually shipped as a liquefied, compressed gas. It is odorless and nonirritating at low concentrations and has a musty or fruity odor at high concentrations (greater than 1,000 ppm). Because methyl bromide lacks adequate physiologic warning properties, up to 2% chloropicrin, a lacrimator, is often added to prevent significant exposure.

Routes of Exposure

Inhalation

Most exposures occur by inhalation and by absorption through the skin. **Odor is not an adequate indicator of the presence of pure methyl bromide and does not provide reliable warning of hazardous concentrations**. Because pure methyl bromide lacks adequate warning properties, significant exposure can occur before symptoms are evident.

Methyl bromide is 3 times heavier than air and can accumulate in poorly ventilated or low-lying areas. Under adverse conditions, it can remain in the air for days after application as

a fumigant. Fatalities have occurred among pesticide appliers and building occupants who were exposed during the application process or who prematurely reentered fumigated buildings.

Children exposed to the same levels of methyl bromide as adults may receive larger doses because they have greater lung surface area:body weight ratios and increased minute volumes:weight ratios. In addition, they may be exposed to higher levels than adults in the same location because of their short stature and the higher levels of methyl bromide found nearer to the ground.

Skin/Eye Contact

Methyl bromide gas easily penetrates most protective clothing (e.g., cloth, rubber, and leather) and skin. Prolonged retention in clothing and rubber boots may lead to chemical dermatitis and severe burns. Skin absorption may contribute to systemic toxicity

Children are more vulnerable to toxicants absorbed through the skin because of their relatively larger surface area:body weight ratio.

Ingestion

Ingestion of methyl bromide is unlikely because it is a gas at room temperature.

Sources/Uses

Methyl bromide is produced by adding sulfuric acid to a mixture of sodium bromide and methyl alcohol. Methyl bromide is used primarily as a pesticide to fumigate soil, spaces, structures, and commodities. It is also used as a methylating agent, low-boiling solvent, and oil extractant in chemical syntheses. Less toxic chemicals have replaced it as a refrigerant and fire-extinguisher constituent.

Standards and Guidelines

OSHA ceiling limit = 20 ppm (skin)

NIOSH IDLH (immediately dangerous to life or health) = 250 ppm

AIHA ERPG-2 (the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms which could impair an individual's ability to take protective action) = 50 ppm

Physical Properties

Description: Colorless; gas at room temperature and liquid below 38.5 °F (3.6 °C)

Warning properties: **Inadequate**; musty or fruity odor at greater than 1,000 ppm; eye and throat irritation at greater than 500 ppm.

Molecular weight: 95.0 daltons

Boiling point (760 mm Hg): 38.5 °F (3.6 °C)

Freezing point: -137 °F (-94 °C)

Vapor pressure: 1420 mm Hg at 68 °F (20 °C)

Gas density: 3.4 (air = 1)

Water solubility: Water soluble (0.09% at 68 °F) (20 °C)

Flammability: Flammable, but only in the presence of a high-energy ignition source.

Flammable range: 13.5% to 14.5% (concentration in air)

Incompatibilities

Methyl bromide reacts with strong oxidizers, magnesium, aluminum, tin, zinc, and alloys. It attacks aluminum to form aluminum trimethyl, which is spontaneously flammable.

Health Effects

Methyl bromide is a neurotoxic gas that can cause convulsions, coma, and long-term neuromuscular and cognitive deficits.

Exposure to high concentrations of pure methyl bromide may cause inflammation of the bronchi or lungs, an accumulation of fluid in the lung, and irritation of the eyes and nose. Tearing agents added to methyl bromide to provide warning of its presence can also cause these symptoms, even at very low concentrations.

Skin contact with high vapor concentrations or with liquid methyl bromide can cause systemic toxicity and may cause stinging pain and blisters.

Acute Exposure

Methyl bromide methylates the sulfhydryl groups of enzymes, causing cellular disruption and reduced glutathione levels. Cellular disruption, primarily in the CNS, results in progressive dysfunction. In sublethal poisoning, a latency period of 2 to 48 hours can occur between exposure and onset of symptoms. Methanol, a metabolite of methyl bromide, may also contribute to the neurologic and visual effects, but this is only likely to be significant at high levels of exposure.

Children do not always respond to chemicals in the same way that adults do. Different protocols for managing their care may be needed.

CNS

The most serious effects of acute inhalation exposure involve the CNS. Depending on the concentration and duration of exposure, initial neurologic effects may be delayed for 2 or more hours after exposure and may include headache, nausea, vomiting, dizziness, malaise, and visual disturbances. Examination may reveal involuntary movements of the eyes, dilated pupils, slurred speech, trembling of the extremities during movement, impaired gait, impaired sensation of touch, brain damage (i.e., cerebellar abnormalities), motor deficits, and decreased reflexes.

Neuropsychiatric abnormalities often occur after acute exposure, although onset may be delayed for days to weeks. In some cases, mental disturbances may predominate with only mild neurologic signs and no seizures; in others, severe and prolonged seizures may occur. Motor and cognitive deficits may persist indefinitely.

Peripheral Neurologic

Peripheral neuropathy may develop after acute exposure to methyl bromide and may persist indefinitely.

Respiratory

Respiratory symptoms are the most likely nonneurologic effects of acute methyl bromide inhalation. Throat irritation, chest pain, and shortness of breath are common. Severe exposures may cause inflammation of the bronchi or lungs and an accumulation of fluid in the lungs, which may be delayed 24 hours or longer after exposure. Death may result from respiratory or cardiovascular failure.

Exposure to certain chemicals can lead to Reactive Airway Dysfunction Syndrome (RADS), a chemically- or irritant-induced type of asthma.

Children may be more vulnerable because of relatively increased minute ventilation per kg and failure to evacuate an area promptly when exposed.

Cardiovascular

Acute inhalation of high concentrations can cause rapid, ineffective beating of the heart.

Renal

Protein and blood in the urine, scant urine production, absence of urine production, and accumulation of urea and other nitrogen wastes in the blood due to death of kidney cells have been described. Complete recovery is usual.

Hepatic

Elevated liver enzymes in serum and jaundice occur occasionally after acute exposure.

Ocular

Eye exposure to liquid methyl bromide or to high concentrations of vapor may cause corneal irritation and burns.

Dermal

Contact with either liquid or high vapor concentrations can cause stinging pain, redness of the skin, and blisters characteristic of second-degree burns.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants absorbed through the skin.

Potential Sequelae

Peripheral nerve damage, speech difficulty, and neuropsychiatric sequelae such as impaired gait, involuntary movements of the eyes, tremors, involuntary muscle jerks, seizures, decline in mental abilities, and severe mental disorders (i.e., psychoses) may develop weeks after exposure.

Chronic Exposure

Repeated exposures have been associated with peripheral neuropathies, especially sensory neuropathy, impaired gait, behavioral changes, and mild liver and kidney dysfunction. Visual impairment secondary to atrophy of the optic nerve has been reported. Chronic exposure may be more serious for children because of their potential longer latency period.

Carcinogenicity

The International Agency for Research on Cancer has determined that methyl bromide is not classifiable as to its carcinogenicity to humans.

Reproductive and Developmental Effects

Methyl bromide is not considered a reproductive or developmental toxicant. No human data are available; one study of experimental animals (rats and rabbits) did not find teratogenic effects at levels below those causing maternal death. Methyl bromide is not included in *Reproductive and Developmental Toxicants*, a 1991 report published by the U.S. General Accounting Office (GAO) that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences.

Prehospital Management

Victims exposed only to methyl bromide gas do not pose substantial risks of secondary contamination to personnel outside the Hot Zone; however, some methyl bromide may permeate clothing. Victims whose clothing or skin is contaminated with liquid methyl bromide (i.e., ambient temperature less than 38.5 °F) can secondarily contaminate response personnel by direct contact or through off-gassing vapor.

Methyl bromide is a neurotoxic gas that may cause headaches, dizziness, visual disturbances, ventricular fibrillation, pulmonary edema, ataxia, convulsions, coma, and death.

Exposures to high concentrations of methyl bromide can cause eye, skin, and respiratory tract irritation, as well as chemical pneumonitis. Dermal absorption may contribute to systemic toxicity.

There is no antidote for methyl bromide. Treatment consists of support of respiratory and cardiovascular functions.

Hot Zone

Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if rescuers have not been trained in its use, assistance should be obtained from a local or regional HAZMAT team or other properly equipped response organization.

Rescuer Protection

Methyl bromide is a highly toxic systemic poison that is absorbed well by inhalation and through the skin.

Respiratory Protection: Positive-pressure, self-contained breathing apparatus (SCBA) with a full facepiece is recommended in response situations that involve exposure to potentially unsafe levels of methyl bromide vapor.

Skin Protection: Chemical-protective clothing (including boots and gloves) is recommended because methyl bromide vapor or liquid can be absorbed through the skin and may contribute to systemic toxicity. Contact with liquid methyl bromide can cause skin irritation and burns.

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible.

Victim Removal

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be removed on backboards or gurneys; if these are not available, carefully carry or drag victims to safety.

Consider appropriate management of chemically contaminated children, such as measures to reduce separation anxiety if a child is separated from a parent or other adult.

Decontamination Zone

Remove clothing, including footwear, from all victims because methyl bromide gas persists in cloth, leather, and rubber. After clothing has been removed, patients exposed only to the gas who have no skin or eye irritation may be transferred immediately to the Support Zone. All others require decontamination (see *Basic Decontamination* below).

Rescuer Protection

If exposure levels are determined to be safe, decontamination may be conducted by personnel wearing a lower level of protection than that worn in the Hot Zone *(see Rescuer Protection*, above).

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. Stabilize the cervical spine with a collar and a backboard if trauma is suspected. Administer supplemental oxygen as required. Assist ventilation with a bag-valve-mask device if necessary.

Basic Decontamination

Victims who are able may assist with their own decontamination. Remove all contaminated clothing including footwear. Methyl bromide can persist in cloth, leather, and rubber, and these materials may contribute to severe chemical burns after prolonged skin contact. Double-bag contaminated clothing and personal belongings. **Leave these items in the Hot Zone.**

Flush exposed skin and hair with water for at least 15 minutes, then wash twice with mild soap. Rinse thoroughly with water. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Irrigate exposed or irritated eyes with plain water or saline for 15 to 20 minutes. Remove contact lenses if easily removable without additional trauma to the eye. If pain or injury is evident, continue irrigation while transferring the victim to the Support Zone.

Oral exposure to methyl bromide is rare (it is a gas at temperatures above 38.5 °F); however, if ingestion occurs, **do not induce emesis**. If the victim is alert and able to swallow, administer a slurry of activated charcoal at 1 gm/kg (usual adult dose 60–90 g, child dose 25–50 g). A soda can and straw may be of assistance when offering charcoal to a child.

Consider appropriate management of chemically contaminated children at the exposure site. Also, provide reassurance to the child during decontamination, especially if separation from a parent occurs. If possible, seek assistance from a child separation expert.

Transfer to Support Zone

As soon as basic decontamination is complete, move the victim to the Support Zone.

Support Zone

Be certain that victims have been decontaminated properly (see *Decontamination Zone* above). Persons who have undergone decontamination pose no serious risks of secondary contamination. Support Zone personnel require no specialized protective gear in such cases.

ABC Reminders

Quickly access for a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Ensure adequate respiration and pulse. Administer supplemental oxygen as required and establish intravenous access if necessary. Place on a cardiac monitor.

Additional Decontamination

Continue irrigating exposed skin and eyes, as appropriate.

Advanced Treatment

In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, perform cricothyroidotomy if equipped and trained to do so.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly).

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine

solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Patients who are comatose, hypotensive, or are having seizures or cardiac arrhythmias should be treated according to advanced life support (ALS) protocols.

If evidence of shock or hypotension is observed begin fluid administration. For adults, bolus 1,000 mL/hour intravenous saline or lactated Ringer's solution if blood pressure is under 80 mm Hg; if systolic pressure is over 90 mm Hg, an infusion rate of 150 to 200 mL/hour is sufficient. For children with compromised perfusion administer a 20 mL/kg bolus of normal saline over 10 to 20 minutes, then infuse at 2 to 3 mL/kg/hour.

Transport to Medical Facility

Only decontaminated patients or patients not requiring decontamination should be transported to a medical facility. "Body bags" are not recommended.

Report to the base station and the receiving medical facility the condition of the patient, treatment given, and estimated time of arrival at the medical facility.

If the patient has ingested methyl bromide, prepare the ambulance in case the patient vomits toxic material or has diarrhea. Have ready several towels and open plastic bags to quickly clean up and isolate vomitus.

Multi-Casualty Triage

Consult with the base station physician or the regional poison control center for advice regarding triage of multiple victims. Because systemic symptoms may be delayed for several hours after exposure, all exposed patients should be transported to a medical facility for evaluation. Symptomatic patients should receive priority in transport.

Emergency Department Management

Hospital personnel away from the scene are not at significant risk of secondary contamination from patients exposed to methyl bromide gas or to liquid methyl bromide at ambient temperatures greater than 38.5 °F; however, some methyl bromide may have permeated clothing.

Methyl bromide is a neurotoxic gas that may cause headaches, dizziness, visual disturbances, ventricular fibrillation, pulmonary edema, ataxia, convulsions, coma, and death.

Exposures to high concentrations of methyl bromide can cause eye, skin, and respiratory tract irritation, as well as chemical pneumonitis. Dermal absorption can contribute to systemic toxicity.

There is no antidote for methyl bromide. Treatment consists of support of respiratory and cardiovascular functions.

Decontamination Area

Patients who have been decontaminated previously may be transferred immediately to the Critical Care Area. Other patients require decontamination as described below.

Be aware that use of protective equipment by the provider may cause fear in children, resulting in decreased compliance with further management efforts.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants absorbed through the skin. Also, emergency room personnel should examine children's mouths because of the frequency of hand-to-mouth activity among children.

ABC Reminders

Evaluate and support airway, breathing, and circulation. Intubate the trachea in cases of respiratory compromise. In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, surgically create an airway.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of

cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly).

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Patients who are comatose, hypotensive, or have seizures or ventricular arrhythmias should be treated in the conventional manner.

Basic Decontamination

Patients who are able may assist with their own decontamination. Remove and double-bag all clothing, including footwear, because methyl bromide penetrates many materials and can remain trapped in them. If clothing is to be reused, it must undergo thorough decontamination. Some contaminated clothing may not be safe for reuse (e.g., leather articles).

Flush exposed skin and hair with water for at least 15 minutes, then wash **twice** with mild soap. Rinse thoroughly with water. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Irrigate exposed or irritated eyes with plain water or saline for 15 to 20 minutes. Remove contact lenses if easily removable without additional trauma to the eye. If pain or injury is evident, continue irrigation while transferring the victim to the Critical Care Area. An ophthalmic anesthetic, such as 0.5% tetracaine, may be necessary to alleviate blepharospasm, and lid retractors may be required to allow adequate irrigation under the eyelids.

Oral exposure to methyl bromide is rare (it is a gas at temperatures above 38.5 °F); however, if ingestion occurs, **do not induce emesis**. If the victim is alert and able to swallow, and if not already done, administer a slurry of activated charcoal (at 1 gm/kg, usual adult dose 60–90 g, child dose 25–50 g). A soda can and straw may be of assistance when offering charcoal to a child.

Critical Care Area

Be certain that appropriate decontamination has been carried out (see *Decontamination Area*, above).

ABC Reminders

Evaluate and support airway, breathing, and circulation as in *ABC Reminders* above. Establish intravenous access in seriously ill patients. Continuously monitor cardiac rhythm.

Patients who are comatose, hypotensive, or have seizures or cardiac arrhythmias should be treated in the conventional manner.

Inhalation Exposure

Administer supplemental oxygen by mask to patients who have respiratory complaints. Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly).

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Observe these patients for 24 hours using repeated chest examinations and other appropriate tests. Follow-up as clinically indicated.

Skin Exposure

If the skin was in contact with concentrated methyl bromide vapor or liquid, chemical burns may result; treat as thermal burns. Burns may be delayed in onset.

Eye Exposure

Continue irrigation for at least 15 minutes. Test visual acuity. Examine the eyes for corneal damage and treat appropriately. Immediately consult an ophthalmologist for patients who have corneal injuries.

Ingestion

Oral exposure to methyl bromide is rare (it is a gas at temperatures above 38.5 °F); however, if ingestion occurs, **do not induce emesis.** If the victim is alert and able to swallow, and if not already done, administer a slurry of activated charcoal (at 1 gm/kg, usual adult dose 60–90 g, child dose 25–50 g). A soda can and straw may be of assistance when offering charcoal to a child.

Antidotes and Other Treatments

There is no proven antidote for methyl bromide poisoning. Dimercaprol (BAL) or acetylcysteine (Mucomyst) have been

suggested as antidotes based on the postulated mechanism of methyl bromide's toxicity. However, no adequate studies have tested the efficacy of these therapies, and they are not recommended for routine use.

Laboratory Tests

Serum bromide levels can be used to document that exposure did occur. However, bromide levels do not accurately predict the clinical course. Routine laboratory studies include CBC, glucose, and electrolyte determinations. Additional studies for patients exposed to methyl bromide include liver-function tests and renal-function tests. In cases of inhalation exposure, chest radiography and pulse oximetry (or ABG measurements) may be helpful.

Disposition and Follow-up

Decisions to admit or discharge a patient should be based on exposure history, physical examination, and test results. The probable delay in onset of serious effects from methyl bromide exposure should be considered.

Delayed Effects

Because the onset of pulmonary edema may be delayed for up to several days, patients who have severe exposure should be monitored with serial examinations before absence of toxic effects can be assured. If pulmonary edema is suspected, admit patients to an intensive care unit. Neurological symptoms also may not develop for several days or weeks.

Patient Release

Patients who have no evidence of neuropsychiatric or pulmonary effects 24 hours after exposure may be discharged with instructions to return to the ED if symptoms develop or recur (see the *Methyl Bromide—Patient Information Sheet).*

Follow-up

Obtain the name of the patient's primary care physician so that the hospital can send a copy of the ED visit to the patient's doctor.

Patients exposed to methyl bromide should be monitored for late neuropsychiatric sequelae.

Patients who have corneal injuries should be reexamined within 24 hours.

Reporting

Methyl bromide is a pesticide. If a pesticide or work-related incident has occurred, you may be legally required to file a report; contact your state or local health department.

Other persons may still be at risk in the setting where this incident occurred. If the incident occurred in the workplace, discussing it with company personnel may prevent future

incidents. If a public health risk exists, notify your state or local health department or other responsible public agency. When appropriate, inform patients that they may request an evaluation of their workplace from OSHA or NIOSH. See Appendices III and IV for a list of agencies that may be of assistance.

Methyl Bromide
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to methyl bromide.

What is methyl bromide?
Methyl bromide is a colorless gas or liquid that is odorless at low concentrations. At very high concentrations, it has a sweet, fruity odor. Tear gas is often mixed with it so that a person exposed to methyl bromide will be warned of its presence. Methyl bromide is used to kill insects in the soil and to rid soils and buildings of termites. Typically, the field or home is covered ("tented") by a large tarp and the methyl bromide is pumped in. Methyl bromide is also used in industry to make other chemicals.

What immediate health effects can be caused by exposure to methyl bromide?
Breathing methyl bromide can cause injury to the brain, nerves, lungs, and throat. High doses can also injure the kidneys and liver. Contact with the skin and eyes can lead to irritation and burns. Generally, the more serious the exposure, the more severe the symptoms.

Can methyl bromide poisoning be treated?
There is no antidote for methyl bromide poisoning, but its effects can be treated and most persons recover. Persons who have experienced serious symptoms may need to be hospitalized and may need follow-up examinations or treatment later on.

Are any future health effects likely to occur?
A single small exposure from which a person recovers quickly is not likely to cause delayed or long-term effects. After a serious exposure that causes lung or nervous system-related problems, permanent brain or nerve damage can result.

What tests can be done if a person has been exposed to methyl bromide?
Specific tests for the presence of bromide in blood may provide some useful information to the doctor. If a severe exposure has occurred, blood and urine analyses and other tests may show whether the lungs, brain, nerves, liver, or kidneys have been damaged. Testing is not needed in every case.

Where can more information about methyl bromide be found?
More information about methyl bromide can be obtained from your regional poison control center; your state, county, or local health department; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in occupational and environmental health. If the exposure happened at work, you may wish to discuss it with your employer, the Occupational Safety and Health Administration (OSHA), or the National Institute for Occupational Safety and Health (NIOSH). Ask the person who gave you this form for help in locating these telephone numbers.

Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow *only* the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:

- coughing or wheezing
- difficulty in breathing, shortness of breath, or chest pain
- difficulty in walking
- numbness of hands or feet
- confusion, dizziness, or fainting
- increased pain or a discharge from exposed eyes
- increased redness or pain or a pus-like discharge in the area of a skin burn

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.
[ ] Call for an appointment with Dr. _____ in the practice of _____. When you call for your appointment, please say that you were treated in the Emergency Department at _ _____ Hospital by _____ and were advised to be seen again in _____ days.
[ ] Return to the Emergency Department/ _____ Clinic on (date) _____at ___ _____ AM/PM for a follow-up examination.
[ ] Do not perform vigorous physical activities for 1 to 2 days.
[ ] You may resume everyday activities including driving and operating machinery.
[ ] Do not return to work for _____ days.
[ ] You may return to work on a limited basis. See instructions below.
[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.
[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.
[ ] Avoid taking the following medications: _____
[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: __ _____
_____
[ ] Other instructions: _____
_____
_____

- Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.
- You or your physician can get more information on the chemical by contacting: _____ _____ or _____, or by checking out the following Internet Web sites: _____; _____.

Signature of patient _____ Date _____

Signature of physician _____ Date _____

Methylene Chloride (CH_2Cl_2)
CAS 75-09-2; UN 1593

Synonyms include dichloromethane, methylene bichloride, methane dichloride, and methylene dichloride.

- **Persons exposed only to methylene chloride vapor do not pose risks of secondary contamination. Persons whose clothing or skin is contaminated with liquid methylene chloride can cause secondary contamination by direct contact or through off-gassing vapor.**
- **Odor is not an adequate warning property for methylene chloride**
- **Methylene chloride is a combustible liquid, but its vapor is flammable only when present in relatively high concentrations (14% to 22% in air).**
- **Methylene chloride is absorbed readily after inhalation and ingestion. Skin absorption is slow but may contribute to total body burden.**

Description

At room temperature, methylene chloride is a clear, colorless liquid with a pleasant odor. It is volatile, producing potentially toxic concentrations at room temperature. It is slightly soluble in water and miscible with most organic solvents.

Routes of Exposure

Inhalation

Inhalation is the most important route of exposure and methylene chloride vapor is absorbed readily from the lungs. **Odor is not an adequate warning property for methylene chloride,** the odor threshold is 250 ppm, which is 10 times higher than the OSHA PEL (25 ppm). Olfactory fatigue may also occur at high concentrations. Methylene chloride is heavier than air and may cause asphyxiation in enclosed, poorly ventilated, or low-lying areas.

Children exposed to the same levels of methylene chloride vapor as adults may receive larger doses because they have greater lung surface area:body weight ratios and increased minute volumes:weight ratios. In addition, they may be exposed to higher levels than adults in the same location because of their short stature and the higher levels of methylene chloride vapor found nearer to the ground.

Skin/Eye Contact

Exposure to high levels of methylene chloride vapor can cause skin and eye irritation. Prolonged dermal contact with liquid

methylene chloride may produce chemical burns. Methylene chloride is absorbed slowly through intact skin but probably not in quantities that cause acute systemic toxicity.

Children are more vulnerable to toxicants absorbed through the skin because of their relatively larger surface area:body weight ratio.

Ingestion

Acute toxic effects, including death, can result from ingestion.

Sources/Uses

Methylene chloride is produced commercially in large volumes by direct chlorination of methane or methyl chloride. Methylene chloride is an important solvent in paint and varnish strippers and in degreasing agents. It is used in the production of photographic films, synthetic fibers, pharmaceuticals, adhesives, inks, and printed circuit boards. It is employed as a blowing agent for polyurethane foams and as a propellant for insecticides, air fresheners, and paints.

Standards and Guidelines

OSHA PEL (permissible exposure limit) = 25 ppm (averaged over an 8-hour workshift)

OSHA STEL (short-term exposure limit) = 125 ppm (over a 15-minute time period)

NIOSH IDLH (immediately dangerous to life or health) = 2,300 ppm

AIHA ERPG-2 (maximum airborne concentration below which it is believed that nearly all persons could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action) = 750 ppm

Physical Properties

Description: Clear, colorless liquid

Warning properties: Sweet, ether-like odor at 250 ppm; inadequate warning for hazardous exposures.

Molecular weight: 84.9 daltons

Boiling point (760 mm Hg): 104.2 °F (39.8 °C)

Freezing point: -139 °F (-95 °C)

Specific gravity: 1.33 (water = 1)

Vapor pressure: 349 mm Hg at 68 °F (20 °C)

Gas density: 2.9 (air = 1)

Water solubility: Water soluble (2% at 68 °F) (20 °C)

Flammability: Combustible liquid

Flammable range: 14% to 22% (concentration in air)

Incompatibilities

Methylene chloride reacts with strong oxidizers, caustic substances, chemically active metals such as aluminum and magnesium powders, potassium, sodium, and concentrated nitric acid.

Health Effects

- **Methylene chloride is irritating to the skin, eyes, and respiratory tract. These effects can result from inhalation or dermal exposure to methylene chloride. Prolonged skin contact may cause chemical burns.**
- **Exposure by any route can cause CNS depression. Ingestion of methylene chloride can cause severe gastrointestinal irritation.**
- **Carbon monoxide, a metabolite of methylene chloride, may contribute to delayed toxic effects. The fetus and neonates are particularly vulnerable to poisoning with carbon monoxide.**

Acute Exposure

Adverse health effects of methylene chloride are due both to the parent compound and carbon monoxide which is a metabolite of methylene chloride. The mechanism of neurotoxic effects of the parent compound is unknown but may be related to the lipophilic properties of the compound. Carbon monoxide induces the formation of carboxyhemoglobin, thus depriving the brain from normal oxygen delivery and utilization. Signs and symptoms of exposure to very high levels (>750 ppm) of methylene chloride may be evident within minutes of exposure onset. Less pronounced exposures may induce adverse signs and symptoms within hours.

Children do not always respond to chemicals in the same way that adults do. Different protocols for managing their care may be needed.

CNS

Methylene chloride exposure causes dose-related CNS depression. Typical acute symptoms (within minutes to hours) include headache, drowsiness, lightheadedness, slurred speech, decreased alertness, slowed reaction times, irritability, impaired gait, and stupor. Rapid loss of consciousness, coma, seizures, and death have been reported.

Metabolic

Methylene chloride is metabolized in the liver, in part to carbon monoxide, which will produce elevated carboxyhemoglobin levels and decrease the oxygen-carrying capacity of the blood. Carboxyhemoglobin levels may continue to rise for several hours after exposure has ceased. The fetus is particularly vulnerable to poisoning with carbon monoxide.

Because of their relatively higher metabolic rate, children may be more vulnerable to toxicants interfering with basic metabolism.

Cardiovascular

Methylene chloride may cause electrocardiographic changes resembling those of carbon monoxide poisoning. Elevated carboxyhemoglobin and carboxymyoglobin levels may cause insufficient oxygen supply to the heart in persons who have preexisting coronary disease. Angina, myocardial infarction, and cardiac arrest associated with methylene chloride inhalation was reported in one patient, but no adverse cardiovascular effects from methylene chloride have been reported for occupationally exposed workers.

Respiratory

Victims of acute, high-level inhalation exposures may suffer airway irritation, inflammation of the lungs, and accumulation of fluid in the lungs.

Children may be more vulnerable because of relatively increased minute ventilation per kg and failure to evacuate an area promptly when exposed.

Hydrocarbon pneumonitis may be a problem in children.

Gastrointestinal

Nausea, vomiting, gastrointestinal ulceration and bleeding have been reported after ingestion.

Hepatic

Liver dysfunction may result from acute, high-level exposure to methylene chloride.

Dermal

Methylene chloride causes skin irritation and blistering. Prolonged dermal contact may result in second- and third-degree chemical burns.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants absorbed through the skin.

Ocular

High concentrations of methylene chloride vapor may cause eye irritation and tearing. When splashed in the eye, methylene chloride can cause burning pain, inflammation of the eye surface, and inflammation of the iris.

Potential Sequelae

Survivors of severe, acute exposure (e.g., cases of coma, seizures, or respiratory arrest) may suffer brain or heart damage from lack of oxygen to these organs. Exposure to high levels of methylene chloride, which may lead to the formation of high

amounts of the metabolite carbon monoxide, may lead to permanent sequelae, including mental deterioration, urinary and fecal incontinence, and gait disturbance. However, most cases of delayed neurologic sequelae are associated with loss of consciousness in the acute phase of intoxication.

Chronic Exposure

Cardiovascular effects have been documented in case reports but have not been demonstrated in epidemiologic studies of workers exposed to methylene chloride. Irritant contact dermatitis manifested by inflammation and hives has been noted in workers who have chronic skin exposure.

Chronic exposure may be more serious for children because of their potential longer latency period.

Carcinogenicity

The DHHS has determined that methylene chloride may be reasonably anticipated to be a human carcinogen based on adequate evidence in experimental animals.

Reproductive and Developmental Effects

In experimental animals, methylene chloride did not produce structural abnormalities but produced behavioral alterations and retarded development in offspring. The levels used in these studies were greater than 1,000 ppm. Whether these effects would have occurred in the absence of maternal toxicity is not clear. Embryotoxic effects have not been documented in humans. Methylene chloride is not included in *Reproductive and Developmental Toxicants*, a 1991 report published by the U.S. General Accounting Office (GAO) that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences.

Methylene chloride has been shown to cross the placenta in animals and has been found in human breast milk. The fetus and neonates are more susceptible to carbon monoxide, a methylene chloride metabolite, poisoning. Acute, nonlethal maternal intoxication with carbon monoxide may result in fetal death or permanent neurologic sequelae.

Prehospital Management

- **Victims exposed only to methylene chloride vapor do not pose contamination risks to rescuers. Victims whose clothing or skin is contaminated with liquid methylene chloride can secondarily contaminate response personnel by direct contact or through off-gassing vapor. Methylene chloride vapor may also off-gas from the toxic vomitus of victims who have ingested methylene chloride.**

- **Methylene chloride can cause acute CNS and respiratory depression, with resultant cardiac dysrhythmia. If inhaled at high levels, methylene chloride can cause respiratory tract irritation, and noncardiogenic pulmonary edema may ensue. Methylene chloride is metabolized slowly to carbon monoxide.**

- **There is no antidote for methylene chloride. Treatment consists of support of respiratory and cardiovascular functions. Oxygen is an antagonist of metabolically released carbon monoxide.**

Hot Zone

Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if rescuers have not been trained in its use, assistance should be obtained from a local or regional HAZMAT team or other properly equipped response organization.

Rescuer Protection

Methylene chloride vapor is absorbed well by inhalation and is a respiratory-tract irritant. The liquid is a mild skin irritant with slow skin absorption.

Respiratory Protection: Positive-pressure, self-contained breathing apparatus (SCBA) is recommended in response situations that involve exposure to potentially unsafe levels of methylene chloride vapor.

Skin Protection: Chemical-protective clothing is not generally required when only vapor exposure is expected because methylene chloride vapor is neither highly irritating nor absorbed well through the skin. Chemical-protective clothing is recommended when repeated or prolonged contact with liquid methylene chloride is anticipated because skin irritation and dermal absorption may occur.

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible.

Victim Removal

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be removed on backboards or gurneys; if these are not available, carefully carry or drag victims to safety.

Consider appropriate management of chemically contaminated children, such as measures to reduce separation anxiety if a child is separated from a parent or other adult.

Decontamination Zone

Victims exposed only to methylene chloride vapor who have no skin or eye irritation do not need decontamination. They may be transferred immediately to the Support Zone. All others require decontamination (see *Basic Decontamination* below).

Rescuer Protection

If exposure levels are determined to be safe, decontamination may be conducted by personnel wearing a lower level of protection than that worn in the Hot Zone (described above).

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. Stabilize the cervical spine with a collar and a backboard if trauma is suspected. Administer supplemental oxygen as required. Assist ventilation with a bag-valve-mask device if necessary.

Basic Decontamination

Victims who are able may assist with their own decontamination. Remove and double-bag contaminated clothing and personal belongings.

Flush exposed skin and hair with plain water for 3 to 5 minutes, then wash with mild soap. Rinse thoroughly with water. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Irrigate exposed or irritated eyes with plain water or saline for at least 15 minutes. Remove contact lenses if easily removable without additional trauma to the eye.

In cases of ingestion, **do not induce emesis**. If the victim is alert and able to swallow, administer a slurry of activated charcoal (at 1 gm/kg, usual adult dose 60–90 g, child dose 25–50 g). A soda can and straw may be of assistance when offering charcoal to a child.

Consider appropriate management of chemically contaminated children at the exposure site. Also, provide reassurance to the child during decontamination, especially if separation from a

parent occurs. If possible, seek assistance from a child separation expert.

Transfer to Support Zone

As soon as basic decontamination is complete, move the victim to the Support Zone.

Support Zone

Be certain that victims have undergone appropriate decontamination (see *Decontamination Zone* above). Victims who have undergone decontamination or have been exposed only to vapor pose no serious risks of secondary contamination to rescuers. In such cases, Support Zone personnel require no specialized protective gear.

ABC Reminders

Quickly access for a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Ensure adequate respiration and pulse. Administer supplemental oxygen as required and establish intravenous access if necessary. Place on a cardiac monitor.

Additional Decontamination

Continue irrigating exposed skin and eyes, as appropriate.

In cases of ingestion, **do not induce emesis**. If activated charcoal has not been given previously and the patient is alert and able to swallow, administer activated charcoal at 1 gm/kg (usual adult dose 60–90 g, child dose 25–50 g).

Advanced Treatment

In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, perform cricothyroidotomy if equipped and trained to do so.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly).

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Patients who are comatose, hypotensive, or are having seizures or cardiac arrhythmias should be treated according to advanced life support (ALS) protocols.

Transport to Medical Facility

Only decontaminated patients or patients not requiring decontamination should be transported to a medical facility. "Body bags" are not recommended.

Report to the base station and the receiving medical facility the condition of the patient, treatment given, and estimated time of arrival at the medical facility.

If methylene chloride has been ingested, prepare the ambulance in case the victim vomits toxic material. Have ready several towels and open plastic bags to quickly clean up and isolate vomitus.

Multi-Casualty Triage

Consult with the base station physician or the regional poison control center for advice regarding triage of multiple victims.

Patients who have evidence suggesting substantial exposure and all patients who have ingested methylene chloride should be transported to a medical facility for evaluation.

Patients who have brief or mild exposure and who are asymptomatic may be discharged from the scene after their names, addresses, and telephone numbers are recorded. These patients should be advised to rest and to seek medical care promptly if symptoms develop (see *Patient Information Sheet* below).

Emergency Department Management

- **Patients exposed only to methylene chloride vapor do not pose secondary contamination risks to hospital personnel. Patients whose clothing or skin is contaminated with liquid methylene chloride can secondarily contaminate hospital personnel by direct contact or through off-gassing vapor. Methylene chloride vapor may also off-gas from the toxic vomitus of victims who have ingested methylene chloride.**

- **Methylene chloride can cause acute CNS and respiratory depression with resultant cardiac dysrhythmias. If inhaled at high levels, methylene chloride may cause irritation of the respiratory tract, and noncardiogenic pulmonary edema may ensue. Methylene chloride is metabolized slowly to carbon monoxide.**

- **There is no antidote for methylene chloride. Treatment consists of support of respiratory and cardiovascular functions. Oxygen is an antagonist of metabolically released carbon monoxide.**

Decontamination Area

Previously decontaminated patients and patients exposed only to methylene chloride vapor who have no skin or eye irritation may be transferred immediately to the Critical Care Area. Others require decontamination as described below.

Be aware that use of protective equipment by the provider may cause fear in children, resulting in decreased compliance with further management efforts.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants absorbed through the skin. Also, emergency room personnel should examine children's mouth because of the frequency of hand-to-mouth activity among children.

ABC Reminders

Evaluate and support airway, breathing, and circulation. In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, surgically create an airway.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals

may pose enhanced risk of cardiac arrhythmias (especially in the elderly).

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Patients who are comatose, hypotensive, or have seizures or ventricular arrhythmia should be treated in the conventional manner.

Basic Decontamination

Patients who are able may assist with their own decontamination. Remove and double-bag the contaminated clothing and personal belongings.

Flush exposed skin and hair with plain water for 2 to 3 minutes (preferably under a shower), then wash with mild soap. Rinse thoroughly with water. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Irrigate exposed eyes with plain water or saline for at least 15 minutes. Remove contact lenses if easily removable without additional trauma to the eye.

In cases of ingestion, **do not induce emesis**. If the victim is alert and asymptomatic, administer a slurry of activated charcoal if it has not been given previously. (More information is provided in *Ingestion Exposure* under *Critical Care Area* below).

Critical Care Area

Be certain that appropriate decontamination has been carried out (see *Decontamination Area* above).

ABC Reminders

Evaluate and support airway, breathing, and circulation as in *ABC Reminders* above. Establish intravenous access in seriously ill patients. Continuously monitor cardiac rhythm.

Patients who are comatose, hypotensive, or have seizures or ventricular arrhythmias should be treated in the conventional manner.

Inhalation Exposure

Administer supplemental oxygen by mask to patients who have respiratory symptoms. Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the

myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly).

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Skin Exposure

If the skin was in prolonged contact with liquid methylene chloride, chemical burns may result; treat as thermal burns.

Because of their relatively larger surface area:weight ratio, children are more vulnerable to toxicants absorbed through the skin.

Eye Exposure

Ensure that adequate eye irrigation has been completed. Examine the eyes for corneal damage and treat appropriately. Immediately consult an ophthalmologist for patients who have severe corneal injuries.

Ingestion Exposure

Do not induce emesis.

If the patient is alert and charcoal has not been given previously, administer a slurry of activated charcoal (at 1 gm/kg, usual adult dose 60–90 g, child dose 25–50 g). A soda can and straw may be of assistance when offering charcoal to a child.

Consider endoscopy to evaluate the extent of gastrointestinal tract injury. Extreme throat swelling may require endotracheal intubation or cricothyroidotomy. Gastric lavage is useful in certain circumstances to remove caustic material and prepare for endoscopic examination. Consider gastric lavage with a small nasogastric tube if : (1) a large dose has been ingested; (2) the patient's condition is evaluated within 30 minutes; (3) the patient has oral lesions or persistent esophageal discomfort; and (4) the lavage can be administered within 1 hour of ingestion. Care must be taken when placing the gastric tube because blind-tube placement may further injure the chemically damaged esophagus or stomach.

Because children do not ingest large amounts of corrosive materials, and because the risk of perforation from nasogastric intubation, lavage is discouraged in children unless intubation is performed under endoscopic guidance.

Antidotes and Other Treatments

There is no antidote for methylene chloride.

It is unlikely that the carbon monoxide produced from methylene chloride metabolism will justify hyperbaric oxygen therapy; however, 100% oxygen at normal pressure is a useful treatment. The comparative efficacy of 100% normobaric oxygen compared with that of hyperbaric oxygen has not been definitively studied.

Laboratory Tests

Routine laboratory studies for all exposed patients include CBC, glucose, and electrolyte determinations. In cases of substantial exposure, additional useful studies include ECG monitoring, determinations of carboxyhemoglobin levels, and liver-function tests. Chest radiography and pulse oximetry (or ABG measurements) are recommended for severe inhalation exposure or if pulmonary aspiration is suspected. Levels of methylene chloride in blood are not clinically useful; however, they may be used to qualitatively document exposure. Carboxyhemoglobin levels of exposed patients rarely exceed 15% but may remain elevated for 1 to 2 days after exposure due to continual metabolic conversion of fat-stored methylene chloride.

Disposition and Follow-up

Consider hospitalizing symptomatic patients who have a suspected serious exposure and are symptomatic.

Delayed Effects

In patients who have been seriously exposed, cardiac dysrhythmias and skin burns may develop several hours after exposure. Exposure to high amount of methylene chloride may give rise to high blood concentration of its metabolite carbon monoxide. This may lead to permanent sequelae including mental deterioration, urinary and fecal incontinence, and gait disturbance. However, most cases of delayed neurologic sequelae are associated with loss of consciousness in the acute phase of intoxication.

Patient Release

Patients who have not experienced respiratory difficulty or alterations in mental status may be discharged. Patients who initially had mild symptoms but who are asymptomatic 6 to 12 hours after exposure may also be discharged. Discharged patients should be advised to rest and to seek medical care promptly if symptoms develop or recur (see the *Methylene Chloride—Patient Information Sheet*). Patients should not be discharged solely on the basis of carboxyhemoglobin levels because oxygen treatment may render carboxyhemoglobin levels unreliable. Metabolic conversion of methylene chloride to carbon monoxide may be ongoing, and carboxyhemoglobin levels may rebound after oxygen therapy is stopped.

Follow-up

Obtain the name of the patient's primary care physician so that the hospital can send a copy of the ED visit to the patient's doctor.

Severely exposed patients should be monitored for lung, brain, heart, and liver damage. Patients who have skin burns or corneal injuries should be reexamined within 24 hours.

Reporting

If a work-related incident has occurred, you may be legally required to file a report; contact your state or local health department.

Other persons may still be at risk in the setting where this incident occurred. If the incident occurred in the workplace, discussing it with company personnel may prevent future incidents. If a public health risk exists, notify your state or local health department or other responsible public agency. When appropriate, inform patients that they may request an evaluation of their workplace from OSHA or NIOSH. See Appendices III and IV for a list of agencies that may be of assistance.

Methylene Chloride
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to methylene chloride.

What is methylene chloride?
Methylene chloride is a colorless, volatile liquid with a sweet smell. It is used in plastics processing, as a paint and varnish remover, and as a cleaning liquid for electronic boards and metal parts.

What immediate health effects can be caused by exposure to methylene chloride?
Methylene chloride can affect the body if the vapor is inhaled, if the liquid touches the skin or eyes, or if it is swallowed. In the body, some methylene chloride is changed to carbon monoxide (a methylene chloride metabolite), which prevents the blood from carrying oxygen to the tissues. At moderate levels, methylene chloride can cause headaches, fatigue, difficulty walking, and dizziness. High levels can cause fainting and even death. Methylene chloride can irritate the lungs, causing a build-up of fluid in the lungs. It can also cause the heart to beat irregularly or to stop beating. Generally, the more serious the exposure, the more severe the symptoms. The fetus and neonates are particularly vulnerable to poisoning with carbon monoxide.

Can methylene chloride poisoning be treated?
If a person has inhaled or swallowed a large amount of methylene chloride, breathing 100% oxygen is helpful. These patients may need to be hospitalized. Most exposed patients get well.

Are any future health effects likely to occur?
A single small exposure from which a person recovers quickly is not likely to cause delayed or long-term effects. After a serious exposure or repeated exposures, damage to the brain can cause memory loss, poor coordination, and decreased ability to think. Long-term exposures over many years have been associated with cancer.

What tests can be done if a person has been exposed to methylene chloride?
Specific tests for the presence of methylene chloride in blood or urine generally are not useful to the doctor. If a severe exposure has occurred, blood and urine analyses and other tests may show whether the liver, brain, heart, or lungs have been injured. Testing is not needed in every case.

Where can more information about methylene chloride be found?
More information about methylene chloride can be obtained from your regional poison control center; your state, county, or local health department; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in occupational and environmental health. If the exposure happened at work, you may wish to discuss it. with your employer, the Occupational Safety and Health Administration (OSHA),or the National Institute for Occupational Safety and Health (NIOSH). Ask the person who gave you this form for help in locating these telephone numbers.

Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow *only* the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:

- headache, nausea, vomiting, dizziness
- chest pains, difficulty thinking, blurred vision
- dyspnea on exertion, weakness
- palpitations, tachycardia, tachypnea

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.
[ ] Call for an appointment with Dr. _____ in the practice of _____. When you call for your appointment, please say that you were treated in the Emergency Department at _ _____ Hospital by _____ and were advised to be seen again in _____ days.
[ ] Return to the Emergency Department/ _____ Clinic on (date) _____at ___ _____ AM/PM for a follow-up examination.
[ ] Do not perform vigorous physical activities for 1 to 2 days.
[ ] You may resume everyday activities including driving and operating machinery.
[ ] Do not return to work for _____ days.
[ ] You may return to work on a limited basis. See instructions below.
[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.
[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.
[ ] Avoid taking the following medications: _____
[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: __ _____
_____
[ ] Other instructions: _____
_____
_____

- Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.

- You or your physician can get more information on the chemical by contacting: _____ _____ or _____, or by checking out the following Internet Web sites: _____; _____.

Signature of patient _____ Date _____

Signature of physician _____ Date _____

Methyl Isocyanate (C_2H_3NO)
CAS 624-83-9; UN 2480

Synonyms include isocyanomethane, isocyanatomethane, methylcarbylamine, and MIC.

- **Persons exposed only to methyl isocyanate gas pose no risk of secondary contamination. Persons whose skin or clothing is contaminated with liquid methyl isocyanate can secondarily contaminate rescuers by direct contact or through off-gassing of vapor.**
- **At temperatures below 39 °C (102 °F), methyl isocyanate is a very flammable colorless liquid that readily evaporates when exposed to air. Gaseous methyl isocyanate is slightly heavier than air.**
- **Although methyl isocyanate has a pungent odor, adverse health effects have been reported at or below the human odor threshold; therefore, odor detection is not a reliable indicator of exposure.**
- **Methyl isocyanate is readily absorbed through the upper respiratory tract. Methyl isocyanate can also be absorbed through the digestive tract or skin.**

Description

At temperatures below 39 °C (102 °F), methyl isocyanate is a very flammable liquid that readily evaporates when exposed to air. Gaseous methyl isocyanate is approximately 1.4 times heavier than air. Methyl isocyanate liquid is colorless with a pungent odor. Most people can smell methyl isocyanate vapors at levels as low as 2 to 5 ppm. Methyl isocyanate is handled and transported as a very flammable and explosive liquid.

Routes of Exposure

Inhalation

Inhalation is the major route of exposure to methyl isocyanate. The vapors are readily absorbed through the lungs. The odor threshold is approximately 100 to 250 times higher than the OSHA PEL-TWA (0.02 ppm). Significant exposures to methyl isocyanate occur primarily in occupational settings. Acute exposure to methyl isocyanate vapors below the odor threshold can be irritating to the eye and respiratory epithelium. Acute exposure to higher vapor concentrations may cause severe pulmonary edema and injury to the alveolar walls of the lung and death. Survivors of acute exposures may exhibit long-term respiratory effects. **Odors of methyl isocyanate may not provide adequate warning of hazardous concentrations** because the Immediately Dangerous to Life or

Health (IDLH) limit is only 3 ppm and the threshold for detection of methyl isocyanate vapors ranges from 2 to 5 ppm in humans. Significant exposure to methyl isocyanate vapors would most likely be the result of accidental release of methyl isocyanate to the air such as occurred in Bhopal, India in 1984, where the primary effect was pulmonary edema with some alveolar wall destruction. Methyl isocyanate is heavier than air; therefore, exposure in poorly ventilated, enclosed, or low-lying areas could result in asphyxiation.

Children exposed to the same levels of methyl isocyanate as adults may receive larger doses because they have relatively greater lung surface area:body weight ratios and higher minute volume:weight ratios. In addition, they may be exposed to higher levels than adults in the same location because of their short stature and the higher levels of methyl isocyanate found nearer to the ground. Children may be more vulnerable to corrosive agents than adults because of the smaller diameter of their airways.

Skin/Eye Contact

Direct contact with liquid or concentrated vapors of methyl isocyanate may cause irritation of the skin or eyes and severe ocular damage. Direct skin contact may result in dermal absorption. Significant dermal exposure to methyl isocyanate would not likely occur outside an occupational environment in which methyl isocyanate is stored or used.

Because of their relatively larger surface area:weight ratio, children are more vulnerable to toxicants absorbed through the skin.

Ingestion

Although unlikely, ingestion of liquid methyl isocyanate could produce severe gastrointestinal irritation.

Sources/Uses

Methyl isocyanate is made by reacting methylamine with phosgene. The primary use of methyl isocyanate is as a chemical intermediate in the production of pesticides. It is also used to produce polyurethane foams and plastics.

Standards and Guidelines

OSHA PEL (permissible exposure limit) = 0.02 ppm (averaged over an 8-hour workshift) with a skin notation

NIOSH IDLH (immediately dangerous to life or health) = 3 ppm

AIHA ERPG-2 (maximum airborne concentration below which it is believed that nearly all persons could be exposed for up to 1 hour without experiencing or developing irreversible or other serious

health effects or symptoms that could impair their abilities to take protective action) = 0.5 ppm

Physical Properties

Description: Colorless liquid at room temperature; volatile, flammable, explosive in air

Warning properties: Pungent odor of methyl isocyanate may not be adequate to warn of acute exposure. Most people can detect methyl isocyanate at levels of 2 to 5 ppm (1 ppm is equivalent to 2.35 mg/m^3)

Molecular weight: 57.05 daltons

Boiling point (760 mm Hg): 102 °F (39.1 °C)

Freezing point: -49 °F (-45 °C)

Vapor pressure: 348 mm Hg at 68 °F (20 °C)

Vapor density: 1.42 (air = 1.00)

Water solubility: 6.7% at 68 °F (20 °C)

Flammability: highly flammable

Flammable Range: 5.3 % to 26 % (concentration in air)

Incompatibilities

Methyl isocyanate reacts violently with water. Methyl isocyanate is incompatible with oxidizers, acids, alkalis, amines, iron, tin, and copper.

Health Effects

- **Methyl isocyanate is irritating and corrosive to the eyes, respiratory tract, and skin. Acute exposure to high vapor concentrations may cause severe pulmonary edema and injury to the alveolar walls of the lung, severe corneal damage, and death. Survivors of acute exposures may exhibit long-term respiratory and ocular effects. Methyl isocyanate may be a dermal and respiratory sensitizer.**

- **Mechanisms of methyl isocyanate-induced toxicity are not known. Persistent respiratory and ocular effects may reflect methyl isocyanate-induced immunologic effects. Methyl isocyanate may cross the placenta and enter a developing fetus. Individuals especially susceptible to the toxic effects of methyl isocyanate include those with existing disorders of the respiratory system or eyes.**

Acute Exposure

Mechanisms of toxicity have not been clearly elucidated for methyl isocyanate; however, carbamylation of globin and blood proteins may play a role. Persistent respiratory and ocular effects may reflect methyl isocyanate-induced immunologic effects since antibodies specific to methyl isocyanate have been demonstrated in the blood of exposed patients. Methyl isocyanate is highly reactive; therefore, it is not metabolized in the classical sense. The onset of respiratory effects following acute exposure to methyl isocyanate can be immediate in some cases. In others, respiratory injury can evolve over periods of hours or days. Exposure-related deaths sometimes can occur as late as 30 or more days post-exposure, due in part to the development of pneumonia.

Children do not always respond to chemicals in the same way that adults do. Different protocols for managing their care may be needed.

Respiratory

Methyl isocyanate vapors are severely irritating and corrosive to the respiratory tract. Symptoms may include cough, chest pain, dyspnea, coma, and death. Irritative respiratory symptoms such as pulmonary edema and bronchial spasms may occur in immediate response to exposure. Methyl isocyanate-induced pulmonary edema may progress to effects such as alveolar wall destruction and pneumonia, which may ultimately lead to respiratory failure and death. Some respiratory effects may progress in severity over a period of hours to days post-exposure. Asthmatic reactions and long-term respiratory effects have been reported.

Children may be more vulnerable to corrosive agents than adults because of the smaller diameter of their airways. Children also may be more vulnerable to gas exposure because of relatively higher minute ventilation per kg and failure to evacuate an area promptly when exposed.

Ocular/Ophthalmic

Severe eye irritation can result from exposure to methyl isocyanate vapors or direct contact with the liquid. Symptoms may include immediate eye pain, lacrimation, photophobia, profuse lid edema, and corneal ulcerations. Ocular exposure may result in long-term or permanent eye damage.

Dermal

Methyl isocyanate is a skin irritant and may cause chemical burns upon dermal contact at high exposure levels.

Because of their relatively larger surface area: body weight ratio, children are more vulnerable to toxicants that affect the skin.

Gastrointestinal

Nausea, vomiting, abdominal pain, and defecation have been reported after acute exposure to methyl isocyanate vapors.

Potential Sequelae

Initial irritative symptoms of the respiratory tract may progress to more serious respiratory injury over a period of hours to days following exposure to methyl isocyanate vapors. Compromised lung tissue may be susceptible to bacterial pneumonias. Exposure may result in permanent eye damage. Methyl isocyanate may also be a respiratory and dermal sensitizer. Renal tubular necrosis, reduced liver function, and miscarriage were associated with methyl isocyanate exposure in the Bhopal, India incident.

Chronic Exposure

Chronic exposure to methyl isocyanate may result in chronic obstructive lung disease.

Carcinogenicity

Methyl isocyanate has not been classified for carcinogenicity.

Reproductive and Developmental Effects

Methyl isocyanate is not included in the list of *Reproductive and Developmental Toxicants*, a 1991 report published by the U.S. General Accounting Office that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences. Increased rates of spontaneous abortions and neonatal deaths among victims of the Bhopal accident were observed for months following exposure. However, the precise role of methyl isocyanate in developmental toxicity is difficult to determine. Poor oxygenation resulting from compromised lung

function may nr involved. Animal studies indicate that inhalation exposure during gestation may result in decreased numbers of live births and decreased survival during lactation. There was no evidence of a dominant lethal effect in exposed male mice. Genotoxicity testing in animals indicates that methyl isocyanate may have the capacity to affect chromosome structure, but it apparently does not induce gene mutations.

Prehospital Management

- **Persons exposed only to methyl isocyanate gas pose no risk of secondary contamination to rescuers. Persons whose skin or clothing is contaminated with liquid methyl isocyanate can secondarily contaminate response personnel by direct contact or through off-gassing of vapor.**

- **Methyl isocyanate is irritating to the eyes, respiratory tract, and skin. Early symptoms may include eye irritation, coughing, and shortness of breath. In cases of severe exposure, later symptoms may include vomiting and diarrhea. Acute exposure to high vapor concentrations may cause relatively rapid and severe pulmonary edema, alveolar wall injury, and corneal damage. Initial signs of irritation may progress to vomiting, diarrhea, and death. Survivors of acute exposures may exhibit long-term respiratory and ocular effects. Methyl isocyanate may be a dermal and respiratory sensitizer.**

- **There is no antidote for methyl isocyanate. Treatment consists of removal of the victim from the contaminated area and support of respiratory and cardiovascular functions.**

Hot Zone

Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if the rescuers have not been trained in its use, call for assistance from a local or regional hazardous materials (HAZMAT) team or other properly equipped response organization.

Rescuer Protection

Inhaled methyl isocyanate is a severe respiratory tract irritant. Contamination of the skin can cause irritation or chemical burns. Contamination of the eyes can cause irritation and serious or long-term damage. Methyl isocyanate is absorbed through the skin.

Respiratory protection: Positive-pressure, self-contained breathing apparatus (SCBA) with a full facepiece and operated in a positive pressure mode is recommended in response to situations that involve exposure to potentially unsafe levels of methyl isocyanate gas.

Skin protection: Chemical protective clothing is recommended because methyl isocyanate can cause skin irritation and burns. Protective eye equipment is recommended to prevent eye contact.

ABC Reminders

Quickly establish a patent airway, ensure adequate respiration and pulse. Maintain adequate circulation. Provide supplemental oxygen if cardiopulmonary compromise is suspected. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar

and a backboard when feasible. Apply direct pressure to stop any heavy bleeding.

Victim Removal

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk should be removed on backboards or gurneys. If these are not available, carefully carry or drag victims to safety.

Consider appropriate management of anxiety in victims with chemically-induced acute disorders, especially childrenwho may suffer separation anxiety if separated from a parent or other adult.

Decontamination Zone

Patients exposed only to methyl isocyanate gas who have no eye or skin irritation do not need decontamination. They may be transferred immediately to the Support Zone. Other patients will require decontamination as described below.

Rescuer Protection

If exposure levels are determined to be safe, decontamination may be conducted by personnel wearing a lower level of protection than that required in the Hot Zone (described above).

ABC Reminders

Quickly establish a patent airway, ensure adequate respiration and pulse. Maintain adequate circulation. Provide supplemental oxygen if cardiopulmonary compromise is suspected. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Administer supplemental oxygen as required. Assist ventilation with a bag-valve-mask device if necessary. Apply direct pressure to control any heavy bleeding.

Basic Decontamination

Rapid skin decontamination is critical. Victims who are able may assist with their own decontamination. Remove contaminated clothing and personal belongings and place them in double plastic bags.

Wash exposed skin thoroughly with soap and water. Use caution to avoid hypothermia when decontaminating victims, particularly children or the elderly. Use blankets or warmers after decontamination as needed.

Irrigate exposed eyes with copious amounts of tepid water for at least **15 minutes**. Remove contact lenses if they are easily removable without additional trauma to the eye. If pain or injury is evident, continue irrigation while transferring the victim to the Support Zone.

In cases of ingestion, **do not induce emesis**. If the victim is not symptomatic, consider administering activated charcoal at a dose of 1 g/kg (infant, child, and adult dose). A soda can and straw may be of assistance when offering charcoal to a child. However, the effectiveness of activated charcoal in binding methyl isocyanate has not been demonstrated.

If the victim is conscious and able to swallow, consider giving 4 to 8 ounces of water.

Consider appropriate management of chemically contaminated children at the exposure site. Also, provide reassurance to the child during decontamination, especially if separation from a parent occurs.

Transfer to Support Zone

As soon as basic decontamination is complete, move the victim to the Support Zone.

Support Zone

Be certain that victims have been decontaminated properly (see *Decontamination Zone*, above). Victims who have undergone decontamination or have been exposed only to methyl isocyanate gas pose no serious risk of secondary contamination to rescuers. In such cases, Support Zone personnel require no specialized protective gear.

ABC Reminders

Quickly establish a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Ensure adequate respiration and pulse. Administer supplemental oxygen as required and establish intravenous access if necessary. Place on a cardiac monitor, if available.

Additional Decontamination

Continue irrigating exposed skin and eyes, as appropriate.

In cases of ingestion, **do not induce emesis**. If the victim is not symptomatic, consider administering charcoal at a dose of 1 g/kg (infant, child, and adult dose). A soda can and straw may be of assistance when offering charcoal to a child. However, the effectiveness of activated charcoal in binding methyl isocyanate has not been demonstrated.

If the victim is conscious and able to swallow, consider giving 4 to 8 ounces of water if it has not been given previously.

Advanced Treatment

Treat cases of respiratory compromise with respiratory support using protocols and techniques available and within the scope of training. Some cases may necessitate procedures such as endotracheal intubation or cricothyrotomy by properly trained and equipped personnel.

Treat patients who have bronchospasm with oxygen, aerosolized bronchodilators such as albuterol, and/or steroids according to established protocol.

In cases of non-cardiogenic pulmonary edema, which may be delayed in onset, maintain adequate ventilation and oxygenation. Early use of mechanical ventilation and positive-end-expiratory pressure (PEEP) may be required. To minimize barotrauma and other complications, use the lowest amount of PEEP possible while maintaining adequate oxygenation. Consider drug therapy for pulmonary edema.

Patients who are comatose, hypotensive, or having seizures or cardiac arrhythmias should be treated according to advanced life support (ALS) protocols.

If evidence of shock or hypotension is observed begin fluid administration. For adults with systolic pressure less than 80 mmHg, bolus perfusion of 1,000 mL/hour intravenous saline or lactated Ringer's solution may be appropriate. Higher adult systolic pressures may necessitate lower perfusion rates. For children with compromised perfusion administer a 20 mL/kg bolus of normal saline over 10 to 20 minutes, then infuse at 2 to 3 mL/kg/hour. Consider vasopressors if patient is hypotensive with a normal fluid volume.

Transport to Medical Facility

Only decontaminated patients or patients not requiring decontamination should be transported to a medical facility. "Body bags" are not recommended.

Report the condition of the patient, treatment given, and estimated time of arrival at the medical facility to the base station and the receiving medical facility.

If methyl isocyanate has been ingested, prepare the ambulance in case the victim vomits toxic material. Have ready several towels and open plastic bags to quickly clean up and isolate vomitus.

Multi-Casualty Triage

Consult with the base station physician or the regional poison control center for advice regarding triage of multiple victims.

Patients who have histories or evidence suggesting significant exposure (e.g., altered behavior, respiratory distress, or chemical burns) should be transported to a medical facility for evaluation. Patients who have a history of chronic pulmonary disease should be clinically evaluated for airflow obstruction.

Patients who have mild symptoms of respiratory or eye irritation should be clinically evaluated because onset of pulmonary edema may be delayed for up to 72 hours post-exposure and eye injury may need to be treated topically for inflammation or secondary infection. Patients who have symptoms of transient skin, nose, or eye irritation may be discharged from the scene after their names, addresses, and telephone numbers are recorded. They should be advised to rest and to seek medical care promptly if symptoms develop or recur (see *Patient Information Sheet* below).

Emergency Department Management

- **Persons exposed only to methyl isocyanate gas pose no risk of secondary contamination to rescuers. Persons whose skin or clothing is contaminated with liquid methyl isocyanate can secondarily contaminate response personnel by direct contact or through off-gassing of vapor.**
- **Methyl isocyanate is irritating to the eyes, respiratory tract, and skin. Acute exposure to high vapor concentrations may cause severe pulmonary edema and injury to the alveolar walls of the lung, severe corneal damage, and death. Survivors of acute exposures may exhibit long-term respiratory and ocular effects. Methyl isocyanate may be a dermal and respiratory sensitizer.**
- **There is no antidote for methyl isocyanate. Treatment consists of removal of the victim from the contaminated area and support of respiratory and cardiovascular functions.**

Decontamination Area

Previously decontaminated patients and those exposed only to methyl isocyanate gas who have no skin or eye irritation may be transferred immediately to the Critical Care Area. Others require decontamination as described below.

Be aware that use of protective equipment by the provider may cause anxiety, particularly in children, resulting in decreased compliance with further management efforts.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxins absorbed through the skin. Also emergency room personnel should examine children's mouths because of the frequency of hand-to-mouth activity among children.

ABC Reminders

Evaluate and support the airways, breathing, and circulation. Provide supplemental oxygen if cardiopulmonary compromise is suspected. Treat cases of respiratory compromise with respiratory support using protocols and techniques available and within the scope of training. Some cases may necessitate procedures such as endotracheal intubation or cricothyrotomy by properly trained and equipped personnel.

Treat patients who have bronchospasm with oxygen, aerosolized bronchodilators such as albuterol, and/or steroids according to established protocol.

Children may be more vulnerable to corrosive agents than adults because of the smaller diameter of their airways.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution, repeat every 20 minutes as needed, cautioning for myocardial variability.

In cases of non-cardiogenic pulmonary edema, which may be delayed in onset, maintain adequate ventilation and oxygenation. Mechanical ventilation and positive-end-expiratory pressure (PEEP) may be required. To minimize barotrauma and other complications, use the lowest amount of PEEP possible while maintaining adequate oxygenation. Consider drug therapy for pulmonary edema. Keep in mind that the use of steroids to prevent or treat chemical pneumonitis and pulmonary edema is controversial.

Patients who are comatose, hypotensive, or are having seizures or cardiac arrhythmias should be treated in the conventional manner.

Basic Decontamination

Patients who are able may assist with their own decontamination.

Because methyl isocyanate can cause burns, ED staff should don chemical-resistant jumpsuits (e.g., of Tyvek or Saranex) or butyl rubber aprons, rubber gloves, and eye protection if the patient's clothing or skin is wet. After the patient has been decontaminated, no special protective clothing or equipment is required for ED personnel.

Quickly remove contaminated clothing while gently washing the skin with soap and water. Double-bag the contaminated clothing and personal belongings. Handle burned skin with caution.

Wash exposed skin thoroughly with soap and water. If pain or injury is evident, continue irrigation while transferring the victim to the Critical Care Area. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Flush exposed or irritated eyes with copious amounts of tepid water for at least **15 minutes**. Remove contact lenses if easily removable without additional trauma to the eye. If pain or injury is evident, continue irrigation while transferring the victim to the Critical Care Area.

In cases of ingestion, **do not induce emesis**. If the victim is not symptomatic, consider administering activated charcoal at a dose of 1 g/kg (infant, child, and adult dose). A soda can and straw may be of assistance when offering charcoal to a child. However, the effectiveness of activated charcoal in binding methyl isocyanate has not been demonstrated.

If the victim is conscious and able to swallow, consider giving 4 to 8 ounces of water.

Critical Care Area

Be certain that appropriate decontamination has been carried out.

ABC Reminders

Evaluate and support the airways, breathing, and circulation as in *ABC Reminders* above. Establish intravenous access in seriously ill patients. Continuously monitor cardiac rhythm.

Patients who are comatose, hypotensive, or are having seizures or cardiac arrhythmias should be treated in the conventional manner.

Inhalation Exposure

Administer supplemental oxygen by mask to patients who have respiratory complaints. Treat patients who have bronchospasm with aerosolized bronchodilators such as albuterol and/or steroids.

In cases of non-cardiogenic pulmonary edema, which may be delayed in onset, maintain adequate ventilation and oxygenation. Monitor arterial blood gases and/or pulse oximetry. If a high FIO_2 is required to maintain adequate oxygenation, mechanical ventilation and positive-end-expiratory pressure (PEEP) may be required. To minimize barotrauma and other complications, use the lowest amount of PEEP possible while maintaining adequate oxygenation. Consider drug therapy for pulmonary edema. Keep in mind that the use of steroids to prevent or treat chemical pneumonitis and pulmonary edema is controversial. Antibiotics should be used as indicated to control infection. Damaged lower respiratory tissue might be more susceptible to infection.

Skin Exposure

If concentrated methyl isocyanate is in contact with the skin, chemical burns may result; treat as thermal burns.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants that affect the skin.

Eye Exposure

Continue irrigation for at least **15 minutes**. Test visual acuity. Examine the eyes for corneal damage and treat appropriately.

Immediately consult an ophthalmologist for patients who have suspected severe corneal injuries.

Ingestion

Do not induce emesis. Consider endoscopy to evaluate the extent of gastrointestinal-tract injury. Extreme throat swelling may require endotracheal intubation or cricothyrotomy. Gastric lavage is useful in certain circumstances to remove caustic material and prepare for endoscopic examination. Consider gastric lavage with a small nasogastric (NG) tube if: (1) a large dose has been ingested; (2) the patient's condition is evaluated within 30 minutes; (3) the patient has oral lesions or persistent esophageal discomfort; and (4) the lavage can be administered within 1 hour of ingestion. Care must be taken when placing the gastric tube because blind gastric-tube placement may further injure the chemically damaged esophagus or stomach.

Because children do not ingest large amounts of corrosive materials, and because of the risk of perforation from NG intubation, lavage is discouraged in children unless intubation is performed under endoscopic guidance.

If the victim is not symptomatic, consider administering activated charcoal at a dose of 1 g/kg (infant, child, and adult dose). A soda can and straw may be of assistance when offering charcoal to a child. However, the effectiveness of activated charcoal in binding methyl isocyanate has not been demonstrated.

Consider giving 4 to 8 ounces of water to alert patients who can swallow, if not done previously.

Antidotes and Other Treatments

There is no antidote for methyl isocyanate. Treatment is supportive of respiratory and cardiac functions.

Laboratory Tests

Routine laboratory studies include chest radiography and pulse oximetry (or ABG measurements).

Disposition and Follow-up

Consider hospitalizing symptomatic patients who have evidence of respiratory or cardiac distress or significant chemical burns.

Delayed Effects

Acute exposure to high concentrations of methyl isocyanate may result in delayed onset of pulmonary edema and risk of secondary infection of the lungs or eyes.

Patient Release

Patients who become totally asymptomatic in terms of pulmonary complaints in a 72-hour observation period are not likely to develop complications. They may be released and advised to rest and to seek medical care promptly if symptoms develop (see the *Methyl Isocyanate—Patient Information Sheet* below). Cigarette smoking can exacerbate pulmonary injury and should be discouraged for 72 hours after exposure.

Follow-up

Obtain the name of the patient's primary care physician so that the hospital can send a copy of the ED visit to the patient's doctor.

Follow-up evaluation of respiratory function should be arranged for severely exposed patients. Patients who have skin or corneal lesions should be reexamined within 24 hours.

Reporting

If a work-related incident has occurred, you might be legally required to file a report; contact your state or local health department.

Other persons might still be at risk in the setting where this incident occurred. If the incident occurred in the workplace, discussing it with company personnel might prevent future incidents. If a public health risk exists, notify your state or local health department or other responsible public agency. When appropriate, inform patients that they may request an evaluation of their workplace from the Occupational Safety and Health Administration (OSHA) or the National Institute for Occupational Safety and Health (NIOSH). See Appendix III for a list of agencies that may be of assistance.

Methyl Isocyanate (C_2H_3NO)
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to methyl isocyanate.

What is methyl isocyanate?
Methyl isocyanate is a very flammable liquid that readily evaporates when exposed to air. Methyl isocyanate liquid is colorless with a pungent odor. The primary use of methyl isocyanate is as a chemical intermediate in the production of pesticides. It is also used to produce polyurethane foams and plastics. It is shipped and handled as a flammable and explosive liquid in a special container.

What immediate health effects can be caused by exposure to methyl isocyanate?
Methyl isocyanate vapors are severely irritating and corrosive to the respiratory tract and eyes. Symptoms may include cough, chest pain, shortness of breath, watery eyes, eye pain (particularly when exposed to light), profuse lid edema, and corneal ulcerations. Respiratory symptoms such as pulmonary edema and bronchial spasms may occur in immediate response to exposure or develop and progress in severity over a period of hours to days post-exposure. Acute exposure to very high concentrations may be quickly fatal due to respiratory failure. Methyl isocyanate is a skin irritant and may cause chemical burns upon dermal contact.

Can methyl isocyanate poisoning be treated?
There is no antidote for methyl isocyanate, but its effects can be treated. Persons who have inhaled large amounts of methyl isocyanate would most likely need to be hospitalized. Persons who have come into direct skin or eye contact with methyl isocyanate liquid or vapors may need to be treated for chemical burns or serious eye injury.

Are any future health effects likely to occur?
A single exposure from which a person recovers quickly may not result in long-term health effects. However, some respiratory and eye damage may persist for a long time after exposure to methyl isocyanate. The chemical may also be a dermal and respiratory sensitizer, causing reactive responses upon subsequent exposures.

What tests can be done if a person has been exposed to methyl isocyanate?
Specific tests for the presence of methyl isocyanate in blood or urine are not generally useful. If a severe exposure has occurred, blood analyses, x-rays, and breathing tests might show whether the lungs have been injured.

Where can more information about methyl isocyanate be found?
More information about methyl isocyanate can be obtained from your regional poison control center; your state, county, or local health department; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in occupational and environmental health. If the exposure happened at work, you might be required to contact your employer and the Occupational Safety and Health Administration (OSHA), or the National Institute for Occupational Safety and Health (NIOSH). Ask the person who gave you this form for help locating these telephone numbers.

Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow *only* the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:

- eye, nose, throat irritation
- coughing or wheezing
- difficulty breathing or shortness of breath
- chest pain or tightness
- nausea, vomiting, diarrhea, or stomach pain

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.

[ ] Call for an appointment with Dr. _____ in the practice of _____. When you call for your appointment, please say that you were treated in the Emergency Department at _____ Hospital by _____ and were advised to be seen again in _____ days.

[ ] Return to the Emergency Department/ _____ Clinic on (date) _____at _ _____ AM/PM for a follow-up examination.

[ ] Do not perform vigorous physical activities for 1 to 2 days.

[ ] You may resume everyday activities including driving and operating machinery.

[ ] Do not return to work for _____ days.

[ ] You may return to work on a limited basis. See instructions below.

[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.

[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.

[ ] Avoid taking the following medications: _____

[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: __
_____
_____

[ ] Other instructions: _____
_____
_____

- Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.

- You or your physician can get more information on the chemical by contacting: _____ _____ or _____, or by checking out the following Internet Web sites: _____; _____.

Signature of patient _____ Date _____

Signature of physician _____ Date _____

Methyl Mercaptan (CH_3SH)
CAS 74-93-1; UN 1064

Synonyms include methanethiol, mercaptomethane, thiomethanol, methyl sulfhydrate, and thiomethyl alcohol.

- **Persons exposed only to methyl mercaptan pose little risk of secondary contamination to personnel outside the Hot Zone.**
- **Methyl mercaptan is a colorless flammable gas with unpleasant odor described as rotten cabbage. It is easily ignited. When heated to decomposition, it emits highly toxic fumes and flammable vapors. Vapors from liquified methyl mercaptan gas are heavier than air and may collect in low-lying areas. Olfactory fatigue may prevent adequate warning of hazardous concentrations.**
- **Methyl mercaptan is highly irritant when it contacts moist tissues such as the eyes, skin, and upper respiratory tract. It can also induce headache, dizziness, nausea, vomiting, coma, and death. Ingestion of methyl mercaptan is unlikely since it is a gas at ambient temperatures.**

Description

At room temperature (above 43 °F), methyl mercaptan is a colorless gas with an unpleasant odor described as rotten cabbage. It is slightly soluble in water. It is generally shipped as a liquified compressed gas. When heated to decomposition, it emits toxic fumes, such as sulfur dioxide, and flammable vapors. Methyl mercaptan should be stored in cool, well ventilated places. The main toxic effect of exposure to methyl mercaptan is irritation of the respiratory airway, skin, and eyes.

Routes of Exposure

Inhalation

Inhalation is the major route of exposure to methyl mercaptan. An odor threshold of 0.002 ppm has been reported for methyl mercaptan, but olfactory fatigue may occur and thus, it **may not provide adequate warning of hazardous concentrations**. Vapors of liquified methyl mercaptan gas are heavier than air and spread along the ground. Exposure in poorly ventilated, enclosed, or low-lying areas can result in asphyxiation.

Children exposed to the same levels of methyl mercaptan as adults may receive a larger dose because they have a greater lung surface area:body weight ratios and higher minute volume:weight ratios. In addition, they may be exposed to higher levels than adults in the

same location because of their short stature and the higher levels of methyl mercaptan found nearer to the ground.

Skin/Eye Contact Direct contact with liquid methyl mercaptan or the gas may cause frostbite injury or irritation of the eyes and skin.

Ingestion Ingestion is unlikely to occur because methyl mercaptan is a gas at room temperature.

Sources/Uses Methyl mercaptan is produced by the reaction of hydrogen sulfide with methanol. It is used as a gas odorant; an intermediate in the production of pesticides, jet fuels, and plastics; in the synthesis of methionine; and as a catalyst.

Standards and Guidelines

OSHA PEL (permissible exposure limit) = 10 ppm (20 mg/m^3)

NIOSH REL (recommended exposure limit) = 0.5 ppm

NIOSH IDLH (immediately dangerous to life or health) = 150 ppm

AIHA ERPG-2 (maximum airborne concentration below which it is believed that nearly all persons could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action) = 25 ppm.

Physical Properties

Description: Colorless flammable gas at room temperature

Warning properties: Odor does not provide adequate warning of hazard

Molecular weight: 48.1 daltons

Boiling point: (760 mm Hg) = 43 °F (6 °C)

Freezing point: -186 °F (-123 °C)

Specific gravity (liquid): 0.87 at 0 °C

Vapor pressure: 1,520 mm Hg at 26 °C

Gas density: 1.66 (air = 1)

Water solubility: 23.3 g/L at 20 °C

Flammability: flammable limits 3.9% to 21.8% at room temperature

Incompatibilities Methyl mercaptan is incompatible with strong oxidizers, bleaches, copper, aluminum, and nickel-copper alloys.

Health Effects

- **Methyl mercaptan gas is irritating to the eyes, skin, and respiratory tract. Edema of the airway and lungs can occur. Other possible effects include headache, dizziness, tremors, and seizures, and nausea and vomiting, and lack of coordination. The gas is rapidly absorbed in the lungs. Skin and eye absorption are minimal; however, upon direct contact with eyes or skin, liquified methyl mercaptan will likely cause frostbite injury.**
- **Methyl mercaptan is a central nervous system depressant that acts on the respiratory center to produce death by respiratory paralysis.**
- **Individuals with pre-existing respiratory, cardiac, nervous system, or liver impairment may be more susceptible to exposure to methyl mercaptan.**

Acute Exposure

Methyl mercaptan inhibits mitochondrial respiration by interfering with cytochrome c oxidase. It also inhibits several enzyme systems such as carbonic anhydrase, beta-tyrosinase, and sodium+, potassium+ATPase. The enzyme inhibition appears to be related to a thiol-metal interference.

Children do not always respond to chemicals in the same way that adults do. Different protocols for managing their care may be needed.

Respiratory

Acute inhalation exposure can irritate the mucous membranes of the respiratory tract. This may cause cough, dyspnea, a sensation of tightness of the chest, and subsequent cyanosis. Respiratory depression, apnea, and pulmonary edema were observed in animals.

Children may be more vulnerable to gas exposure because of relatively higher minute ventilation per kg and failure to evacuate an area promptly when exposed.

Hematologic

Severe hemolytic anemia may occur in people with glucose-6-phosphate dehydrogenase deficiency.

Neurologic

Restlessness, headache, staggering, and dizziness may develop; severe exposure may lead to convulsions and coma.

Dermal

Frostbite injury can occur from contact with the liquified gas.

Because of their relatively larger surface area:weight ratio, children are more vulnerable to toxicants that may affect the skin.

Ocular/Ophthalmic

High concentrations of methyl mercaptan can cause eye irritation.

Gastrointestinal

Although ingestion is unlikely, irritation of the mouth, throat, and esophagus are possible. Nausea and vomiting may occur even with inhalation exposure to the gas.

Potential Sequelae

Methyl mercaptan exposure may result in altered heme synthesis.

Chronic Exposure

Dermatitis can occur with chronic exposure to methyl mercaptan.

Carcinogenicity

Methyl mercaptan has not been classified for carcinogenic effects.

Reproductive and Developmental Effects

No information is available regarding reproductive or developmental effects of methyl mercaptan in experimental animals or humans. Methyl mercaptan is not included in *Reproductive and Developmental Toxicants*, a 1991 report published by the U.S. General Accounting Office (GAO) that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences.

Prehospital Management

- **Rescue personnel are at low risk of secondary contamination from victims who have been exposed to methyl mercaptan gas. However, rescuers entering areas with potential high concentrations should wear appropriate equipment to avoid self-exposure to methyl mercaptan.**
- **Acute exposure to methyl mercaptan gas causes chest tightness, coughing, and skin and eye irritation. Respiratory impairment and noncardiogenic pulmonary edema may occur. Headache, dizziness, and staggering gait can also occur.**
- **There is no specific antidote for methyl mercaptan poisoning. Treatment is supportive of respiratory and cardiovascular functions.**

Hot Zone

Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if rescuers have not been trained in its use, assistance should be obtained from a local or regional HAZMAT team or other properly equipped response organization. Open flames and other ignition sources should be excluded from areas containing methyl mercaptan gas.

Rescuer Protection

Methyl mercaptan is a central nervous system depressant as well as respiratory-tract and skin irritant. Vapors are well absorbed through the lungs. Skin absorption is minimal.

Respiratory Protection: Positive-pressure, self-contained breathing apparatus (SCBA) is recommended in response situations that involve exposure to potentially unsafe levels of methyl mercaptan.

Skin Protection: Chemical-protective clothing should be worn because contact with the liquified gas can cause skin irritation and frostbite injury.

ABC Reminders

Quickly establish a patent airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible.

Victim Removal

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be removed on backboards or gurneys; if these are not available, carefully carry or drag victims to safety.

Consider appropriate management of chemically contaminated victims, particularly children who may suffer separation anxiety if separated from a parent or other adult.

Decontamination Zone

Victims exposed to methyl mercaptan gas who have no skin or eye irritation do not need decontamination. They may be transferred immediately to the Support Zone. All others require decontamination as described below.

Rescuer Protection

If exposure levels are determined to be safe, decontamination may be conducted by personnel wearing a lower level of protection than that worn in the Hot Zone (described above).

ABC Reminders

Quickly establish a patent airway, ensure adequate respiration and pulse. Stabilize the cervical spine with a collar and a backboard if trauma is suspected. Administer supplemental oxygen as required. Assist ventilation with a bag-valve-mask device if necessary.

Basic Decontamination

Victims who are able may assist with their own decontamination. Remove and double-bag contaminated clothing and personal belongings.

Flush exposed skin and hair with water for 3 to 5 minutes. Wash exposed area thoroughly with soap and water. Use caution to avoid hypothermia when decontaminating victims, partifularly children or the elderly. Use blankets or warmers after decontamination as needed.

Do not irrigate eyes that have sustained frostbite injury. Otherwise, irrigate exposed or irritated eyes with copious amounts of tepid water for at least 15 minutes. Eye irrigation may be carried out simultaneously with other basic care and transport. Remove contact lenses if it can be done without additional trauma to the eye. If pain or injury is evident, continue irrigation while transferring the victim to the support zone.

Consider appropriate management of chemically contaminated children at the exposure site. Provide reassurance to the child during decontamination, especially if separation from a parent occurs.

Transfer to Support Zone

As soon as basic decontamination is complete, move the victim to the Support Zone.

Support Zone

Be certain that victims have been decontaminated properly (see *Decontamination Zone* above). Victims who have undergone decontamination pose no serious risks of secondary contamination to rescuers. In such cases, Support Zone personnel require no specialized protective gear.

ABC Reminders

Quickly establish a patent airway and ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Administer supplemental oxygen as required and establish intravenous access if necessary. Place on a cardiac monitor, if available. Watch for signs of airway swelling and obstruction such as progressive hoarseness, stridor, or cyanosis.

Additional Decontamination

Continue irrigating exposed skin and eyes, as appropriate.

Advanced Treatment

Treat cases of respiratory compromise with respiratory support using protocols and techniques available and within the scope of training. Some cases may necessitate procedures such as endotracheal intubation or cricothyrotomy by properly trained and equipped personnel.

Treat patients who have bronchospasm with an aerosolized bronchodilator such as albuterol.

Treat seizures with a benzodiazepine such as diazepam. Severe hypertension may be treated according to local protocols, although nitro prusside may be the best choice for treating methyl mercaptan-induced hypertension.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution, repeat every 20 minutes as needed.

Patients who are comatose, hypotensive, or having seizures or who have cardiac arrhythmias should be treated according to advanced life support (ALS) protocols.

If frostbite is present, treat by rewarming in a water bath at a temperature of 104–108 °F (40–42 °C) for 20 to 30 minutes and continue until a flush has returned to the affected area.

Transport to Medical Facility

Only decontaminated patients or those not requiring decontamination should be transported to a medical facility. "Body bags" are not recommended.

Report to the base station and the receiving medical facility the condition of the patient, treatment given, and estimated time of arrival at the medical facility.

Multi-Casualty Triage

Consult with the base station physician or the regional poison control center for advice regarding triage of multiple victims.

Patients with evidence of significant exposure (e.g., severe or persistent cough, dyspnea or chemical burns) should be transported to a medical facility for evaluation. Patients who have minor or transient irritation of the eyes or throat may be discharged from the scene after their names, addresses, and telephone numbers are recorded. They should be advised to seek medical care promptly if symptoms develop or recur (see *Patient Information Sheet* below).

Emergency Department Management

- **Hospital personnel are at minimal risk of secondary contamination from patients who have been exposed to methyl mercaptan. However, hospital personnel in an enclosed area can be secondarily contaminated by vapors off-gassing from heavily contaminated clothing or skin.**
- **Acute exposure to methyl mercaptan causes coughing, eye and nose irritation, lacrimation, and a burning sensation in the chest; noncardiogenic pulmonary edema may occur. Headache, dizziness, and staggering gait can also occur.**
- **Methyl mercaptan irritates the skin and eyes and can cause burning pain and blisters. Exposure to liquefied methyl mercaptan can result in frostbite.**
- **There is no specific antidote for methyl mercaptan poisoning. Treatment consists of support of respiratory and cardiovascular functions.**

Decontamination Area

Unless previously decontaminated, all patients with skin or eye irritation require decontamination as described below.

Be aware that use of protective equipment by the provider may cause anxiety, particularly in children, resulting in decreased compliance with further management efforts.

ABC Reminders

Evaluate and support airway, breathing, and circulation. Treat cases of respiratory compromise with respiratory support using protocols and techniques available and within the scope of training. Some cases may necessitate procedures such as endotracheal intubation or cricothyrotomy by properly trained and equipped personnel.

Treat patients who have bronchospasm with an aerosolized bronchodilator such as albuterol.

Treat seizures with a benzodiazepine such as diazepam Severe hypertension may be treated according to local protocols, although nitro prusside may be the best choice for treating methyl mercaptan-induced hypertension.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution, repeat every 20 minutes as needed.

Patients who are comatose, hypotensive, or having seizures or cardiac arrhythmias should be treated in the conventional manner.

Basic Decontamination

Patients who are able may assist with their own decontamination. Remove and double bag contaminated clothing and personal belongings.

If skin and eye contact with liquified methyl mercaptan occurred, handle frostbite with caution. Place frostbitten skin in warm water, 104–108 °F (40–42 °C). If warm water is not available, wrap the affected part gently in blankets. Let the circulation reestablish itself naturally. Encourage the victim to exercise the affected part while it is being warmed.

Flush exposed skin and hair with plain water for no less than 15 minutes. Wash exposed area thoroughly with soap and water. Use caution to avoid hypothermia when decontaminating victims, particularly children or the elderly. Use blankets or warmers after decontamination as needed.

Do not irrigate frostbitten eyes. Eye irritation that does not involve frostbite should be irrigated conventionally. Remove contact lenses if it can be done without additional trauma to the eye. Continue irrigation while transporting the patient to the Critical Care Area.

Critical Care Area

Be certain that appropriate decontamination has been carried out.

ABC Reminders

Evaluate and support airway, breathing, and circulation as in ABC Reminders above under *Decontamination Zone*. Establish intravenous access in seriously ill patients if this has not been done previously. Continuously monitor cardiac rhythm, if appropriate.

Patients who are comatose, hypotensive, or having seizures or cardiac arrhythmias should be treated in the conventional manner.

Inhalation Exposure

Administer supplemental oxygen by mask to patients who have respiratory symptoms. Treat patients who have bronchospasm with an aerosolized bronchodilator such as albuterol.

Treat seizures with a benzodiazepine such as diazepam. Severe hypertension may be treated according to local protocols, although nitro prusside may be the best choice for treating methyl mercaptan-induced hypertension.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution, repeat every 20 minutes as needed.

If pulmonary edema develops, maintain ventilation and oxygenation and evaluate with frequent arterial blood gas or pulse oximetry monitoring. Early use of PEEP and mechanical ventilation may be needed. Prophylactic antibiotic therapy may reduce the chances of respiratory infection.

Skin Exposure

If the skin was in contact with methyl mercaptan, thermal burns may occur. Treat thermal burns by assuring that affected area is cool by flushing with cool water, then apply dry sterile dressings.

If the liquefied methyl mercaptan gas contacts the skin, frostbite may result. If a victim has frostbite, treat by rewarming affected areas in a water bath at a temperature of 104–108 °F (40–42 °C) for 20 to 30 minutes and continue until a flush has returned to the affected area.

Eye Exposure

Exposed eyes should be irrigated for at least 15 minutes. Test visual acuity and examine the eyes for corneal damage and treat appropriately. Immediately consult an ophthalmologist for patients who have corneal injuries.

Antidotes and Other Treatments

There is no specific antidote for methyl mercaptan. Treatment is supportive.

Laboratory Tests

The diagnosis of acute methyl mercaptan toxicity is primarily clinical, based on respiratory difficulties and irritation. However, laboratory testing is useful for monitoring the patient and evaluating complications. Routine laboratory studies for all exposed patients include CBC, glucose, and electrolyte determinations. Patients who have respiratory complaints require pulse oximetry (or ABG measurements) and chest radiography. Massive inhalation may be complicated by hyperchloremic metabolic acidosis; in addition to electrolytes, monitor blood pH.

Disposition and Follow-up

Consider hospitalizing patients who have a suspected significant exposure or have eye burns or serious skin burns.

Delayed Effects

Symptomatic patients complaining of persistent shortness of breath, severe cough, or chest tightness should be admitted to the hospital

and observed until symptom-free. Pulmonary injury may progress for several hours.

Patient Release

Asymptomatic patients and those who experienced only minor sensations of burning of the nose, throat, eyes, and respiratory tract (with perhaps a slight cough) may be released. In most cases, these patients will be free of symptoms in an hour or less. They should be advised to seek medical care promptly if symptoms develop or recur (see the *Methyl Mercaptan—Patient Information Sheet* below).

Follow-up

Obtain the name of the patient's primary care physician so that the hospital can send a copy of the ED visit to the patient's doctor.

Follow up is recommended for all hospitalized patients because long-term respiratory problems can result. Respiratory monitoring is recommended until the patient is symptom-free.

Patients who have skin or corneal injury should be re-examined within 24 hours. Anyone who had significant dermal exposure should be followed for several months.

Reporting

If a work-related incident has occurred, you may be legally required to file a report; contact your state or local health department.

Other persons may still be at risk in the setting where this incident occurred. If the incident occurred in the workplace, discussing it with company personnel may prevent future incidents. If a public health risk exists, notify your state or local health department or other responsible public agency. When appropriate, inform patients that they may request an evaluation of their workplace from OSHA or NIOSH. See Appendix III for a list of agencies that may be of assistance.

Methyl Mercaptan
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to methyl mercaptan.

What is methyl mercaptan?
Methyl mercaptan is a flammable colorless gas with unpleasant odor described as rotten cabbage. It is used as a gas odorant; an intermediate in the production of pesticides, jet fuels, and plastics; and in the synthesis of the amino acid methionine. Because methyl mercaptan is a gas a ambient temperature, the most likely exposure routes are inhalation and dermal.

What immediate health effects can be caused by exposure to methyl mercaptan?
Exposure to methyl mercaptan may cause immediate irritation of the eyes, nose, and throat, and shortness of breath, as well as coughing, wheezing, shortness of breath, and tearing of the eyes. Exposure to methyl mercaptan can also cause nausea and vomiting and dizziness, headache, and lack of coordination. Generally, the more serious the exposure, the more severe the symptoms.

Can methyl mercaptan poisoning be treated?
There is no antidote for methyl mercaptan, but its effects can be treated and most exposed persons get well. Persons who have experienced serious symptoms may need to be hospitalized.

Are any future health effects likely to occur?
A single small exposure from which a person recovers quickly is not likely to cause delayed or long-term effects. After a serious exposure, symptoms may worsen for several hours and respiratory effects may persist for hours or days following exposure.

What tests can be done if a person has been exposed to methyl mercaptan?
Methyl mercaptan is normally present in human blood and urine. Detection of abnormally high levels of methyl mercaptan in the blood may be an indication of recent exposure. However, blood tests do not indicate the extent or time of exposure. Specific tests for the presence of methyl mercaptan in the blood or urine are, therefore, not generally useful to the doctor. If a severe exposure has occurred, blood and urine analyses and other tests may show whether the upper respiratory airways and lungs or brain have been injured. Testing is not needed in every case.

Where can more information about methyl mercaptan be found?
More information about methyl mercaptan can be obtained from your regional poison control center, your state, county, or local health department; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in occupational and environmental health. If the exposure happened at work, you may wish to discuss it with your employer, the Occupational Safety and Health Administration (OSHA), or the National Institute for Occupational Safety and Health (NIOSH). Ask the person who gave you this form for help in locating these telephone numbers.

Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow *only* the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:

- coughing or wheezing
- difficulty breathing, shortness of breath, or chest pain
- increased pain or a discharge from injured eyes
- increased redness or pain or a pus-like discharge in the area of a skin burn
- headache, dizziness, or lack of coordination

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.

[ ] Call for an appointment with Dr. _____ in the practice of _____. When you call for your appointment, please say that you were treated in the Emergency Department at _____ Hospital by _____ and were advised to be seen again in _____ days.

[ ] Return to the Emergency Department/ _____ Clinic on (date) _____ at _____ AM/PM for a follow-up examination.

[ ] Do not perform vigorous physical activities for 1 to 2 days.

[ ] You may resume everyday activities including driving and operating machinery.

[ ] Do not return to work for _____ days.

[ ] You may return to work on a limited basis. See instructions below.

[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.

[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.

[ ] Avoid taking the following medications: _____

[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: _____
_____
_____

[ ] Other instructions: _____
_____
_____

- Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.

- You or your physician can get more information on the chemical by contacting: _____ _____ or _____, or by checking out the following Internet Web sites: _____; _____.

Signature of patient _____ Date _____

Signature of physician _____ Date _____

Nerve Agents
Tabun (GA) CAS 77-81-6; Sarin (GB) CAS 107-44-8; Soman (GD) CAS 96-64-0; and VX CAS 5078269-9

Synonyms:

GA: ethyl dimethylamidocyanophosphate; ethyl N,N-dimethylphosphoramidocyanidate; ethyl dimethyl-phosphoramidocyanidate; dimethylaminoethoxy-cyanophosphine oxide; dimethyl-amidoethoxy-phosphoryl cyanide; EA1205; dimethylphosphoramidocyanidic acid ethyl ester

GB: isopropyl methylphosphonofluoridate; isopropoxymethylphosphoryl fluoride; trilone; MFI; TL1 618; isopropylmethanefluorophosphonate; T144; T2106; fluoro(isopropoxy)methylphosphine oxide; methylisopropoxyfluorophosphine oxide; zarin

GD: pinacolyl methylphosphonofluoridate; 1,2,2-trimethylpropyl methylphosphonofluoridate; methyl-pinacolyloxyfluorophosphine oxide; pinacolyloxymethylphosphonyl fluoride; pinacolylmethyl-fluorophosphonate; 1,2,2-trimethylpropoxyfluoro(methyl)phosphine oxide; pinacolyl methyl-phosphonyl fluoride

VX: O-ethyl S-(2-diisopropylaminoethyl) methylphosphonothiolate; methylphosphonothioic acid; S-2-(diisopropylamino)ethyl O-ethyl methylphosphonothioate; O-ethyl S-(2-diisopropyl-aminoethyl)methylphosphonothioate; O-ethyl S-(2-diisopropoylaminoethyl) methylthiol-phosphonoate; O-ethyl S-diisopropylaminoethyl methylphosphonothiolate

- **Persons whose skin or clothing is contaminated with nerve agent can contaminate rescuers by direct contact or through off-gassing vapor. Persons whose skin is exposed only to nerve agent vapor pose no risk of secondary contamination; however, clothing can trap vapor.**
- **G-type nerve agents (GA, GB, and GD) are clear, colorless liquids that are volatile at ambient temperatures. VX is an amber-colored, oily liquid with low volatility unless temperatures are high.**
- **Nerve agents are readily absorbed by inhalation, ingestion, and dermal contact. Rapidly fatal systemic effects may occur.**

Description

Nerve agents are the most toxic of the known chemical warfare agents. **They are chemically similar to organophosphate pesticides and exert their biological effects by inhibiting acetylcholinesterase enzymes.** G-type agents are clear,

colorless, and tasteless liquids that are miscible in water and most organic solvents. GB is odorless and is the most volatile nerve agent; however, it evaporates at about the same rate as water. GA has a slightly fruity odor, and GD has a slight camphor-like odor. VX is a clear, amber-colored, odorless, oily liquid. It is miscible with water and soluble in all solvents. It is the least volatile nerve agent. Table 1 lists selected physical properties for each of the nerve agents.

Routes of Exposure

Inhalation

Nerve agents are readily absorbed from the respiratory tract. Rhinorrhea and tightness in the throat or chest begin within seconds to minutes after exposure. Nerve agent vapors are heavier than air. Odor does not provide adequate warning of detection. The estimated LCt_{50} (the product of concentration times time that is lethal to 50% of the exposed population by inhalation) ranges from 10 mg-min/m^3 for VX to 400 mg-min/m^3 for GA.

Skin/Eye Contact

Nerve agent liquids are readily absorbed from the skin and eyes. Vapors are not absorbed through the skin except at very high concentrations. Ocular effects may result from both direct contact and systemic absorption. The nature and timing of symptoms following dermal contact with liquid nerve agents depend on exposure dose; effects may be delayed for several hours. As little as one drop of VX on the skin can be fatal and 1 to 10 mL of GA, GB, or GD can be fatal.

Ingestion

Ingestion of nerve agents is expected to be relatively rare compared to inhalation exposure or skin contact; however, they are readily absorbed from the GI tract and are highly toxic.

Sources/Uses

Most of the nerve agents were originally synthesized in a search for insecticides, but because of their toxicity, they were evaluated for military use. GA was synthesized in 1936 by a German scientist who synthesized GB 2 years later. During World War II, Germany developed chemical weapons using both GA and GB but never used them. GD was synthesized in 1944 by a German chemist, and VX was synthesized in the early 1950s by a British scientist. Although related organophosphate chemicals are used in medicine, pharmacology, and agriculture, these are not as toxic as the nerve agents. Nerve agents were used by Iraq against Iran and have been used by terrorists. They are known to be included in military stockpiles of several nations, including the United States.

Standards and

Guidelines Workplace time-weighted average: GA and GB, 0.0001 mg/m^3; GD, 0.00003 mg/m^3; VX, 0.00001 mg/m^3

General population limits: 0.000003 mg/m^3 (all) over an 8-hour workshift)

Physical Properties

Table 1. Physical Properties of Nerve Agents

Property	Nerve Agent			
	Tabun (GA)	**Sarin (GB)**	**Soman (GD)**	**VX**
Description	clear, colorless, and tasteless liquid	clear, colorless, tasteless, and odorless liquid	pure liquid is clear, colorless, and tasteless; discolors with aging to dark brown	amber colored, tasteless, and odorless oily liquid
Warning properties	Although GA has a slight fruit odor, this cannot be relied on to provide sufficient warning against toxic exposure	none	Although GD has a slight fruity or camphor odor, this cannot be relied on to provide sufficient warning against toxic exposure.	none
Molecular weight	162.3 daltons	140.1 daltons	182.2 daltons	267.4 daltons
Boiling point	(760 mm Hg) = 428 to 475 °F) (220 to 246 °C)	(760 mm Hg) = 316 °F (158 °C)	(760 mm Hg) = 332.6 to 392 °F (167 to 200 °C)	(760 mm Hg) = 568.4 °F (298 °C)
Freezing point	-58 °F (-50 °C)	-68.8 °F (-56 °C)	-43.6 °F (-42 °C)	-59.8 °F (-51 °C)
Specific gravity	1.073 g/mL (water = 1.0)	1.089 (water = 1.0)	1.022 (water = 1.0)	1.008 (water = 1.0)
Vapor pressure	0.037 mm Hg at 68 °F (20 °C); 0.057 mm Hg at 77 °F (25 °C)	2.1 mm Hg at 68 °F (20 °C); 2.9 mm Hg at 77 °F (25 °C)	0.4 mm Hg at 77 °F (25 °C)	0.0007 mm Hg at 77 °F (25 °C)
Vapor density	5.6 (air = 1.0)	4.9 (air = 1.0)	6.33 (air = 1.0)	9.2 (air = 1.0)
Liquid density	1.08 g/mL at 77 °F (25 °C)	1.10 g/mL at 68 °F (20 °C)	1.02 g/mL at 77 °F (25 °C)	1.008 g/mL at 68 °F (20 °C)
Flash point	172.4 °F (78 °C)	nonflammable	249.8 °F (121 °C)	318.2 °F (159 °C)
Solubility in water	9.8 g/100 g at 77 °F (25 °C)	miscible	2.1 g/100g at 68 °F (20 °C)	3 g/100 g (miscible below 48.9 °F [9.4 °C])
Volatility	490 mg/m^3 at 77 °F (25 °C)	22,000 mg/m^3 at 77 °F (25 °C)	3,900 mg/m^3 at 77 °F (25 °C)	10.5 mg/m^3 at 77 °F (25 °C)
NAERG#	153	153	153	153

Incompatibilities

Decomposition of GA may produce HCN, oxides of nitrogen, oxides of phosphorus, carbon monoxide, and hydrogen cyanide. Under acid conditions GB and GD hydrolyze to form HF. GB decomposes tin, magnesium, cadmium plated steel, and aluminum. Hydrolysis of VX produces a class B poison.

Health Effects

Manifestations of nerve agent exposure include rhinorrhea, chest tightness, pinpoint pupils, shortness of breath, excessive salivation and sweating, nausea, vomiting, abdominal cramps, involuntary defecation and urination, muscle twitching, confusion, seizures, flaccid paralysis, coma, respiratory failure, and death.

- **Nerve agents are potent acetylcholinesterase inhibitors causing the same signs and symptoms regardless of the exposure route. However, the initial effects depend on the dose and route of exposure.**

Acute Exposure

Nerve agents alter cholinergic synaptic transmission at neuroeffector junctions (muscarinic effects), at skeletal myoneural junctions and autonomic ganglia (nicotinic effects), and in the CNS. Initial symptoms depend on the dose and route of exposure.

Muscarinic effects include pinpoint pupils; blurred or dim vision; conjunctivitis; eye and head pain; hypersecretion by salivary, lacrimal, sweat, and bronchial glands; narrowing of the bronchi; nausea, vomiting, diarrhea, and crampy abdominal pains; urinary and fecal incontinence; and slow heart rate.

Nicotinic effects include skeletal muscle twitching, cramping, and weakness. Nicotinic stimulation can obscure certain muscarinic effects and produce rapid heart rate and high blood pressure.

Relatively small to moderate vapor exposure causes pinpoint pupils, rhinorrhea, bronchoconstriction, excessive bronchial secretions, and slight to moderate dyspnea. Mild to moderate dermal exposure results in sweating and muscular fasciculations at the site of contact, nausea, vomiting, diarrhea, and weakness. The onset of these mild to moderate signs and symptoms following dermal exposure may be delayed for as long as 18 hours. Higher exposures (any route) cause loss of consciousness, seizures, muscle fasciculations, flaccid paralysis, copious secretions, apnea, and death.

Children do not always respond to chemicals in the same way that adults do. Different protocols for managing their care may be needed.

CNS

Nerve agents cause behavioral and psychological changes in humans. CNS effects include irritability, nervousness, fatigue, insomnia, memory loss, impaired judgment, slurred speech, and depression. High exposures may produce loss of consciousness, seizures, and apnea.

Respiratory

Inhalation of nerve agent vapors causes respiratory tract effects within seconds to minutes. Symptoms include excessive rhinorrhea and bronchial secretions, chest tightness, and difficulty breathing due to constriction of bronchial muscles and mucous secretions. Respiratory failure may occur due to CNS depression.

Cardiovascular

Vagal stimulation may produce bradycardia, but pulse rate may be increased due to ganglionic stimulation, and the effects of hypoxia. Bradyarrhythmias and hypertension may occur.

Gastrointestinal

Abdominal pain, nausea and vomiting are common manifestations of exposure by any route but may be the first systemic effects from liquid exposure on skin. If these symptoms occur within an hour of dermal exposure, severe intoxication is indicated. Diarrhea and fecal incontinence may also occur.

Skeletal muscles

Nerve agents stimulate skeletal muscle producing fasciculations and twitching leading to fatigue and flaccid paralysis. Muscle twitching/fasciculations are clinical identifiers that indicate possible nerve agent exposure.

Metabolic

Profuse sweating may occur.

Ocular

Symptoms may occur from local effects of vapor exposure and from systemic absorption. Pinpoint pupils and spasm of the muscle of visual accommodation (i.e., ciliary muscle) leading to blurred and dim vision, aching pain in the eye, and conjunctivitis are typical effects.

Potential Sequelae

CNS effects such as fatigue, irritability, nervousness and impairment of memory may persist for as long as 6 weeks after recovery from acute effects. Although exposure to some organophosphate compounds may cause a delayed mixed sensory-motor peripheral neuropathy, there are no reports of this condition among humans exposed to nerve agents.

Chronic Exposure

Very little information is available regarding prolonged exposures to low levels of nerve agents.

Carcinogenicity

No information is available regarding the potential carcinogenicity of nerve agents in humans. Limited animal data indicate that nerve agents are not likely to be carcinogenic.

Reproductive and

Developmental Effects The limited data available indicate that nerve agents are not reproductive or developmental toxicants.

Prehospital Management

Victims whose skin or clothing is contaminated with liquid nerve agent can contaminate rescuers by direct contact or through off-gassing vapor.

Nerve agents are extremely toxic and can cause loss of consciousness and convulsions within seconds and death from respiratory failure within minutes of exposure.

Atropine and pralidoxime chloride (2-PAM Cl) are antidotes for nerve agent toxicity; however, pralidoxime must be administered within minutes to a few hours following exposure (depending on the specific agent) to be effective. Treatment consists of supportive measures and repeated administration of antidotes.

Hot Zone

Responders should be trained and appropriately attired before entering the Hot Zone. If the proper personal protective equipment (PPE) is not available, or if the rescuers have not been trained in its use, call for assistance in accordance with local Emergency Operational Guides (EOG). Sources of such assistance include local HAZMAT teams, mutual aid partners, the closest metropolitan strike system (MMRS) and the U.S. Soldier and Biological Chemical Command (SBCCOM)-Edgewood Research Development and Engineering Center. SBCCOM may be contacted (from 0700-1630 EST call 410-671-4411 and from 1630-0700 EST call 410-278-5201), ask for the Staff Duty Officer.

Rescuer Protection

Nerve agent vapor is readily absorbed by inhalation and ocular contact and produces rapid local and systemic effects. The liquid is readily absorbed thorough the skin; however, effects may be delayed for several minutes to up to18 hours.

Respiratory protection: Pressure-demand, self-contained breathing apparatus (SCBA) is recommended in response situations that involve exposure to any nerve agent vapor or liquid.

Skin protection: Chemical-protective clothing and butyl rubber gloves are recommended when skin contact is possible because nerve agent liquid is rapidly absorbed through the skin and may cause systemic toxicity.

ABC Reminders

Chemical casualty triage is based on walking feasibility, respiratory status, age, and additional conventional injuries. The triage officer must know the natural course of a given injury, the medical resources immediately available, the current and likely

casualty flow, and the medical evacuation capabilities. General principles of triage for chemical exposures are presented in the box on the following page. There are four triage categories: immediate (priority 1), delayed (priority 2), minimal (priority 3), and expectant (priority 4). Clinical signs and effects of nerve agents associated with each of these categories are presented in Table 2.

Before transport, all casualties must be decontaminated. If needed, consult with the base station physician or the regional poison control center for advice concerning management of multiple casualties.

General principles of triage for chemical exposures

(1) Check triage tag/card for any previous treatment or triage.
(2) Survey for evidence of associated traumatic/blast injuries.
(3) Observe for sweating, labored breathing, coughing/vomiting, secretions.
(4) Severe casualty triaged as immediate if assisted breathing is required.
(5) Blast injuries or other trauma, where there is question whether there is chemical exposure, victims must be tagged as immediate in most cases. Blast victims evidence delayed effects such as ARDS, etc.
(6) Mild/moderate casualty: self/buddy aid, triaged as delayed or minimal and release is based on strict follow up and instructions.
(7) If there are chemical exposure situations which may cause delayed but serious signs and symptoms, then overtriage is considered appropriate to the proper facilities that can observe and manage any delayed onset symptoms.
(8) Expectant categories in multi-casualty events are those victims who have experienced a cardiac arrest, respiratory arrest, or continued seizures immediately. Resources should not be expended on these casualties if there are large numbers of casualties requiring care and transport with minimal or scant resources available.

1. *Immediate:* casualties who require lifesaving care within a short time, when that care is available and of short duration. This care may be a procedure that can be done within minutes at an emergency treatment station (e.g., relief of an airway obstruction, administering antidotes) or may be acute lifesaving surgery.

2. *Delayed:* casualties with severe injuries who are in need of major or prolonged surgery or other care and who will require hospitalization, but delay of this care will not adversely affect the outcome of the injury (e.g., fixation of a stable fracture).

3. *Minimal:* casualties who have minor injuries, can be helped by nonphysician medical personnel, and will not require hospitalization.

4. *Expectant:* casualties with severe life-threatening injuries who would not survive with optimal medical care, or casualties whose injuries are so severe that their chance of survival does not justify expenditure of limited resources. As circumstances permit, casualties in this category may be reexamined and possibly be retriaged to a higher category.

Table 2. Triage for Nerve Agent Casualties

Category (Priority)	Effects	Clinical Signs
Immediate (1)	Unconscious, talking but not walking, or moderate to severe effects in two or more systems (e.g., respiratory, GI, muscular, CNS)	Seizing or post-ictal, severe respiratory distress or apneic. Recent cardiac arrest.
Delayed (2)	Recovering from agent exposure or antidote	Diminished secretions, improving respiration.
Minimal (3)	Walking and talking	Miosis, rhinorrhea, mild to moderate dyspnea.
Expectant (4)	Unconscious	Cardiac/respiratory arrest of long duration.

ABC Reminders

Quickly ensure that the victim has a patent airway. Maintain adequate circulation. If trauma is suspected, maintain cervical immobilization manually and apply a decontaminable cervical collar and a backboard when feasible. Apply direct pressure to stop arterial bleeding, if present.

Antidotes

Administration of antidotes is a critical step in managing a nerve agent victim; however, this may be difficult to achieve in the Hot Zone, because the antidotes may not be readily available, and procedures or policies for their administration while in the Hot Zone may be lacking. If the military Mark I kits containing autoinjectors are available, they provide the best way to administer the antidotes. One autoinjector automatically delivers 2 mg atropine and the other automatically delivers 600 mg 2-PAM Cl. Otherwise, administer antidotes as described in Table 3.

Victim Removal

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Dependant upon available resources, triage of remaining victims should be performed. Victims who are unable to walk may be removed on backboards or gurneys. If these are not available, carefully carry or drag victims to safety. Should there be a large number of casualties, and if decontamination resources permit, separate decontamination corridors should be established for ambulatory and non-ambulatory victims.

Table 3. Recommendations for Nerve Agent Therapy -- Prehospital Management.

Patient Age	Antidotes[1]		Other Treatment
	Mild/Moderate Symptoms[2]	Severe Symptoms[3]	
Infant (0 - 2 yrs)	Atropine: 0.05 mg/kg IM; 2-PAM Cl: 15 mg/kg IM	Atropine: 0.1 mg/kg IM; 2-PAM Cl: 25 mg/kg IM	**Assisted ventilation** should be started after administration of antidotes for severe exposures. **Repeat atropine (2 mg IM)** at 5 - 10 minute intervals until secretions have diminished and breathing is comfortable or airway resistence has returned to near normal.
Child (2 - 10 yrs)	Atropine: 1 mg IM; 2-PAM Cl: 15 mg/kg IM	Atropine: 2 mg IM; 2-PAM Cl: 25 mg/kg IM	
Adolescent (>10 yrs)	Atropine: 2 mg IM; 2-PAM Cl: 15 mg/kg IM	Atropine: 4 mg IM; 2-PAM Cl: 25 mg/kg IM	
Adult	Atropine: 2 to 4 mg IM; 2-PAM Cl: 600 mg IM	Atropine: 6 mg IM; 2-PAM Cl: 1800 mg IM	
Elderly, frail	Atropine: 1 mg IM; 2-PAM Cl: 10 mg/kg IM	Atropine: 2 to 4 mg IM; 2-PAM Cl: 25 mg/kg IM	

1. **2-PAMCl solution needs to be prepared** from the ampule containing 1 gram of desiccated 2-PAMCl: **inject** 3 ml of saline, 5% distilled or sterile water into ampule and shake well. Resulting solution is 3.3 ml of 300 mg/ml.
2. **Mild/Moderate symptoms** include localized sweating, muscle fasciculations, nausea, vomiting, weakness, dyspnea.
3. **Severe symptoms** include unconsciousness, convulsions, apnea, flaccid paralysis.

Decontamination Zone

Rapid decontamination is critical to prevent further absorption by the patient and to prevent exposure to others. Decontaminable gurneys and back boards should be used if possible when managing casualties in a contaminated area. Decontaminable gurneys are made of a monofilament polypropylene fabric that allows drainage of liquids, does not absorb chemical agents, and is easily decontaminated. Fiberglass back boards have been developed specifically for use in HAZMAT incidents. These are nonpermeable and readily decontaminated. The **Chemical Resuscitation Device** is a bag-valve mask equipped with a chemical agent cannister that can be used to ventilate casualties in a contaminated environment.

Rescuer Protection

Personnel should continue to wear the same level of protection as required in the Hot Zone (see *Rescuer Protection* under Hot Zone, above).

ABC Reminders

Quickly ensure that the victim has a patent airway. Maintain adequate circulation. Stabilize the cervical spine with a decontaminable collar and a backboard if trauma is suspected. Antidote administration may be required to allow ventilation. Suction oral and bronchial secretions. Administer supplemental oxygen if cardiopulmonary compromise is suspected. Assist ventilation with a bag-valve-mask device equipped with a cannister or air filter if necessary. Direct pressure should be applied to control heavy bleeding, if present.

Antidotes

Administer antidotes if they have not been administered. If possible, a system should be employed to track antidotes administered. If atropine was previously administered and signs and symptoms have not diminished within 5 to 10 minutes, give a second dose of atropine (2 mg for adults or 0.05 to 0.1 mg/kg for children) (see *Antidotes* under *Hot Zone*, Table 3).

Basic Decontamination

The eyes must be decontaminated within minutes of exposure to liquid nerve agent to limit injury. Flush the eyes immediately with water for about 5 to 10 minutes by tilting the head to the side, pulling eyelids apart with fingers, and pouring water slowly into eyes. There is no need to flush the eyes following exposure to nerve agent vapor. Do not cover eyes with bandages.

If exposure to liquid agent is suspected, cut and remove all clothing and wash skin immediately with soap and water. If shower areas are available, a thorough shower with soap and water should be used. However, if water supplies are limited, and showers are not available, an alternative form of decontamination is to use 0.5% sodium hypochlorite solution, or absorbent powders such as flour, talcum powder, or Fuller's earth If exposure to vapor only is certain, remove outer clothing and wash exposed skin with soap and water or 0.5% sodium hypochlorite. Place contaminated clothes and personal belongings in a sealed double bag.

In cases of ingestion, **do not induce emesis**. If the victim is alert and able to swallow, immediately administer a slurry of activated charcoal.

Transfer to Support Zone

As soon as basic decontamination is complete, move the victim to the Support Zone.

Support Zone

All victims must be decontaminated properly before entering the Support Zone (see *Decontamination Zone*, above).

ABC Reminders

Quickly ensure that the victim has a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Ensure adequate respiration; administer supplemental oxygen if cardiopulmonary compromise is suspected. **In a severely exposed casualty (unconscious, gasping, or not breathing), the antidotes will be required to allow ventilation**. Suction oral and bronchial secretions. Maintain adequate circulation. Establish intravenous access if necessary. Attach a cardiac monitor, as needed. Direct pressure should be applied to stop bleeding, if present.

Antidotes

Administer antidotes if they have not been administered (see *Antidotes* under *Hot Zone*, Table 3). Administer atropine (2 mg for adults and 0.05 to 0.1 mg/kg for children) every 5 to 10 minutes until dyspnea, resistence to ventilation, and secretions are minimized.

Additional Decontamination

In cases of ingestion, **do not induce emesis**. If the victim is alert and able to swallow, immediately administer a slurry of activated charcoal if not given previously.

Advanced Treatment

Intubate the trachea in cases of coma or respiratory compromise, or to facilitate removal of excessive pulmonary secretions. When the patient's condition precludes endotracheal intubation, perform cricothyrotomy if equipped and trained to do so. Frequent suctioning of the airways will be necessary to remove mucous secretions.
When possible, atropine and 2-PAM Cl should be given under medical supervision to symptomatic patients who have known or strongly suspected nerve agent toxicity (see *Antidote* sections, above).

Patients who are comatose, hypotensive, or seizing or have cardiac dysrhythmias should be treated according to advanced life support (ALS) protocols. Diazepam (5 to 10 mg in adults and 0.2 to 0.5 mg/kg in children) should be used to control convulsions. Lorazepam or other benzodiazepines may be used but barbiturates, phenytoin, and other anticonvulsants are not effective.

Transport to Medical Facility

Report to the base station and the receiving medical facility the condition of the patient, treatment given, and estimated time of arrival at the medical facility.

Emergency Department Management

Patients whose skin or clothing is contaminated with liquid nerve agent can contaminate rescuers by direct contact or through off-gassing vapor.

Nerve agents are extremely toxic and can cause death within minutes to hours after exposure from respiratory failure.

Atropine and pralidoxime (2-PAM Cl) are antidotes for nerve agent toxicity; however, pralidoxime must be administered within minutes to a few hours following exposure (depending on the specific agent) to be effective. Treatment consists of supportive measures and repeated administration of antidotes.

Decontamination Area

Previously decontaminated patients may be treated or held for observation. Others require decontamination as described below.

ABC Reminders

Evaluate and support the airway, breathing, and circulation. If the patient is apneic, give antidotes immediately (see *Antidote* section below). Intubate the trachea in cases of respiratory compromise. Suctioning may be required for excessive bronchial secretions. If the patient's condition precludes intubation, surgically create an airway. Antidote administration may be required to allow ventilation.

Personal Protection

If contaminated patients arrive at the Emergency Department, they must be decontaminated before being allowed to enter the facility. Decontamination can only take place inside the hospital if there is a decontamination facility with negative air pressure and floor drains to contain contamination. Personnel should wear the same level of protection required in the Hot Zone (see *Rescuer Protection* under *Hot Zone*, above).

Basic Decontamination

Patients who are able and cooperative may assist with their own decontamination. Remove and double bag contaminated clothing and all personal belongings.

For patients exposed to nerve agent vapor only, remove outer clothing and wash exposed areas including the head and hair with soap and water. For patients exposed to liquid agent, remove all clothing and wash entire body and hair with soap and water or 0.5% hypochlorite followed by a water rinse.

Irrigate exposed eyes with plain water or saline for about 5 to 10 minutes (see Basic Decontamination under Decontamination Zone, above). Remove contact lenses if present and easily removable without additional trauma to the eye.

In cases of ingestion, **do not induce emesis**. If the patient is able to swallow, immediately administer a slurry of activated charcoal if not given previously. (More information is provided in *Ingestion Exposure* above.)

Treatment Area

All patients should undergo decontamination before entering the treatment area (see *Decontamination Area*, above).

ABC Reminders

Evaluate and support the airway, breathing, and circulation (as in *ABC Reminders*, above). Establish intravenous access in seriously ill patients. Continuously monitor cardiac rhythm.

Triage

Patients who are conscious and have full muscular control will need minimal care. Patients who may have been exposed to liquid must be kept under observation for at least 18 hours.

Patients with a history of possible exposure to vapor only (with no possibility of liquid exposure) who have no signs of exposure by the time they reach the medical facility have not been exposed (because these effects occur within seconds to minutes after exposure). They can be discharged.

Antidotes and Other Treatments

Patients exposed to vapor who have miosis and rhinorrhea will need no care unless (a) they have eye or head pain or nausea and vomiting; under these circumstances topical atropine or homatropine in the eye should relieve the symptoms and the patient can be discharged within an hour or so; or (b) the rhinorrhea is very severe; under these circumstances, atropine IM (2 mg in adults and 0.05 mg/kg in children) should relieve this and the patient can be discharged in an hour or so. Topical atropine and homatropine should not be used routinely for miosis because they cause visual impairment for about 24 hours. See Table 4 for other antidote and treatment recommendations.

Table 4. Recommendations for Nerve Agent Therapy -- Emergency Department Management.

Patient Age	Antidotes		Other Treatment
	Mild/Moderate Symptoms[1]	Severe Symptoms[2]	
Infant (0 - 2 yrs)	Atropine: 0.05 mg/kg IM or 0.02 mg/kg IV; 2-PAM Cl: 15 mg/kg IV slowly	Atropine: 0.1 mg/kg IM or 0.02 mg/kg IV; 2-PAM Cl: 15 mg/kg IV slowly	**Assisted ventilation** as needed. **Repeat atropine (2 mg IM or 1 mg IM for infants)** at 5 - 10 minute intervals until secretions have diminished and breathing is comfortable or airway resistence has returned to near normal. **Phentolamine** for 2-PAM induced hypertension: (5 mg IV for adults; 1 mg IV for children) **Diazepam** for convulsions: (0.2 to 0.5 mg IV for infants 5 years; 1 mg IV for children >5 years; 5 mg IV for adults)
Child (2 - 10 yrs)	Atropine: 1 mg IM; 2-PAM Cl: 15 mg/kg IV slowly	Atropine: 2 mg IM; 2-PAM Cl: 15 mg/kg IV slowly	
Adolescent (>10 yrs)	Atropine: 2 mg IM; 2-PAM Cl: 15 mg/kg IV slowly	Atropine: 4 mg IM; 2-PAM Cl: 15 mg/kg IV slowly	
Adult	Atropine: 2 to 4 mg IM; 2-PAM Cl: 15 mg/kg (1 g) IV slowly	Atropine: 6 mg IM; 2-PAM Cl: 15 mg/kg (1 g) IV slowly	
Elderly, frail	Atropine: 1 mg IM; 2-PAM Cl: 5 to 10 mg/kg IV slowly	Atropine: 2 mg IM; 2-PAM Cl: 5 to 10 mg/kg IV slowly	

1. **Mild/Moderate symptoms** include localized sweating, muscle fasciculations, nausea, vomiting, weakness, dyspnea.
2. **Severe symptoms** include unconsciousness, convulsions, apnea, flaccid paralysis.

Inhalation Exposure

Ventilatory support is essential. Following low-dose exposure, administration of antidotes and supplemental oxygen may be adequate. Suction secretions from the nose, mouth, and

respiratory tract. Marked resistance to ventilation is expected due to bronchial constriction and spasm. Resistance lessens after administration of atropine.

Skin Exposure

Skin must be decontaminated within minutes following exposure to nerve agent. Because of the high toxicity, rapid absorption, and volatility, it is unlikely that a patient brought to a medical facility will have nerve agent on the skin. However, some nerve agent may remain in the hair
or clothing and should be decontaminated if not previously done (see *Basic Decontamination*, above).

Eye Exposure

Severity of miosis cannot be used as an indicator of the amount of exposure or effectiveness of the antidotes. Maximum miosis may not occur until an hour or more after exposure. If severe eye pain or nauseaand vomiting occur, protect eyes from bright light and consider topical administration of atropine or homatropine. Test visual acuity.

Ingestion Exposure

Do not induce emesis because of the risk of pulmonary aspiration of gastric contents which may result from abrupt respiratory arrest, seizures, or vomiting. If the patient is alert and charcoal has not been given previously, administer a slurry of activated charcoal. If the patient's condition is evaluated within 30 minutes after ingestion, consider gastric lavage. (Gastric contents should be considered potentially hazardous by skin contact or inhalation and should be quickly isolated.)

Laboratory Tests

Routine laboratory studies for all admitted patients include CBC, glucose, and serum electrolyte determinations. Chest X-ray and pulse oximetry (or ABG measurements) are recommended for severe exposures. Symptomatic and asymptomatic patients suspected of significant exposure should have determinations of red blood cell (RBC) cholinesterase activity, the most useful test for nerve agent poisoning. Severe symptoms of toxicity are usually present when more than 70% of RBC cholinesterase is inhibited. However, there is no correlation between cholinesterase activity and severity of topical signs and symptoms (e.g., miosis, rhinorrhea, dyspnea). If this test is not available, plasma cholinesterase can be measured.

Disposition and Follow-up

Patients exposed to nerve agent vapor who have only miosis and/or mild rhinorrhea when they reach the medical facility do not need to be admitted. All other patients who have had exposure to nerve agent should be hospitalized and observed closely.

Delayed Effects

Effects from skin exposure to liquid nerve agent may not develop for up to 18 hours following exposure.
Patients who have inhalation exposure and who complain of chest pain, chest tightness, or cough should be observed and examined periodically for 6 to 12 hours to detect delayed-onset bronchitis, pneumonia, pulmonary edema, or respiratory failure.

Formaldehyde poisoning can cause permanent alterations of nervous system function, including problems with memory, learning, thinking, sleeping, personality changes, depression, headache, and sensory and perceptual changes.

Follow-up

Patients who have severe exposure should be evaluated for persistent CNS sequelae. Patients should be advised to avoid organophosphate insecticide exposure until sequential RBC cholinesterase activity (measured at weekly to monthly intervals) has stabilized in the normal range, a process that may take 3 to 4 months after severe poisoning (see *Follow-up Instructions*, included with the *Nerve Agent Patient Information Sheet* below).

Reporting

Other persons may still be at risk in the setting where this incident occurred. If a public health risk exists, notify your state or local health department or other responsible public agency.

Nerve Agents
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to nerve agents.

What are nerve agents?
Nerve agents are chemical warfare agents, similar to but much more potent than organophosphate insecticides. They are colorless to amber-colored, tasteless liquids that may evaporate to create a gas. GB and VX are odorless, while GA has a slight fruity odor, and GD has a slight camphor odor.

What immediate health effects can result from exposure to nerve agents?
Nerve agents are extremely toxic chemicals that attack the nervous system. As little as one drop to a few milliliters of nerve agent contacting the skin can cause death within 15 minutes. Nerve agent exposure can cause runny nose, sweating, blurred vision, headache, difficulty breathing, drooling, nausea, vomiting, muscle cramps and twitching, confusion, convulsions, paralysis, and coma. Symptoms occur immediately if you inhale nerve agent vapor but may be delayed for several hours if you get nerve agent liquid on your skin.

Can nerve agent poisoning be treated?
There are antidotes for nerve agent poisoning but they must be administered quickly after exposure. Immediate decontamination is critical and hospitalization may be needed.

Are any future health effects likely to occur?
Complete recovery may take several months. After a severe exposure with prolonged seizures, permanent damage to the central nervous system is possible.

What tests can be done if a person has been exposed to nerve agents?
Activity of a blood enzyme called acetylcholinesterase can be measured to assess exposure and recovery.

Where can more information about nerve agents be found?
More information about nerve agents can be obtained from your regional poison control center; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in toxicology or occupational and environmental health. Ask the person who gave you this form for help locating these telephone numbers.

Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow *only* the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:
dizziness, loss of coordination, loss of memory
coughing, wheezing, or shortness of breath
nausea, vomiting, cramps, or diarrhea
muscle weakness or twitching
blurred vision

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.
[ ] Call for an appointment with Dr. _____ in the practice of _____.
When you call for your appointment, please say that you were treated in the Emergency Department at _____ Hospital by _____ and were advised to be seen again in _____ days.
[ ] Return to the Emergency Department/ _____ Clinic on (date) _____at __ _____ AM/PM for a follow-up examination.
[ ] Do not perform vigorous physical activities for 1 to 2 days.
[ ] You may resume everyday activities including driving and operating machinery.
[ ] Do not return to work for _____ days.
[ ] You may return to work on a limited basis. See instructions below.
[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.
[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.
[ ] Avoid taking the following medications: _____
[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: __
_____
_____
[ ] Other instructions: _____
_____
_____

- Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.

- You or your physician can get more information on the chemical by contacting: _____ _____ or _____, or by checking out the following Internet Web sites: _____; _____.

Signature of patient _____ Date _____

Signature of physician _____ Date_____

Nitrogen Oxides (NO, NO_2, and others)
CAS 10102-43-9; UN 1660 (NO)
CAS 10102-44-0; UN 1067 (NO_2)
UN 1975 (Mixture)

Synonyms for nitric oxide (NO) include mononitrogen monoxide and nitrogen monoxide. Synonyms for nitrogen dioxide (NO_2) include dinitrogen tetroxide, nitrogen peroxide, nitrogen tetroxide, and NTO. Synonyms for mixtures of nitrogen oxides include nitrogen fumes and nitrous fumes.

Persons exposed only to nitrogen oxide gases do not pose substantial secondary contamination risks. Persons whose clothing is contaminated with liquid nitrogen oxides can secondarily contaminate others by direct contact or through off-gassing vapors.

Nitric oxide and nitrogen dioxide are nonflammable liquids or gases; however, they will accelerate the burning of combustible materials. Odor generally provides an adequate warning of acute exposure providing the higher oxides (NO_2, N_2O_4 and N_2O_5) are present. Nitric oxide (NO) is odorless and nitrous oxide (N_2O) has only a very faint odor.

The primary route of exposure to nitrogen oxides is by inhalation, but exposure by any route can cause systemic effects. Nitrogen oxides are irritating to the eyes, skin, mucous membranes, and respiratory tract. On contact with moisture, nitrogen dioxide forms a mixture of nitric and nitrous acids.

Description

Nitrogen oxides represent a mixture of gases designated by the formula NO_x. The mixture includes nitric oxide (NO), nitrogen dioxide (NO_2), nitrogen trioxide (N_2O_3), nitrogen tetroxide (N_2O_4), and nitrogen pentoxide (N_2O_5). The toxicity of nitrous oxide (N_2O) or laughing gas, which is used as an anesthetic, is different from that of the other nitrogen oxides and is not discussed in this protocol.

The most hazardous of the nitrogen oxides are nitric oxide and nitrogen dioxide; the latter exists in equilibrium with its dimer, nitrogen tetroxide. Nitric oxide is a colorless gas at room temperature, very sparingly soluble in water. Nitrogen dioxide is a colorless to brown liquid at room temperature and a reddish-brown gas above 70 °F poorly soluble in water. Nitric oxide is rapidly oxidized in air at high concentrations to form nitrogen dioxide.

Routes of Exposure

Inhalation

Nitrogen oxides (NO_2, N_2O_4, N_2O_3 and N_2O_5) are irritating to the upper respiratory tract and lungs even at low concentrations. Only one or two breaths of a very high concentration can cause severe toxicity. Odor is generally an adequate warning property for acute

exposures. Nitrogen dioxide is heavier than air, such that exposure in poorly ventilated, enclosed, or low-lying areas can result in asphyxiation.

Children exposed to the same levels of nitrogen oxides as adults may receive larger doses because they have greater lung surface area:body weight ratios and increased minute volumes:weight ratios. In addition, they may be exposed to higher levels of nitrogen dioxide than adults in the same location because of their short stature and the higher levels of nitrogen dioxide found nearer to the ground.

Skin/Eye Contact

Exposure to relatively high air concentrations can produce eye irritation and inflammation.

Children are more vulnerable to toxicants affecting the skin because of their relatively larger surface area:body weight ratio.

Ingestion

Both nitrogen dioxide and nitric oxide are gases at room temperature. However, nitrogen dioxide exists as a liquid below 21 °C and, if ingested, will cause gastrointestinal irritation or burns.

Sources/Uses

Nitrogen oxides form naturally during the oxidation of nitrogen-containing compounds such as coal, diesel fuel, and silage. Nitrogen oxides are also formed during arc welding, electroplating, engraving, dynamite blasting, as components of rocket fuel, and nitration reactions such as in the production of nitro-explosives, including gun-cotton, dynamite and TNT. They are produced commercially, usually as the first step in the production of nitric acid, either by the direct oxidation of atmospheric nitrogen in the electric arc (Birkeland-Eyder Process) or by the catalytic oxidation of anhydrous ammonia (Oswald Process). Trace metal impurities most likely cause nitrogen oxides to form in nitric acid and its solutions. Nitrogen oxides are intermediates in the production of lacquers, dyes, and other chemicals and are important components of photo-oxidant smog.

Standards and Guidelines

Nitric Oxide: OSHA PEL (permissible exposure limit) = 25 ppm (averaged over an 8-hour workshift)

NIOSH IDLH (immediately dangerous to life or health) = 100 ppm
Nitrogen Dioxide: OSHA PEL (permissible exposure limit) = 5 ppm (Ceiling)

NIOSH IDLH (immediately dangerous to life or health) = 20 ppm

Physical Properties	Nitric Oxide	Nitrogen Dioxide
Description:	Colorless gas	Yellow-brown liquid or red-brown gas
Warning properties:	Non-irritating, odorless and colorless gas; no adequate warning for acute exposure unless accompanied by NO2 or another higher oxide as is usual.	Irritating, sharp odor at 1–5 ppm; adequate warning for acute exposure; inadequate warning for chronic exposure.
Molecular weight:	30.0 daltons	46.0 daltons
Boiling point (760 mm Hg):	-241 °F (-152 °C)	70 °F (21 °C)
Freezing point:	-263 °F (-164 °C)	12 °F (-11 °C)
Vapor pressure:	>760 mm Hg at 68 °F (20 °C)	720 mm Hg at 68 °F (20 °C)
Gas density:	1.0 (air = 1)	1.5 (air = 1)
Water solubility:	Water soluble	Highly soluble, but reacts with water to form a mixture of nitric and nitrous acids.
Flammability:	Not flammable, but will accelerate burning of combustible materials	Not flammable, but will accelerate burning of combustible materials

Incompatibilities

Nitrogen dioxide and nitric acid react with combustible materials, chlorinated hydrocarbons, carbon disulfide, and ammonia. May react violently with cyclohexane, fluorine, formaldehyde and alcohol, nitrobenzene, petroleum, and toluene.

Health Effects

Most of the higher oxides of nitrogen are eye, skin, and respiratory tract irritants. Nitrogen dioxide is a corrosive substance that forms nitric and nitrous acids upon contact with water; it is more acutely toxic than nitric oxide, except at lethal concentrations when nitric oxide may kill more rapidly.

Nitric oxide is a potent and rapid inducer of methemoglobinemia.

Exposure to nitrogen oxides may result in changes of the pulmonary system including pulmonary edema, pneumonitis, bronchitis, bronchiolitis, emphysema, and possibly methemoglobinemia. Cough, hyperpnea, and dyspnea may be seen after some delay.

- **Damage to, and subsequent scarring of, the bronchioles may result in a life-threatening episode several weeks following exposure involving cough, rapid, shallow breathing, rapid heartbeat, and inadequate oxygenation of the tissues.**
- **Populations that may be particularly sensitive to nitrogen oxides include asthmatics and those with chronic obstructive pulmonary disease or heart disease.**

Acute Exposure

Nitrogen dioxide is thought to damage lungs in three ways: (1) it is converted to nitric and nitrous acids in the distal airways, which directly damages certain structural and functional lung cells; (2) it initiates free radical generation, which results in protein oxidation, lipid peroxidation, and cell membrane damage; and (3) it reduces resistance to infection by altering macrophage and immune function. There may be an immediate response to exposure to nitrogen oxide vapors that may include coughing, fatigue, nausea, choking, headache, abdominal pain, and difficulty breathing. A symptom-free period of 3 to 30 hours may then be followed by the onset of pulmonary edema with anxiety, mental confusion, lethargy, and loss of consciousness. If survived, this episode may be followed by bronchiolitis obliterans (fibrous obstruction of the bronchioles) several weeks later. Any of these phases can be fatal.

Children do not always respond to chemicals in the same way that adults do. Different protocols for managing their care may be needed.

Respiratory

The higher nitrogen oxides are respiratory irritants. The primary site of toxicity is the lower respiratory tract. Low concentrations initially may cause mild shortness of breath and cough; then, after a period of hours to days, victims may suffer bronchospasm and

pulmonary edema. Inhalation of very high concentrations can rapidly cause burns, spasms, swelling of tissues in the throat, upper airway obstruction, and death.

Exposure to certain chemicals can lead to Reactive Airway Dysfunction Syndrome (RADS), a chemically- or irritant-induced type of asthma.

Children may be more vulnerable to corrosive agents than adults because of the relatively smaller diameter of their airways. Children also may be more vulnerable because of relatively increased minute ventilation per kg and failure to evacuate an area promptly when exposed.

Cardiovascular Absorption of nitrogen oxides can lead to a weak rapid pulse, dilated heart, chest congestion, and circulatory collapse.

Hematologic High-dose exposure may convert Fe^{+2} in hemoglobin to Fe^{+3}, by virtue of the presence of nitric oxide (NO), causing methemoglobinemia and impaired oxygen transport.

Dermal Higher nitrogen oxides are skin irritants and corrosives. Skin moisture in contact with liquid nitrogen dioxide or high concentrations of its vapor can result in nitric acid formation, which may lead to second-and third-degree skin burns. Nitric acid may also cause yellowing of the skin and erosion of dental enamel.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants affecting the skin.

Ocular Liquid nitrogen oxides cause severe eye burns after brief contact. High concentrations of the gas cause irritation and, after prolonged exposure, may cause clouding of the eye surface and blindness.

Potential Sequelae Obstruction of the bronchioles may develop days to weeks after severe exposure. Patients suffer malaise, weakness, fever, chills, progressive shortness of breath, cough, hemorrhage of the lungs or bronchioles, blue or purple coloring of the skin, and respiratory failure. This condition may be confused with the adult respiratory distress syndrome secondary to infectious diseases such as miliary tuberculosis.

Victims of inhalation exposure may suffer reactive airways dysfunction syndrome (RADS) after a single acute, high-dose exposure.

Chronic Exposure

Chronic exposure to nitrogen oxides is associated with increased risk of respiratory infections in children. Permanent restrictive and obstructive lung disease from bronchiolar damage may occur.

Carcinogenicity

Nitrogen oxides have not been classified for carcinogenic effects.

Reproductive and Developmental Effects

Nitric oxide and nitrogen dioxide are not included in *Reproductive and Developmental Toxicants,* a 1991 report published by the U.S. General Accounting Office (GAO) that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences. Methemoglobin inducers are considered harmful to the fetus and nitrogen dioxide has been shown to be fetotoxic in rats and has affected behavior and growth statistics in newborn mice. Nitrogen dioxide also causes DNA damage, mutations, sister chromatid exchanges, and other DNA aberrations.

Special consideration regarding the exposure of pregnant women may be warranted, since nitrogen oxides have been shown to be mutagenic and clastogenic, and fetotoxic in rats; thus, medical counseling is recommended for the acutely exposed pregnant woman.

Prehospital Management

- **Victims exposed only to nitrogen oxide gases do not pose risks of secondary contamination to rescuers. Victims whose clothing or skin is contaminated with liquid nitrogen oxides or nitric acid can secondarily contaminate response personnel by direct contact or through off-gassing vapors.**

  Most of the higher nitrogen oxides are eye, skin, and respiratory tract irritants. Initial respiratory symptoms after exposure to nitrogen oxides may be mild, but progressive inflammation of the lungs may develop several hours to days after exposure. Noncardiogenic pulmonary edema may develop even if initial pulmonary signs were minimal. Exposures may result in methemoglobinemia, depending upon the presence of nitric oxide (NO) in the gas mixture.

  There is no antidote for nitrogen oxides. Primary treatment consists of respiratory and cardiovascular support. Methylene blue may be necessary to treat methemoglobinemia.

Hot Zone

Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if rescuers have not been trained in its use, assistance should be obtained from a local or regional HAZMAT team or other properly equipped response organization.

Rescuer Protection

Nitrogen oxides are severe respiratory tract irritants.

Respiratory Protection: Positive-pressure, self-contained breathing apparatus (SCBA) is recommended in response situations that involve exposure to potentially unsafe levels of nitrogen oxides.

Skin Protection: Chemical-protective clothing is recommended when repeated or prolonged contact with liquids of nitrogen oxides or with high concentrations of nitrogen oxide vapors is anticipated because skin irritation or burns may occur.

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible.

Victim Removal

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be removed on backboards or gurneys; if these are not available, carefully carry or drag victims to safety.

Consider appropriate management of chemically contaminated children, such as measures to reduce separation anxiety if a child is separated from a parent or other adult.

Decontamination Zone

Victims exposed only to nitrogen oxide gases may appear to have no skin or eye irritation. However, they should still be decontaminated as described below as irritation may not become evident until washing commences.

Rescuer Protection

If exposure levels are determined to be safe, decontamination may be conducted by personnel wearing a lower level of protection than that worn in the Hot Zone (described above).

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. Stabilize the cervical spine with a collar and a backboard if trauma is suspected. Administer supplemental oxygen as required. Assist ventilation with a bag-valve-mask device if necessary.

Basic Decontamination

Victims who are able may assist with their own decontamination. Remove and double-bag contaminated clothing and personal belongings.

Flush exposed skin and hair with water for 20 minutes. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Immediately begin irrigation of exposed or irritated eyes with plain water or saline and continue for at least 20 minutes. Remove contact lenses if easily removable without additional trauma. Continue eye irrigation during other basic care and transport.

If the victim has ingested a solution of nitrogen oxides or nitric acid, **do not induce emesis**. Do not administer activated charcoal. Victims who are conscious and able to swallow should be given 4 to 8 ounces of water or milk.

Consider appropriate management of chemically contaminated children at the exposure site. Also, provide reassurance to the child during decontamination, especially if separation from a parent occurs. If possible, seek assistance from a child separation expert.

Transfer to Support Zone

As soon as decontamination is complete, move the victim to the Support Zone.

Support Zone

Be certain that victims have been decontaminated properly (see *Decontamination Zone* above). Victims who have undergone decontamination pose no serious risks of secondary contamination to rescuers. In such cases, Support Zone personnel require no specialized protective gear.

ABC Reminders

Quickly access for a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Ensure adequate respiration and pulse. Administer supplemental oxygen as required and establish intravenous access if necessary. Place on a cardiac monitor.

Additional Decontamination

Continue irrigating exposed skin and eyes, as appropriate.

If the patient has ingested a solution of nitrogen oxides or nitric acid, **do not induce emesis**. Do not administer activated charcoal. Patients who are able to swallow should be given 4 to 8 ounces of water or milk, if not provided previously.

Advanced Treatment

In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, perform cricothyroidotomy if equipped and trained to do so.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly).

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Patients who are comatose, hypotensive, or are having seizures or cardiac arrhythmias should be treated according to advanced life support (ALS) protocols.

If evidence of shock or hypotension is observed begin fluid administration. For adults, bolus 1,000 mL/hour intravenous saline or lactated Ringer's solution if blood pressure is under 80 mm Hg; if systolic pressure is over 90 mm Hg, an infusion rate of 150 to 200 mL/hour is sufficient. For children with compromised perfusion

administer a 20 mL/kg bolus of normal saline over 10 to 20 minutes, then infuse at 2 to 3 mL/kg/hour.

Transport to Medical Facility

Only decontaminated patients or patients not requiring decontamination should be transported to a medical facility. "Body bags" are not recommended.

Report to the base station and the receiving medical facility the condition of the patient, treatment given, and estimated time of arrival at the medical facility.

If a solution of nitrogen oxides, which means in effect a mixture of nitric (HNO_3) and nitrous (HNO_2) acids, has been ingested, prepare the ambulance in case the victim vomits toxic material. Have ready several towels and open plastic bags to quickly clean up and isolate vomitus.

Multi-Casualty Triage

Consult with the base station physician or regional poison control center for advice regarding triage of multiple victims. Because delayed respiratory compromise may occur even with minimal initial symptoms, all patients who have histories or evidence of exposure should be transported to a medical facility for evaluation. Because of the danger of acute, though delayed, onset of severe, life-threatening pulmonary edema from 3 to 30 hours after what may appear to have been quite a trivial exposure it is important that exposed subjects be maintained under medical surveillance for the first 48 hours post-exposure. If such are allowed to return home and acute pulmonary edema develops in a home environment during sleep it may not be possible to get the patient to resuscitative medical treatment in time. Others may be discharged at the scene after their names, addresses, and telephone numbers are recorded. Those discharged should be advised to seek medical care promptly if symptoms develop (see *Patient Information Sheet* below).

Emergency Department Management

Patients exposed only to nitrogen oxide gases do not pose risks of secondary contamination to rescuers. Patients whose clothing or skin is contaminated with liquid nitrogen oxides or nitric acid can secondarily contaminate response personnel by direct contact or through off-gassing vapors.

Most of the higher nitrogen oxides are eye, skin, and respiratory tract irritants. Initial respiratory symptoms after exposure to nitrogen oxides may be mild, but progressive inflammation of the lungs may develop several hours to days after exposure. Noncardiogenic pulmonary edema may develop even if initial pulmonary signs were minimal. Exposures may result in methemoglobinemia, depending upon the presence of nitric oxide (NO) in the gas mixture.

There is no antidote for nitrogen oxides. Treatment consists of respiratory and cardiovascular support. Methylene blue may be necessary to treat methemoglobinemia.

Decontamination Area

Previously decontaminated patients may be transferred immediately to the Critical Care Area. Others require decontamination as described below.

Be aware that use of protective equipment by the provider may cause fear in children, resulting in decreased compliance with further management efforts.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants absorbed affecting the skin. Also, emergency room personnel should examine children's mouths because of the frequency of hand-to-mouth activity among children.

ABC Reminders

Evaluate and support airway, breathing, and circulation. Administer supplemental oxygen as required. Children may be more vulnerable to corrosive agents than adults because of the relatively smaller diameter of their airways. In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, surgically create an airway.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents

after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly).

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Patients who are comatose, hypotensive, or have seizures or ventricular arrhythmias should be treated in the conventional manner.

Basic Decontamination

Patients who are able may assist with their own decontamination. If the patient's clothing is wet with nitrogen oxides or nitric acid, remove and double-bag the contaminated clothing and all personal belongings.

Flush exposed skin and hair with water for 20 minutes (preferably under a shower). Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Begin irrigation of exposed eyes **immediately** and continue for at least 20 minutes. Remove contact lenses if easily removable without additional trauma to the eye. Continue irrigation while transporting the patient to the Critical Care Area.

If the patient has ingested a solution of nitrogen oxides or nitric acid, **do not induce emesis**. Do not administer activated charcoal. Activated charcoal is unlikely to be of benefit and may obscure endoscopic findings if GI tract irritation or burns are present. Patients who are conscious and able to swallow should be given 4 to 8 ounces of water or milk if not provided earlier.

Critical Care Area

Be certain that appropriate decontamination has been carried out (see *Decontamination Area* above).

ABC Reminders

Evaluate and support airway, breathing, and circulation as in *ABC Reminders* above. Administer supplemental oxygen as required. Children may be more vulnerable to corrosive agents than adults because of the relatively smaller diameter of their airways. Establish intravenous access in seriously symptomatic patients. Continuously monitor cardiac rhythm.

Patients who are comatose, hypotensive, or have seizures or ventricular arrhythmias should be treated in the conventional manner.

Inhalation Exposure

Administer supplemental oxygen by mask to patients who have respiratory symptoms. Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Some clinicians recommend high doses of corticosteroids for seriously symptomatic patients, especially with severe bronchospasm; in patients with acute respiratory failure without bronchospasm, the value of steroids is unproven.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Skin Exposure

If the skin was in contact with liquid nitrogen oxides or their solutions, chemical burns may occur; treat as thermal burns.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants affecting the skin.

Eye Exposure

Continue irrigation for at least 20 minutes. If liquid nitrogen oxides or nitric acid has been splashed in the eyes, irrigate until the pH of the conjunctival fluid has returned to normal. Test visual acuity. Examine the eyes for corneal damage and treat appropriately. Immediately consult an ophthalmologist for patients who have severe corneal injuries.

Ingestion Exposure

If the patient has ingested a solution of nitrogen oxides or nitric acid, **do not induce emesis**. Do not administer activated charcoal. Patients who are conscious and able to swallow should be given 4 to 8 ounces of water or milk if not provided earlier.

Consider endoscopy to evaluate the extent of gastrointestinal tract injury. Extreme throat swelling may require endotracheal intubation or cricothyroidotomy. Gastric lavage is useful in certain circumstances to remove caustic material and prepare for endoscopic examination. Consider gastric lavage with a small nasogastric tube if: (1) a large dose has been ingested; (2) the patient's condition is evaluated within 30 minutes; (3) the patient has oral lesions or persistent esophageal discomfort; and (4) the lavage can be administered within 1 hour of ingestion. Care must be taken when placing the gastric tube because blind gastric tube

placement may further injure the chemically damaged esophagus or stomach.

Because children do no ingest large amounts of corrosive materials, and because of the risk of perforation from NG intubation, lavage is discouraged in children unless intubation is performed under endoscopic guidance.

Toxic vomitus or gastric washings should be isolated, e.g., by attaching the lavage tube to isolated wall suction or another closed container.

Antidotes and Other Treatments

There are no antidotes for nitrogen oxide poisoning. Methylene blue (tetramethylthionine chloride) should be considered for patients who have signs and symptoms of hypoxia (other than cyanosis) or for patients who have methemoglobin levels >30%. Cyanosis alone does not require treatment. Methylene blue may not be effective in patients who have G6PD deficiency and may cause hemolysis.

The standard dose of methylene blue is 1 to 2 mg/kg body weight (0.1 to 0.2 mL/kg of a 1% solution) intravenously over 5 to 10 minutes, repeated in 1 hour if needed. The total initial dose should not exceed 7 mg/kg. (Doses greater than 15 mg/kg may cause hemolysis.) Clinical response to methylene blue treatment is usually observed within 30 to 60 minutes. Side effects include nausea, vomiting, abdominal and chest pain, dizziness, diaphoresis, and dysuria.

Consider exchange transfusion in severely poisoned patients who are deteriorating clinically in spite of methylene blue treatment. Intravenous ascorbic acid administered to severely poisoned patients has not proved to be effective.

Administration of steroids is thought by some physicians to reduce the likelihood of the development of bronchiolitis obliterans by reducing inflammation and therefore lung damage. Steroids should be started soon after exposure and continued for 8 weeks, then tapered gradually. The data on steroid use to prevent late sequelae (bronchiolitis obliterans) is anecdotal and somewhat controversial.

Laboratory Tests

The diagnosis of acute nitrogen oxide toxicity is primarily based on respiratory symptoms and establishing a history of exposure to nitrogen oxides. Routine laboratory studies for all exposed patients include CBC, glucose, and electrolyte determinations. Additional studies for patients exposed to nitrous oxides include determination

of methemoglobin levels. The condition of victims who have respiratory complaints should be evaluated with pulse oximetry (or ABG measurements), chest radiography, spirometry, and peak flow measurements. Pulse oximetry is not reliable if methemoglobin is present.

NO and NO_2 are metabolized to nitrite (NO_2^-) and nitrate (NO_3^-) and are excreted in the urine. The levels of these urinary metabolites are not medically useful but may be helpful in documenting exposure.

Disposition and Follow-up

Consider hospitalizing patients who have histories of significant inhalation exposure and are symptomatic.

Delayed Effects

Symptomatic patients should be observed in a controlled setting for 48 hours for delayed noncardiogenic pulmonary edema. All patients determined to have been exposed to nitrogen oxides should be advised that life-threatening symptoms may develop as late as several weeks after the exposure.

Patient Release

Patients who have been observed for several hours after minimal exposure and remain asymptomatic may be treated as outpatients. They should be advised to seek medical care promptly if symptoms develop (see *Nitrogen Oxides—Patient Information Sheet*). A patient whose symptoms resolve within 24 to 36 hours may be released with a follow-up appointment to assess pulmonary status.

Follow-up

Obtain the name of the patient's primary care physician so that the hospital can send a copy of the ED visit to the patient's doctor.

Close outpatient follow-up should be continued in patients who experienced significant respiratory compromise because these patients are at high risk of developing bronchiolitis obliterans within several weeks.

Patients who have corneal injuries should be reexamined within 24 hours.

Reporting

If a work-related incident has occurred, you may be legally required to file a report; contact your state or local health department.

Other persons may still be at risk in the setting where this incident occurred. If the incident occurred in the workplace, discussing it with company personnel may prevent future incidents. If a public health risk exists, notify your state or local health department or other responsible public agency. When appropriate, inform patients that they may request an evaluation of their workplace from OSHA

or NIOSH. See Appendices III and IV for a list of agencies that may be of assistance.

Nitrogen Oxides
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to nitrogen oxides.

What are nitrogen oxides?
Nitrogen oxides are a mixture of gases that each contain nitrogen and oxygen. Nitrogen oxides are formed naturally when fossil fuels (e.g., coal, oil, gas, kerosene) are burned and when silage containing nitrate fertilizer ferments in storage silos. They are also formed during electric arc welding, electroplating, and engraving. They are part of airborne smog and are partly indirectly responsible for the burning eyes, nose, and throat caused by air pollution, through formation of the intensely irritating compound peroxyacetylnitrate, PAN.

What immediate health effects can be caused by exposure to nitrogen oxides?
Breathing low levels of nitrogen oxides may cause brief, nonspecific symptoms such as cough, shortness of breath, tiredness, and nausea. However, even if removed from exposure, a person who has breathed nitrogen oxides can develop more serious lung injury over the next 1 to 2 days. Exposure to massive concentrations can cause sudden death due to lung injury and suffocation or choking. Generally, the more serious the exposure, the more severe the symptoms.

Can nitrogen oxide poisoning be treated?
There is no antidote for nitrogen oxide poisoning. Treatment for exposure usually involves giving the patient oxygen and medications to make breathing easier.

Are any future health effects likely to occur?
A single small exposure from which a person recovers quickly may not cause delayed or long-term effects. After a serious exposure or repeated exposures, a patient may develop asthma or other lung conditions.

What tests can be done if a person has been exposed to nitrogen oxides?
Specific tests for the presence of nitrogen oxides in blood or urine generally are not useful to the doctor. If a severe exposure has occurred, blood and urine analyses and other tests may show whether damage has been done to the lungs, heart, and brain. Testing is not needed in every case.

Where can more information about nitrogen oxides be found?
More information about nitrogen oxides can be obtained from your regional poison control center; your state, county, or local health department; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in occupational and environmental health. If the exposure happened at work, you may wish to discuss it with your employer, the Occupational Safety and Health Administration (OSHA), or the National Institute for Occupational Safety and Health (NIOSH). Ask the person who gave you this form for help in locating these telephone numbers.

Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow *only* the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 48 to 72 hours, especially:

- coughing or wheezing
- difficulty breathing, shortness of breath, or chest pain
- weakness, fatigue, or flu-like symptoms
- increased redness or pain or a pus-like discharge in the area of a skin burn

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.
[ ] Call for an appointment with Dr. _____ in the practice of _____.
When you call for your appointment, please say that you were treated in the Emergency Department at _____ _____ Hospital by _____ and were advised to be seen again in _____ days.
[ ] Return to the Emergency Department/ _____ Clinic on (date) _____at _____ _____ AM/PM for a follow-up examination.
[ ] Do not perform vigorous physical activities for 1 to 2 days.
[ ] You may resume everyday activities including driving and operating machinery.
[ ] Do not return to work for _____ days.
[ ] You may return to work on a limited basis. See instructions below.
[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.
[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.
[ ] Avoid taking the following medications: _____
[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: __
_____
_____
[ ] Other instructions: _____
_____
_____

- Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.

- You or your physician can get more information on the chemical by contacting: _____ _____ or _____, or by checking out the following Internet Web sites: ___ _____; _____.

Signature of patient _____ Date _____

Signature of physician _____ Date _____

Parathion ($[C_2H_5O]_2P[S]OC_6H_4NO_2$)
CAS 56-38-2; UN 2783

Synonyms include O,O-Diethyl-O-(p-nitrophenyl) phosphorothioate, diethyl parathion, ethyl parathion, parathion ethyl and a variety of trade names such as Alkron, Alleron, Danthion, DNTP, DPP, Etilon, E-605, Stathion, Sulphos, and Thiophos.

- **Persons whose skin or clothing is contaminated with liquid or powdered parathion can cause secondary contamination by direct contact.**
- **Parathion is an organophosphate pesticide. At room temperature, it is a combustible pale yellow to dark brown liquid that may be difficult to ignite. In commercial products, parathion is usually dissolved in hydrocarbon solvents such as toluene or xylene, which are flammable. Parathion has a garlic-like odor, which does not provide adequate warning of hazardous concentrations.**
- **Because parathion has a low vapor pressure, significant inhalation is unlikely at ordinary temperatures. However, the hydrocarbon solvents in commercial preparations can be inhaled. Parathion is rapidly absorbed by ingestion and through intact skin and the eyes, resulting in acute systemic toxicity.**

Description

At room temperature, parathion is a yellow-to-brown liquid with an odor of garlic. It is often dissolved in a hydrocarbon solvent before use. Parathion itself is not volatile. It is almost insoluble in water, slightly soluble in petroleum oils, and miscible with many organic solvents.

Routes of Exposure

Inhalation

Toxic inhalation of parathion vapor is unlikely at ordinary temperatures because of its low volatility, but toxic effects can occur after inhalation of parathion sprays or dusts. The hydrocarbon solvents (most commonly toluene and xylene) used to dissolve parathion are more volatile than parathion itself, and toxicity can result from inhalation of solvent vapor as well. The odor threshold of parathion is five times the OSHA PEL (0.1 mg/m^3) and **does not provide adequate warning of hazardous concentrations**.

Children exposed to the same levels of parathion as adults may receive a larger dose because they have greater lung surface area:body weight ratios and increased minute volumes:weight ratios.

Skin/Eye Contact

Parathion is not irritating to the skin or eyes, but is rapidly absorbed through intact skin and eyes, contributing to systemic toxicity.

Children are more vulnerable to toxicants absorbed through the skin because of their relatively larger surface area:body weight ratio.

Ingestion

Acute toxic effects, including rapidly fatal systemic poisoning, can result from ingestion of parathion.

Sources/Uses

Parathion is prepared by the reaction of diethyl phosphorothionchloridate with sodium p-nitrophenate. It is widely used as an agricultural insecticide. It has been used extensively by U.S. farmers on major crops such as wheat, fruit, vegetables, nuts, citrus fruits, alfalfa, corn, soybeans, and other field crops.

Standards and Guidelines

OSHA PEL (permissible exposure limit) = 0.1 mg/m^3 (skin) (averaged over an 8-hour workshift)

NIOSH IDLH (immediately dangerous to life or health) = 10 mg/m^3

Physical Properties

Description: Pale-yellow to dark-brown liquid at room temperature

Warning properties: Weak odor of garlic at 0.47 mg/m^3; inadequate warning for acute and chronic exposures. Does not generally produce skin irritation.

Molecular weight: 291.3 daltons

Boiling point: (760 mm Hg): 707 °F (375 °C)

Freezing point: 43 °F (6.1 °C)

Specific gravity: 1.27 (water = 1)

Vapor pressure: 4×10^{-5} mm Hg at 68 °F (20 °C)

Water solubility: insoluble (0.001% at 68 °F) (20 °C)

Flammability: 392 °F (200 °C)

Incompatibilities

Parathion reacts with strong oxidizers and alkaline materials.

Health Effects

Systemic toxicity due to parathion can result from all routes of exposure. Symptoms include abdominal cramps, vomiting, diarrhea, pinpoint pupils and blurred vision, excessive sweating, salivation and lacrimation, wheezing, excessive tracheobronchial secretions, agitation, seizures, bradycardia or tachycardia, muscle twitching and weakness, and urinary bladder and fecal incontinence. Seizures are much more common in children than in adults.

Death results from loss of consciousness, coma, excessive bronchial secretions, respiratory depression and cardiac irregularity.

Commercial parathion products often contain hydrocarbon solvents, such as xylene or toluene, which themselves can cause toxicity.

Toxicity of parathion depends on metabolic activation; thus, symptoms may be delayed for 6 to 24 hours after exposure.

Acute Exposure

Parathion, like all organophosphate pesticides, inhibits acetylcholinesterase and alters cholinergic synaptic transmission at neuroeffector junctions (muscarinic effects), at skeletal myoneural junctions and autonomic ganglia (nicotinic effects), and in the CNS. Inhibition occurs when a metabolite of parathion binds to acetylcholinesterase; thus, symptoms may be delayed after exposure. Signs and symptoms of poisoning vary according to age, dose, and concentration.

Muscarinic effects include: pinpoint pupils; blurred vision; hypersecretion by salivary, lacrimal, sweat, and bronchial glands; narrowing of the bronchi; nausea, vomiting, diarrhea, and crampy abdominal pains; urinary and fecal incontinence; and slow heart rate.

Nicotinic effects include muscle twitching, cramping, and weakness. Nicotinic stimulation can obscure certain muscarinic effects and produce rapid heart rate and high blood pressure.

CNS

CNS effects are often the earliest manifestations of poisoning in adults and constitute the major signs and symptoms in children. CNS effects include irritability, nervousness, giddiness, fatigue, lethargy, impairment of memory, confusion, slurred speech, visual disturbance, depression, impaired gait, convulsions, loss of consciousness, coma, and respiratory depression.

Peripheral Neurologic

Peripheral neurologic effects include muscle twitching and weakness due to inhibition of acetylcholinesterase at neuromuscular junctions.

Respiratory

Respiratory failure is the most common cause of death due to parathion poisoning. Narrowing of the bronchi and markedly increased bronchial secretions can occur. Respiratory failure results from respiratory depression coupled with paralysis of the respiratory muscles and progressive airway obstruction from bronchorrhea. In addition, pulmonary aspiration of the hydrocarbon solvents found in many commercial preparations can cause inflammation of the lungs.

Children may be more vulnerable because of relatively increased minute ventilation per kg and failure to evacuate as area promptly when exposed.

Cardiovascular

Most exposure victims experience bradycardia, but pulse rate may be increased initially and tachycardia is more common in very severe poisoning. Irregular heartbeat may occur.

Gastrointestinal

Nausea, vomiting, abdominal cramps, diarrhea, and fecal incontinence are common manifestations, regardless of the exposure route. These are generally the earliest symptoms to occur.

Metabolic

Profuse sweating is likely to occur and may lead to profound dehydration. This is somewhat less common in children.

Dermal

Parathion is not generally irritating, but is readily absorbed through the skin. Skin contact can result in systemic poisoning.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants absorbed through the skin.

Ocular

Systemic poisoning typically causes pinpoint pupils and spasm of the muscle of visual accommodation (i.e., ciliary muscle) leading to blurred vision and aching pain in the eye. However, organophosphate poisoning may still be present without pinpoint pupils, and dilation of the pupils may even be noted occasionally. Eye irritation, if it occurs, is most likely caused by the hydrocarbon solvents used in commercial pesticide preparations.

Potential Sequelae

Complete recovery generally occurs within 10 days unless severe lack of oxygen has caused residual brain damage. CNS effects such as confusion, fatigue, irritability, nervousness, and

impairment of memory can occasionally last for several weeks. Six to twenty-one days after acute exposure to some organophosphate compounds, onset of nerve disorders of mixed sensory-motor type may occur; peripheral nerve recovery may never be complete. It is uncertain if parathion produces this delayed polyneuropathy.

Chronic Exposure

Persistent weakness and impaired memory have been reported to occur from low-level exposures to organophosphates in the absence of acute cholinergic effects.

Carcinogenicity

The International Agency for Research on Cancer has determined that parathion is not classifiable as to its carcinogenicity to humans. However, EPA lists parathion as a possible human carcinogen.

Reproductive and Developmental Effects

Studies have been reported in which parathion was embryo-toxic and fetotoxic in rodents. There are no studies addressing reproductive or developmental effects in humans exposed to parathion. Parathion is not included in *Reproductive and Developmental Toxicants*, a 1991 report published by the U.S. General Accounting Office (GAO) that lists 30 other chemicals of concern because of widely acknowledged reproductive and developmental consequences.

Prehospital Management

Parathion is highly contaminating. Victims whose skin or clothing is contaminated with liquid or powdered parathion can secondarily contaminate response personnel by direct contact or evaporation of solvent vapor. Clothing and leather goods (e.g., belts or shoes) cannot be reliably decontaminated; they should be incinerated.

Systemic effects of parathion poisoning can occur from all routes of exposure. Symptoms of parathion poisoning can include headache, nausea, vomiting, abdominal cramps, diarrhea, generalized muscle weakness and twitching, slurred speech, pinpoint pupils, excessive secretions and shortness of breath.

Severely poisoned patients may develop seizures, skeletal-muscle paralysis, cardiac arrhythmias and respiratory failure, or may become comatose.

Commercial parathion products often contain hydrocarbon solvents, such as xylene or toluene, which themselves can cause toxicity. Treatment for breathing the solvent is fresh air.

Treatment for parathion poisoning consists of thorough decontamination, cardiorespiratory support, and administration of the antidotes atropine and pralidoxime. Antidotes should be administered as prevention even if the diagnosis is in doubt.

Hot Zone

Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if rescuers have not been trained in its use, assistance should be obtained from a local or regional HAZMAT team or other properly equipped response organization.

Rescuer Protection

Parathion is a highly toxic systemic poison that is absorbed well by all routes of exposure.

Respiratory Protection: Positive-pressure, self-contained breathing apparatus (SCBA) is recommended in response situations that involve exposure to potentially unsafe levels of parathion.

Skin Protection: Chemical-protective clothing is recommended because parathion is rapidly absorbed through the skin and may cause systemic poisoning.

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible.

Victim Removal

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be removed on backboards or gurneys; if these are not available, carefully carry or drag victims to safety.

Consider appropriate management of chemically-contaminated children, such as measures to reduce separation anxiety if a child is separated from a parent or other adult.

Decontamination Zone

All victims suspected of parathion ingestion, or substantial exposure to aerosolized parathion, or who have skin or eye exposure to liquid or powdered parathion require thorough decontamination as described below.

Rescuer Protection

If exposure levels are determined to be safe, decontamination may be conducted by personnel wearing a lower level of protection than that worn in the Hot Zone (described above).

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. Stabilize the cervical spine with a collar and a backboard if trauma is suspected. Administer supplemental oxygen as required. Assist ventilation with a bag-valve-mask device if necessary.

Basic Decontamination

Rapid and thorough decontamination is critical, but must proceed concurrently with supportive and antidotal measures.

Victims who are able may assist with their own decontamination. Quickly remove and double-bag contaminated clothing and personal belongings. Clothing (especially leather items) is extremely difficult to decontaminate; in most cases, contaminated clothing should be incinerated as directed by hazardous materials experts.

Victims should be washed repeatedly with copious amounts of soap and water. Rescuers should wear rubber gloves as vinyl gloves provide no protection against skin absorption. It is important to observe the patient closely for sudden appearance of symptoms. It is important to thoroughly clean hair, fingernails, and skin folds. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Irrigate exposed or irritated eyes with plain water or saline for 15 minutes. Remove contact lenses if easily removable without additional trauma to the eye. If a corrosive material is suspected or if pain or injury is evident, continue irrigation while transferring the victim to the Support Zone.

In cases of ingestion, **do not induce emesis**. If the victim is alert and asymptomatic, administer a slurry of activated charcoal (at 1 gm/kg, usual adult dose 60–90 g, child dose 25–50 g). A soda can and straw may be of assistance when offering charcoal to a child.

Consider appropriate management of chemically contaminated children at the exposure site. Provide reassurance to the child during decontamination, especially if separation from a parent occurs.

Transfer to Support Zone

As soon as basic decontamination is complete, move the victim to the Support Zone.

Support Zone

Be certain that victims have been decontaminated properly (see *Decontamination Zone* above). Victims who have undergone decontamination or have been exposed only to vapor generally pose no serious risks of secondary contamination to rescuers. However, the Support Zone team should wear disposable aprons or gowns and rubber gloves for protection.

ABC Reminders

Quickly access for a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Ensure adequate respiration and pulse. Administer supplemental oxygen as required and establish intravenous access if necessary. Place on a cardiac monitor. Airway suctioning may be required for excessive bronchial secretions.

Additional Decontamination

Continue irrigating exposed skin and eyes, as appropriate.

In cases of ingestion, **do not induce emesis**. If the victim is alert and asymptomatic, administer a slurry of activated charcoal if it has not already been given (at 1 gm/kg, usual adult dose 60–90 g, child dose 25–50 g). A soda can and straw may be of assistance when offering charcoal to a child.

Advanced Treatment

In cases of respiratory compromise, coma, or to facilitate removal of excessive pulmonary secretions secure airway and respiration via endotracheal intubation. If not possible, perform cricothyroidotomy if equipped and trained to do so.

When possible, atropine (see *Antidotes*, below) should be given under medical supervision to all symptomatic patients who have known or strongly suspected parathion poisoning.

Patients who are comatose, hypotensive, or having seizures or cardiac arrhythmias should be treated according to advanced life support (ALS) protocols.

Antidotes

Two antidotes are administered to treat organophosphate poisoning. Atropine is a competitive antagonist of acetylcholine at muscarinic receptors and is used to control the excessive bronchial secretions which are often responsible for death. Pralidoxime relieves both the nicotinic and muscarine effects of organophosphate poisoning by regenerating acetylcholinesterase and can reduce both the bronchial secretions and the muscle weakness associated with poisoning.

The initial intravenous dose of atropine in adults should be determined by the severity of symptoms: An initial adult dose of 1.0 to 2.0 mg or pediatric dose of 0.01 mg/kg (minimum 0.01 mg) should be administered intravenously. If intravenous access cannot be established, atropine may also be given subcutaneously or via endotracheal tube. Doses should be repeated every 15 minutes until excessive secretions and sweating have been controlled. Once bronchial secretion has been controlled, atropine administration should be repeated whenever the secretions begin to recur. In seriously poisoned patients, very large doses may be required. Alterations of pulse rate and pupillary size should not be used as indicators of treatment adequacy.

Pralidoxime should be administered as early in poisoning as possible as its efficacy may diminish when given more than 24 to 36 hours after exposure. Doses are as follows: adult 1.0 g; pediatric 25 to 50 mg/kg. The drug should be administered intravenously over 30 to 60 minutes, but in a life-threatening situation, one-half of the total dose can be given per minute for a total administration time of 2 minutes. Treatment should begin to take effect within 40 minutes with a reduction in symptoms and the amount of atropine necessary to control bronchial secretion. The initial dose can be repeated in 1 hour and then every 8 to 12 hours until the patient is clinically well and no longer requires atropine.

Transport to Medical Facility

Only decontaminated patients or patients not requiring decontamination should be transported to a medical facility. “Body bags” are not recommended.

Report to the base station and the receiving medical facility the condition of the patient, treatment given, and estimated time of arrival at the medical facility. Severely ill patients should be taken to a medical facility immediately.

If parathion has been ingested, prepare the ambulance in case the victim vomits toxic material. Have ready several towels and open plastic bags to quickly clean up and isolate vomitus.

Multi-Casualty Triage

Consult with the base station physician or the regional poison control center for advice regarding triage of multiple victims.

Patients with evidence of significant exposure, such as nausea or excessive sweating, and all persons who have ingested parathion should be transported to a medical facility for evaluation. Others may be discharged at the scene after their names, addresses, and telephone numbers are recorded. It is very important to ensure that individuals have been completely decontaminated before discharge; otherwise life-threatening symptoms may occur in the absence of assistance. Those discharged should be advised to seek medical care promptly if symptoms develop (see *Patient Information Sheet* below).

Emergency Department Management

Parathion is highly contaminating. Patients whose skin or clothing is contaminated with liquid or powdered parathion can secondarily contaminate hospital personnel by direct contact or off-gassing of solvent vapor from clothing, skin, or vomitus. Clothing and leather goods (e.g., belts or shoes) cannot be reliably decontaminated; they should be incinerated.

Systemic effects of parathion poisoning can occur from all routes of exposure. Symptoms of parathion poisoning can include headache, nausea, vomiting, abdominal cramps, diarrhea, generalized muscle weakness and twitching, slurred speech, pinpoint pupils, excessive secretions and shortness of breath.

Severely poisoned patients may develop seizures, skeletal-muscle paralysis, cardiac arrhythmias and respiratory failure, or may become comatose.

Commercial parathion products often contain hydrocarbon solvents such as xylene or toluene, which themselves can cause toxicity.

Treatment consists of thorough decontamination, cardiorespiratory support, and administration of the antidotes atropine and pralidoxime. Antidotes should be

Decontamination Area

Unless decontaminated previously, all patients suspected of skin or eye contact with liquid or powdered parathion require decontamination immediately. If a solvent such as xylene or toluene is involved, decontamination should take place outdoors or with proper ventilation.

Health care personnel should don butyl rubber aprons and butyl rubber gloves. If butyl rubber items are not available, limited protection will be provided by two layers of latex gloves and a waterproof apron or chemical-resistant jumpsuit. Wash hands frequently during decontamination and promptly dispose of latex gloves. Personnel who come in contact with parathion secondarily should undergo decontamination.

Be aware that use of protective equipment by the provider may cause fear in children, resulting in decreased compliance with further management efforts.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants absorbed through the skin. Also emergency room personnel should examine children's mouths because of the frequency of hand-to-mouth activity among children.

ABC Reminders

Evaluate and support airway, breathing, and circulation. In cases of respiratory compromise, coma, or to facilitate tracheal suctioning, secure airway and respiration via endotracheal intubation. If not possible, surgically create an airway. Suctioning may be required for excessive bronchial secretions.

Patients who are comatose, hypotensive, or have seizures or ventricular arrhythmias should be treated in the conventional manner.

Basic Decontamination

Patients who are able may assist with their own decontamination. Remove and double-bag contaminated clothing and personal belongings. Dispose of contaminated clothing and leather goods (e.g., belts, wallets, and shoes); they should be incinerated as directed by hazardous materials experts.

Victims should be washed repeatedly with copious amounts of soap and water. Rescuers should wear rubber gloves as vinyl gloves provide no protection against skin absorption. It is important to observe the patient closely for sudden appearance of symptoms. It is important to thoroughly clean hair, fingernails, and skin folds.Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Flush exposed eyes with plain water or saline for 15 minutes. Remove contact lenses if easily removable without additional trauma to the eye. Continue irrigation during transport to the Critical Care Area.

In cases of ingestion, **do not induce emesis**. If the victim is alert and asymptomatic, administer a slurry of activated charcoal if it has not already been given (administer at 1 gm/kg, usual adult dose 60–90 g, child dose 25–50 g). A soda can and straw may be of assistance when offering charcoal to a child.

Critical Care Area

Be certain that appropriate decontamination has been carried out (see *Decontamination Area* above).

ABC Reminders

Evaluate and support airway, breathing, and circulation as in ABC Reminders above. Establish intravenous access in seriously ill patients. Continuously monitor cardiac rhythm.

Patients who are comatose, hypotensive, or have seizures or cardiac arrhythmias should be treated in the conventional manner.

Inhalation Exposure

Administer supplemental oxygen by mask to patients who have respiratory symptoms. Refer to *Antidotes and Other Treatments* below for appropriate clinical treatment.

Skin Exposure

Parathion does not generally burn or irritate the skin, but dermal exposure produces systemic toxicity. Thorough washing of the skin, as described in *Basic Decontamination* above, should be performed and may need to be repeated. Unexplained, persistent symptoms may indicate inadequate decontamination.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants affecting the skin.

Eye Exposure

Continue irrigation for at least 15 minutes. Test visual acuity. Examine the eyes for corneal damage and treat appropriately. Immediately consult an ophthalmologist for patients who have severe corneal injuries.

Ingestion

Do not induce emesis. If the victim is alert and asymptomatic, administer a slurry of activated charcoal if it has not already been given (administer at 1 gm/kg, usual adult dose 60–90 g, child dose 25–50 g). A soda can and straw may be of assistance when offering charcoal to a child.

Gastric lavage is useful in certain circumstances to remove toxic material. Consider gastric lavage with a small nasogastric tube if: (1) a large dose has been ingested; (2) the patient's condition is evaluated within 30 minutes; (3) the patient has oral lesions or persistent esophageal discomfort; and (4) the lavage can be administered within one hour of ingestion. Care must be taken when placing the gastric tube because blind gastric-tube placement may further injure the chemically damaged esophagus or stomach.

Because children do not ingest large amounts of toxic materials, and because of the risk of perforation from NG intubation, lavage is discouraged in children unless performed under endoscopic guidance.

Toxic vomitus or gastric washings should be isolated, e.g., by attaching the lavage tube to isolated wall suction or another closed container.

Antidotes and Other Treatments

All patients who have signs or symptoms of systemic toxicity require antidotal treatment. In the United States, primary antidotal treatment for parathion poisoning involves administration of

atropine. In addition, pralidoxime (2-PAM) is indicated for seriously poisoned patients.

Atropine is a competitive antagonist of acetylcholine at muscarinic receptors and is used to control the excessive bronchial secretions which are often responsible for death. Pralidoxime relieves both the nicotinic and muscarine effects of organophosphate poisoning by regenerating acetylcholinesterase and can reduce both the bronchial secretions and the muscle weakness associated with poisoning.

The initial intravenous dose of atropine in adults should be determined by the severity of symptoms: An initial adult dose of 1.0 to 2.0 mg or pediatric dose of 0.01 mg/kg (minimum 0.01 mg) should be administered intravenously. If intravenous access cannot be established, atropine may also be given subcutaneously or via endotracheal tube. Doses should be repeated every 15 minutes until excessive secretions and sweating have been controlled. Once bronchial secretion has been controlled, atropine administration should be repeated whenever the secretions begin to recur. In seriously poisoned patients, very large doses may be required. Alterations of pulse rate and pupillary size should not be used as indicators of treatment adequacy.

Pralidoxime should be administered as early in poisoning as possible as its efficacy may diminish when given more than 24 to 36 hours after exposure. Doses are as follows: adult 1.0 g; pediatric 25 to 50 mg/kg. The drug should be administered intravenously over 30 to 60 minutes, but in a life-threatening situation, one-half of the total dose can be given per minute for a total administration time of 2 minutes. Treatment should begin to take effect within 40 minutes with a reduction in symptoms and the amount of atropine necessary to control bronchial secretion. The initial dose can be repeated in 1 hour and then every 8 to 12 hours until the patient is clinically well and no longer requires atropine.

Patients who have seizures most often respond to atropine and pralidoxime; however, if they do not respond, administer diazepam or lorazepam.

Avoid other acetylcholinesterase inhibitors (e.g., physostigmine and edrophonium chloride), and do not use succinylcholine for rapid sequence intubation. The paralyzing effects of succinylcholine are likely to be prolonged because it will not be metabolized normally.

Non-depolarizing neuromuscular blockers (e.g., pancuronium and vecuronium) may not be effective because of unsuccessful competition with acetylcholinesterase for the motor end-plate receptors.

Laboratory Tests

The diagnosis of acute parathion toxicity is primarily clinical and is based on the combination of nausea, excessive sweating and salivation, miosis, and muscle weakness. Routine laboratory studies for all exposed patients include CBC, glucose, and electrolyte determinations. A chest radiograph is useful to examine for hydrocarbon aspiration and non-cardiogenic pulmonary edema. Symptomatic and asymptomatic patients suspected of significant exposure should have determinations of plasma and red blood cell (RBC) cholinesterase activity. Symptoms of acute poisoning are usually present when more than 50% of RBC cholinesterase activity is inhibited. However, these tests are not always readily available and are more useful in diagnosis and follow-up. Blood and urine analyses for the presence of parathion or its metabolite may show whether damage has been done to the brain, heart, lungs, and nerves.

Disposition and Follow-up

Patients with life threatening illness must be hospitalized, also consider hospitalizing patients who have a suspected serious exposure and are symptomatic.

Delayed Effects

Skin absorption can cause delayed or recurrent symptoms. Contaminated clothing and leather items (e.g., shoes, wallets, and belts) should not be reused, even if they have been washed.

Aspiration of commercial parathion preparations that contain hydrocarbon solvents can result in chemical pneumonitis.

Chronic neurologic symptoms have been reported for some patients exposed to organophosphates. Symptoms develop after acute toxicity has resolved (24 to 96 hours after exposure) and can include cognitive impairment, depression, Guillian-Barré syndrome, and peripheral neuropathy.

Patient Release

Patients who remain asymptomatic for 4 to 6 hours after exposure may be discharged with instructions to seek medical care promptly if symptoms develop (see *Parathion—Patient Information Sheet* below).

Follow-up

Obtain the name of the patient's primary care physician so that the hospital can send a copy of the ED visit to the patient's doctor.

Patients who have severe exposure should be evaluated for persistent CNS sequelae and delayed peripheral neuropathy.

Patients who have been acutely poisoned should be advised to avoid further organophosphate exposure until sequential RBC

cholinesterase levels have stabilized in the normal range, a process that may take 3 to 4 months after severe poisoning.

Patients who have corneal injuries or severe skin burns should be reexamined within 24 hours.

Reporting

If a work-related incident has occurred, you may be legally required to file a report; contact your state or local health department.

Other persons may still be at risk in the setting where this incident occurred. If the incident occurred in the workplace, discussing it with company personnel may prevent future incidents. If a public health risk exists, notify your state or local health department or other responsible public agency. When appropriate, inform patients that they may request an evaluation of their workplace from OSHA or NIOSH. See Appendices III and IV for a list of agencies that may be of assistance.

Parathion
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to parathion.

What is parathion?
Parathion is a potent organophosphate pesticide. It is a pale yellow-to-brown liquid with an odor like garlic. It is used by farmers as a pesticide on fruits, vegetables, nuts, and grains. Commercial pesticides often contain a hydrocarbon solvent, which itself can cause illness.

What immediate health effects can be caused by exposure to parathion?
Parathion can cause nausea, vomiting, stomach cramps, and diarrhea, as well as confusion, blurred vision, sweating, muscle twitching, irregular heartbeat, convulsions, and death. Symptoms occur when parathion is inhaled, swallowed or absorbed through the skin. Breathing the solvent used to dissolve the pesticide may cause dizziness, headache, and nausea. Generally, the more serious the exposure, the more severe the symptoms.

Can parathion poisoning be treated?
For minor exposures (for example, breathing the pesticide solvent), the only treatment needed is fresh air. For serious parathion poisoning, thorough washing of all exposed skin, removal and burning of exposed clothing, and hospitalization and administration of an antidote may be needed.

Are any future health effects likely to occur?
A single small exposure from which a person recovers quickly is not likely to cause delayed or long-term effects. After a serious exposure, a patient may feel ill for several weeks.

What tests can be done if a person has been exposed to parathion?
Specific tests for the presence of parathion or its breakdown product in blood and urine generally are not useful to the doctor. If a severe exposure has occurred, blood and urine analyses and other tests may show whether damage has been done to the brain, heart, lungs, and nerves. Testing is not needed in every case.

Where can more information about parathion be found?
More information about parathion can be obtained from your regional poison control center; your state, county, or local health department; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in occupational and environmental health. If the exposure happened at work, you may wish to discuss it with your employer, the Occupational Safety and Health Administration (OSHA), or the National Institute for Occupational Safety and Health (NIOSH). Ask the person who gave you this form for help in locating these telephone numbers.

Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow *only* the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:

- irritability, confusion, or fatigue
- coughing, wheezing, or shortness of breath
- nausea, vomiting, cramps, or diarrhea
- muscle weakness or twitching
- blurred vision

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.
[ ] Call for an appointment with Dr. _____ in the practice of _____.
When you call for your appointment, please say that you were treated in the Emergency Department at _____ _____ Hospital by _____ and were advised to be seen again in _____ days.
[ ] Return to the Emergency Department/ _____ Clinic on (date) _____at _____ _____ AM/PM for a follow-up examination.
[ ] Do not perform vigorous physical activities for 1 to 2 days.
[ ] You may resume everyday activities including driving and operating machinery.
[ ] Do not return to work for _____ days.
[ ] You may return to work on a limited basis. See instructions below.
[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.
[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.
[ ] Avoid taking the following medications: _____
[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: __
_____
_____
[ ] Other instructions: _____
_____
_____

- Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.

- You or your physician can get more information on the chemical by contacting: _____ _____ or _____, or by checking out the following Internet Web sites: ___ _____; _____.

Signature of patient _____ Date _____

Signature of physician _____ Date _____

Phenol (C_6H_5OH)
CAS 108-95-2; UN 1671 (solid), 2312 (molten), 2821 (solution)

Synonyms include carbolic acid, hydroxybenzene, monohydroxybenzene, benzenol, monophenol, phenyl hydroxide, phenyl alcohol, phenic acid, phenylic acid, and phenylic alcohol.

- **Persons exposed only to phenol vapor do not pose substantial risks of secondary contamination. Persons whose clothing or skin is contaminated with liquid phenol can secondarily contaminate personnel by direct contact or through off-gassing vapor.**
- **Phenol is a flammable, highly corrosive chemical with a sickeningly sweet, acrid odor. Phenol's odor generally provides adequate warning of hazardous concentrations.**
- **Phenol is well absorbed by all routes of exposure. Exposure by any route can cause systemic effects.**

Description

At room temperature, phenol is a translucent, colorless, crystalline mass, white powder, or thick, syrupy liquid. The crystals are hygroscopic and turn pink to red in air. When pure, phenol has a sweet, tar-like odor that is readily detected at low concentrations (0.05 ppm in air). Phenol is soluble in alcohol, glycerol, petroleum, and, to a lesser extent, water. Phenol is designated as "Poison B" by the Department of Transportation (DOT), but no special containers are required due to its modest fire hazard and low reactivity.

Routes of Exposure

Inhalation

Phenol is absorbed rapidly from the lungs. However, because of its low volatility, inhalation hazard is limited. The odor threshold of phenol is about 100 times lower than the OSHA PEL; therefore, it provides adequate warning of hazardous concentrations. Phenol vapor is heavier than air.

Children exposed to the same levels of phenol vapor as adults may receive larger doses because they have greater lung surface area:body weight ratios and increased minute volumes:weight ratios. Children may be more vulnerable to corrosive agents than adults because of the relatively smaller diameter of their airways. In addition, they may be exposed to higher levels than adults in the same location because of their short stature and the higher levels of phenol vapor found nearer to the ground.

Skin/Eye Contact

All forms of phenol cause irritation, and acute toxic effects of phenol most often occur by skin contact. Even dilute solutions (1% to 2%) may cause severe burns if contact is prolonged. Systemic

toxicity can result from skin or eye exposures. Phenol vapor and liquid penetrate the skin with an absorption efficiency approximately equal to the absorption efficiency by inhalation. In one case, death occurred within 30 minutes after skin contact.

Children are more vulnerable to toxicants absorbed through the skin because of their relatively larger surface area:body weight ratio.

Ingestion

Accidental and intentional ingestions of phenol have been reported. As little as 50 to 500 mg has been fatal in infants. Deaths in adults have resulted after ingestions of 1 to 32 g.

Sources/Uses

Phenol is obtained by fractional distillation of coal tar and by organic synthesis. By far, its largest single use is in manufacture of phenolic resins and plastics. Other uses include manufacture of explosives, fertilizers, paints, rubber, textiles, adhesives, drugs, paper, soap, wood preservatives, and photographic developers. When mixed with slaked lime and other reagents, phenol is an effective disinfectant for toilets, stables, cesspools, floors, and drains.

Phenol was once an important antiseptic and is still used as a preservative in injectables. It also is used as an antipruritic, a cauterizing agent, a topical anesthetic, and as a chemical skin-peeler (chemexfoliant). It can be found in low concentrations in many over-the-counter products including preparations for treatment of localized skin disorders (Castellani's paint, PRID salve, CamphoPhenique lotion), in topical preparations (Sting-Eze), and in throat sprays and lozenges (Chloraseptic, Ambesol, Cepastat, Cheracol).

Standards and Guidelines

OSHA PEL (permissible exposure limit) = 5 ppm (skin) (averaged over an 8-hour workshift)

NIOSH IDLH (immediately dangerous to life or health) = 250 ppm

AIHA ERPG-2 (emergency response planning guideline) (maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms which could impair an individual's ability to take protective action) = 50 ppm

Physical Properties

Description: Colorless to pink crystalline mass or white powder, syrupy liquid when mixed with water.

Warning properties: Adequate; sweet, acrid odor at > 0.05 ppm

Molecular weight: 94.1 daltons

Boiling point (760 mm Hg): 359 °F (182 °C)

Freezing point: 104.9 °F (43 °C)

Specific gravity: 1.06 at 68 °F (20 °C) (water = 1)

Vapor pressure: 0.36 mm Hg at 68 °F (20 °C)

Gas density: 3.24 (air = 1)

Water solubility (9% at 77 °F) (25 °C); hygroscopic

Flammability: 175 °F (79 °C)

Flammable range: 1.7% to 8.6% (concentration in air)

Incompatibilities

Phenol reacts with strong oxidizers, calcium hypochlorite, aluminum chloride, and acids.

Health Effects

Exposure to phenol by any route can produce systemic poisoning. Phenol is corrosive and causes chemical burns at the contact site.

Symptoms of systemic poisoning often involve an initial, transient CNS stimulation, followed rapidly by CNS depression. Coma and seizures can occur within minutes or may be delayed up to 18 hours after exposure.

Other symptoms include nausea, vomiting, diarrhea, methemoglobinemia, hemolytic anemia, profuse sweating, hypotension, arrhythmia, pulmonary edema, and tachycardia.

Acute Exposure

As a corrosive substance, phenol denatures proteins and generally acts as a protoplasmic poison. Phenol may also cause peripheral nerve damage (i.e., demyelination of axons). Systemic poisoning can occur after inhalation, skin contact, eye contact, or ingestion. Typically, transient CNS excitation occurs, then profound CNS depression ensues rapidly. Damage to the nervous system is the primary cause of death from phenol poisoning. However, damage to other organ systems (e.g., acid-base imbalance and acute kidney failure) may complicate the condition. Symptoms may be delayed for up to 18 hours after exposure.

Children do not always respond to chemicals in the same way that adults do. Different protocols for managing their care may be needed.

CNS

Initial signs and symptoms may include nausea, excessive sweating, headache, dizziness, and ringing in the ears. Seizures, loss of consciousness, coma, respiratory depression, and death may ensue. Coma and seizures usually occur within minutes to a few hours after exposure but may be delayed up to 18 hours.

Cardiovascular

Phenol exposure causes initial blood pressure elevation, then progressively severe low blood pressure and shock. Cardiac arrhythmia and bradycardia have also been reported following dermal exposure to phenol.

Respiratory

Mild exposure may cause upper respiratory tract irritation. With more serious exposure, swelling of the throat, inflammation of the trachea, tracheal ulceration, and an accumulation of fluid in the lungs can occur. Ingestion may lead to death from respiratory failure.

Children may be more vulnerable to corrosive agents than adults because of the relatively smaller diameter of their airways.

Children may be more vulnerable because of relatively increased minute ventilation per kg and failure to evacuate an area promptly when exposed.

Gastrointestinal

Nausea, vomiting, abdominal pain, and diarrhea are common symptoms after exposure to phenol by any route. Ingestion of phenol can also cause severe corrosive injury to the mouth, throat, esophagus, and stomach, with bleeding, perforation, scarring, or stricture formation as potential sequelae.

Renal

Renal failure has been reported in acute poisoning. Urinalysis may reveal the presence of protein (i.e., albuminuria), casts, and a green-to-brown discoloration of the urine.

Hematologic

Components of the blood and blood-forming organs can be damaged by phenol.

Most hematologic changes (e.g., hemolysis, methemoglobinemia, bone marrow suppression, and anemia) can be detected by blood tests or simply by the color or appearance of the blood.

Methemoglobinemia is a concern in infants up to 1 year old. Children may be more vulnerable to loss of effectiveness of hemoglobin because of their relative anemia compared to adults.

Ocular

Contact with concentrated phenol solutions can cause severe eye damage including clouding of the eye surface, inflammation of the eye, and eyelid burns.

Dermal

When phenol is applied directly to the skin, a white covering of precipitated protein forms. This soon turns red and eventually sloughs, leaving the surface stained slightly brown. If phenol is left on the skin, it will penetrate rapidly and lead to cell death and gangrene. If more than 60 square inches of skin are affected, there is risk of imminent death. Phenol appears to have local anesthetic properties and can cause extensive damage before pain is felt.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants absorbed through the skin.

Potential Sequelae

Chronic nerve damage has been reported due to acute exposure. Chemical burns may result in chronic skin and eye effects. Phenol

ingestion may lead to narrowing of the esophagus, and cardiac and renal damage.

Chronic Exposure

Repeated phenol exposure in the workplace has caused renal damage including kidney inflammation, swelling in the kidney tubules and cells, and degenerative changes in glomeruli. Liver damage and pigment changes of the skin have been noted in some workers. Chronic exposure has also been correlated with an increased risk of coronary artery disease and insufficient blood supply to the heart in workers.

Chronic exposure may be more serious for children because of their potential longer latency period.

Carcinogenicity

Phenol has not been classified for carcinogenic effects. Phenol is, however, a known promoter of tumors.

Reproductive and Developmental Effects

Phenol is not included in *Reproductive and Developmental Toxicants*, a 1991 report published by the U.S. General Accounting Office (GAO) that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences. No reports were located of developmental or reproductive effects of phenol in humans. In animal studies phenol has been reported to be embryotoxic and fetotoxic, but not teratogenic. In experimental animals, phenol has generally not caused developmental effects except at doses that also caused maternal toxicity.

Special consideration regarding the exposure of pregnant women is warranted, since phenol has been shown to be genotoxic at high doses; thus, medical counseling is recommended for the acutely exposed pregnant woman. No known teratogenic effects from acute exposure are known.

Prehospital Management

Victims exposed only to phenol vapor do not pose substantial risks of secondary contamination. Victims whose clothing or skin is contaminated with liquid phenol can secondarily contaminate response personnel by direct contact or through off-gassing vapor from heavily soaked clothing. Protect rescue personnel with butyl rubber gloves and aprons. Phenol vapor may also off-gas from the toxic vomitus of victims who have ingested phenol.

Phenol is corrosive and causes severe chemical burns on contact. Systemic effects can occur from all routes of exposure and may include convulsions, sudden collapse, coma, nausea, vomiting, diarrhea, methemoglobinemia, hemolytic anemia, profuse sweating, hypotension, arrhythmia, pulmonary edema, and tachycardia.

There is no antidote for phenol. Rapid decontamination may greatly affect the odds of survival. Treatment consists of support of respiratory and cardiovascular functions.

Hot Zone

Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if rescuers have not been trained in its use, assistance should be obtained from a local or regional HAZMAT team or other properly equipped response organization.

Rescuer Protection

Phenol is a severe irritant and highly toxic systemic poison that is absorbed well by inhalation and through the skin.

Respiratory Protection: Positive-pressure, self-contained breathing apparatus (SCBA) is recommended in response situations that involve exposure to potentially unsafe levels of phenol vapor.

Skin Protection: Chemical-protective clothing (butyl rubber gloves and aprons) is recommended because phenol liquid and vapor can be quickly absorbed through the skin and may contribute to systemic toxicity. Contact with liquid phenol can cause severe skin burns.

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible.

Victim Removal

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be removed on backboards or gurneys; if these are not available, carefully carry or drag victims to safety.

Consider appropriate management of chemically contaminated children, such as measures to reduce separation anxiety if a child is separated from a parent or other adult.

Decontamination Zone

Patients exposed only to phenol vapor who have no skin or eye irritation may be transferred immediately to the Support Zone. Other patients will require decontamination as described below.

Rescuer Protection

If exposure levels are determined to be safe, decontamination may be conducted by personnel wearing a lower level of protection than that worn in the Hot Zone (described above).

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. Stabilize the cervical spine with a collar and a backboard if trauma is suspected. Administer supplemental oxygen as required. Assist ventilation with a bag-valve-mask device if necessary.

Basic Decontamination

Rapid skin decontamination is critical. Patients who are able may assist with their own decontamination.

Rescuers should wear protective clothing and gloves while treating patients whose skin is contaminated with phenol. Remove contaminated clothing rapidly and either irrigate or wipe exposed areas immediately and repeatedly with low-molecular-weight polyethylene glycol (PEG 300 or PEG 400) which can be diluted to 50% for easier application. Treatment should be continued until there is no detectable odor of phenol. If PEG is not available, a glycerine solution can be used instead. If neither of these are available, irrigation with a high-density shower will reduce phenol uptake, but lesser amounts of water will merely dilute the phenol and expand the area of exposure. After treatment with the high pressure shower, the skin should be washed with soap and water for at least 15 minutes. **Decontamination must begin as soon as possible to minimize phenol absorption.** Double-bag contaminated clothing and personal belongings.

Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Flush exposed or irritated eyes with copious amounts of water or saline for at least 15 minutes. Remove contact lenses if easily removable without additional trauma to the eye. If a corrosive material is suspected or if pain or injury is evident, continue irrigation while transferring the victim to the Support Zone.

In cases of ingestion, **do not induce emesis**. If the victim is alert, asymptomatic, and has a gag reflex, administer a slurry of activated

charcoal at 1 gm/kg (usual adult dose 60–90 g, child dose 25–50 g). A soda can and straw may be of assistance when offering charcoal to a child.

Victims who are conscious and able to swallow should be given 4 to 8 ounces of milk, egg whites, or gelatin solution; if the patient is symptomatic, delay decontamination until other emergency measures have been instituted.

Consider appropriate management of chemically contaminated children at the exposure site. Provide reassurance to the child during decontamination, especially if separation from a parent occurs.

Transfer to Support Zone

As soon as basic decontamination is complete, move victims to the Support Zone.

Support Zone

Be certain that victims have been decontaminated properly (see *Decontamination Zone* above). Victims who have undergone decontamination or who have been exposed only to vapor generally pose no serious risks of secondary contamination. In such cases Support Zone personnel require no specialized protective gear.

ABC Reminders

Quickly access for a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Ensure adequate respiration and pulse. Administer supplemental oxygen as required and establish intravenous access if necessary. Place on a cardiac monitor.

Additional Decontamination

Continue irrigating exposed skin and eyes, as appropriate.

In cases of ingestion, **do not induce emesis**. If the victim is alert, asymptomatic, and has a gag reflex, administer a slurry of activated charcoal at 1 gm/kg (usual adult dose 60–90 g, child dose 25–50 g), if it has not been given previously. A soda can and straw may be of assistance when offering charcoal to a child.

Victims who are conscious and able to swallow should be given 4 to 8 ounces of milk, egg whites, or gelatin solution if this has not been given previously; or, if the patient is symptomatic, delay decontamination until other emergency measures have been instituted.

Advanced Treatment

In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, perform cricothyroidotomy if equipped and trained to do so.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly).

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Patients who are comatose, hypotensive, or are having seizures or cardiac arrhythmias should be treated according to advanced life support (ALS) protocols.

Transport to Medical Facility

Only decontaminated patients or patients not requiring decontamination should be transported to a medical facility. "Body bags" are not recommended.

Report to the base station and the receiving medical facility the condition of the patient, treatment given, and estimated time of arrival at the medical facility.

If a chemical has been ingested, prepare the ambulance in case the victim vomits toxic material. Have ready several towels and open plastic bags to quickly clean up and isolate vomitus.

Multi-Casualty Triage

Consult with the base station physician or the regional poison control center for advice regarding triage of multiple victims.

Patients with significant exposures, skin burns over a large body-surface area, who have ingested phenol, or who have experienced serious symptoms such as syncope or convulsions should be transported to a medical facility for evaluation. (The severity of exposure can be estimated by the concentration of phenol and the amount and duration of contact.)

Persons who have been exposed only to phenol vapor and are asymptomatic are not likely to develop complications. After their names, addresses, and telephone numbers are recorded, these patients may be released from the scene with instructions to seek medical care promptly if symptoms develop (see *Patient Information Sheet* below).

Emergency Department Management

Hospital personnel can be secondarily contaminated by direct contact or from vapor off-gassing from heavily soaked clothing or from the vomitus of victims who have ingested phenol. Protect hospital personnel with butyl gloves and aprons. Patients do not pose contamination risks after contaminated clothing is removed and the skin is thoroughly washed.

Phenol is corrosive and causes severe chemical burns on contact. Systemic effects can occur from all routes of exposure and may include convulsions, sudden collapse, coma, nausea, vomiting, diarrhea, methemoglobinemia, hemolytic anemia, profuse sweating, hypotension, arrhythmia, pulmonary edema, and tachycardia.

There is no antidote for phenol. Rapid decontamination may greatly affect the odds of survival. Treatment consists of support of respiratory and cardiovascular functions.

Decontamination Area

Unless previously decontaminated, all patients suspected of contact with liquid phenol and all victims with skin or eye irritation require decontamination as described below. Because phenol is absorbed through the skin, don butyl rubber gloves and apron before treating patients. Phenol readily penetrates most rubbers and barrier fabrics or creams, but butyl rubber provides good skin protection. All other patients may be transferred to the Critical Care area.

Be aware that use of protective equipment by the provider may cause fear in children, resulting in decreased compliance with further management efforts.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants absorbed through the skin. Also, emergency room personnel should examine children's mouths because of the frequency of hand-to-mouth activity among children.

ABC Reminders

Evaluate and support airway, breathing, and circulation. Children may be more vulnerable to corrosive agents than adults because of the relatively smaller diameter of their airways. In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, surgically create an airway.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents

may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly).

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Patients who are comatose, hypotensive, or have seizures or ventricular arrhythmias should be treated in the conventional manner.

If evidence of shock or hypotension is observed begin fluid administration. For adults, bolus 1,000 mL/hour intravenous saline or lactated Ringer's solution if blood pressure is under 80 mm Hg; if systolic pressure is over 90 mm Hg, an infusion rate of 150 to 200 mL/hour is sufficient. For children with compromised perfusion administer a 20 mL/kg bolus of normal saline over 10 to 20 minutes, then infuse at 2 to 3 mL/kg/hour.

Basic Decontamination

Rapid skin decontamination is critical. Patients who are able may assist with their own decontamination.

Rescuers should wear protective clothing and gloves while treating patients whose skin is contaminated with phenol. Remove contaminated clothing rapidly and either irrigate or wipe exposed areas immediately and repeatedly with low-molecular-weight polyethylene glycol (PEG 300 or PEG 400) which can be diluted to 50% for easier application. Treatment should be continued until there is no detectable odor of phenol. If PEG is not available, a glycerine solution can be used instead. If neither of these are available, irrigation with a high-density shower will reduce phenol uptake, but lesser amounts of water will merely dilute the phenol and expand the area of exposure. After treatment with the high pressure shower, the skin should be washed with soap and water for at least 15 minutes. **Decontamination must begin as soon as possible to minimize phenol absorption.** Double-bag contaminated clothing and personal belongings.

Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Flush exposed or irritated eyes with copious amounts of water or saline for at least 15 minutes. Remove contact lenses if easily removable without additional trauma to the eye. If a corrosive

material is suspected or if pain or injury is evident, continue irrigation while transferring the patient to the Critical Care Area.

In cases of ingestion, **do not induce emesis**. If the victim is alert, asymptomatic, and has a gag reflex, administer a slurry of activated charcoal at 1 gm/kg (usual adult dose 60–90 g, child dose 25–50 g), if it has not been previously given. A soda can and straw may be of assistance when offering charcoal to a child.

Victims who are conscious and able to swallow should be given 4 to 8 ounces of milk, egg whites, or gelatin solution if this has not been given previously; if the patient is symptomatic delay decontamination until other emergency measures have been instituted.

Critical Care Area

Be certain that appropriate decontamination has been carried out (see *Decontamination Area* above).

ABC Reminders

Evaluate and support airway, breathing, and circulation as in ABC Reminders above. Children may be more vulnerable to corrosive agents than adults because of the relatively smaller diameter of their airways. Establish intravenous access in seriously ill patients if this has not been done previously. Continuously monitor cardiac rhythm.

Patients who are comatose, hypotensive, or have seizures or cardiac arrhythmias should be treated in the conventional manner.

Inhalation Exposure

Administer supplemental oxygen by mask to patients who have respiratory symptoms. Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly).

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Patients in respiratory distress or who have abnormal pulmonary examinations may require chest radiography and pulse oximetry (or ABG measurements). Beta-blockers may be more effective than lidocaine in treating patients who have arrhythmias.

Skin Exposure

If liquid phenol came in contact with the skin, chemical burns may result; treat as thermal burns.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants absorbed through the skin.

Eye Exposure

Continue irrigation for at least 15 minutes. Test visual acuity. Examine the eyes for corneal damage and treat appropriately. Immediately consult an ophthalmologist for patients who have severe corneal injuries.

Ingestion Exposure

Do not induce emesis. If the patient is alert, administer a slurry of activated charcoal at 1 gm/kg (usual adult dose 60–90 g, child dose 25–50 g), if not done previously. A soda can and straw may be of assistance when offering charcoal to a child.

Victims who are conscious and able to swallow should be given 4 to 8 ounces of milk, egg whites, or gelatin solution if this has not been given previously; if the patient is symptomatic, delay decontamination until other emergency measures have been instituted.

Consider endoscopy to evaluate the extent of gastrointestinal tract injury. Extreme throat swelling may require endotracheal intubation or cricothyroidotomy. Gastric lavage is useful in certain circumstances to remove caustic material and prepare for endoscopic examination. Consider gastric lavage with a small nasogastric tube if: (1) a large dose has been ingested; (2) the patient's condition is evaluated within 30 minutes; (3) the patient has oral lesions or persistent esophageal discomfort; and (4) the lavage can be administered within 1 hour of ingestion. Care must be taken when placing the gastric tube because blind gastric-tube placement may further injure the chemically damaged esophagus or stomach.

Because children do not ingest large amounts of corrosive materials, and because of the risk of perforation from NG intubation, lavage is discouraged in children unless performed under endoscopic guidance.

Toxic vomitus or gastric washings should be isolated (e.g., by attaching the lavage tube to isolated wall suction or another closed container).

Antidotes and

Other Treatments

There is no antidote for phenol. Although charcoal hemoperfusion can remove free phenol from the blood and exchange transfusion has been suggested for phenol poisoning, the clinical value of these procedures is unproven.

Patients should be checked for methemoglobinemia. Symptomatic patients should be treated by slowly administering 1 to 2 mg/kg of 1% methylene blue intravenously. Further doses may be required.

Laboratory Tests

The diagnosis of acute phenol toxicity is primarily clinical based on CNS depression and other symptoms such as skin burns, nausea, profuse sweating, and cardiac arrhythmia. Routine laboratory studies for all exposed patients include CBC, glucose, and electrolyte determinations. Depending on the initial evaluation, additional studies for patients exposed to phenol include ECG monitoring and kidney-function tests. Laboratory tests to determine hemolysis include peripheral blood smear, urinalysis, and plasma free hemoglobin and haptoglobin analyses. Chest radiography and pulse oximetry (or ABG measurements) are also recommended for severe inhalation exposure or if pulmonary aspiration is suspected.

Urinary phenol levels above 81.5 mg/L or creatinine levels above 250 mg/g suggest overexposure.

Disposition and Follow-up

Consider hospitalizing patients who have evidence of systemic toxicity from any route of exposure.

Delayed Effects

Because pulmonary edema or CNS effects may be delayed, patients who have suspected serious exposure should be observed and reexamined periodically for 18 to 24 hours.

Patient Release

Patients who have mild exposure and remain asymptomatic for 2 to 4 hours may be discharged with instructions to seek medical care promptly if symptoms develop (see the *Phenol—Patient Information Sheet* below).

Follow-up

Obtain the name of the patient's primary care physician so that the hospital can send a copy of the ED visit to the patient's doctor.

Patients who have skin or eye burns should be reexamined in 24 hours. Patients with significant phenol intoxication may be at risk and should be monitored for long-term CNS (peripheral neuropathy) gastrointestinal, and cardiac and renal damage.

Reporting

If a work-related incident has occurred, you may be legally required to file a report; contact your state or local health department.

Other persons may still be at risk in the setting where this incident occurred. If the incident occurred in the workplace, discussing it with company personnel may prevent future incidents. If a public health risk exists, notify your state or local health department or other responsible public agency. When appropriate, inform patients that they may request an evaluation of their workplace from OSHA or NIOSH. See Appendices III and IV for a list of agencies that may be of assistance.

Phenol
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to phenol.

What is phenol?
Phenol may be found as a translucent, clear, or light-pink crystalline mass; a white powder, or a clear liquid. It has a sweet, sharp odor. Phenol is used in many commercially available products including plastics, resins, fertilizers, paints, photographic developers, and some medicines.

What immediate health effects can result from exposure to phenol?
Poisoning can occur when phenol gets on the skin or in the eyes, when it is inhaled, or when it is swallowed. Skin and eyes can be mildly or severely burned, depending on how much and how long the phenol was in contact with them. Breathing phenol vapors can burn the lining of the nose, throat, and lungs, just as it burns the skin. Severe injury to the lungs can cause them to fill with fluid, making breathing difficult. Swallowing phenol burns the lining of the digestive tract and can result in internal bleeding. Generally, the more serious the exposure, the more severe the symptoms. Phenol is absorbed easily into the body through the skin, lungs, and stomach. The brain is very sensitive to phenol. Phenol can cause seizures and coma and may interfere with the brain's control of regular breathing patterns. It can cause dangerous rhythm changes in the heart.

Can phenol poisoning be treated?
There is no antidote for phenol, but its effects can be treated, and most exposed persons do get well. Persons who have had a serious exposure may need to be hospitalized. If phenol got in your eyes, the doctor may put a special dye in your eyes and examine them with a magnifying device. If you swallowed phenol, you may have been given a solution containing charcoal, which will soak up phenol in your stomach.

Are any future health effects likely to occur?
A single small exposure from which a person recovers quickly is not likely to cause delayed or long-term effects. After a severe exposure, you may not notice any symptoms for up to 24 hours.

What tests can be done if a person has been exposed to phenol?
Depending on the severity of symptoms, the doctor may order blood tests, urine tests, chest x-ray, and a heart monitoring test. These tests may show whether damage has been done to the heart, kidneys, lungs, or nervous system, Abnormally high amounts of phenol may be found in the urine if exposure was severe. Testing is not needed in every case.

Where can more information about phenol be found?
More information about phenol can be obtained from your regional poison control center; your state, county, or local health department; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in occupational and environmental health. If the exposure happened at work, you may wish to discuss it with your employer, the Occupational Safety and Health Administration (OSHA), or the National Institute for Occupational Safety and Health (NIOSH). Ask the person who gave you this form for help in locating these telephone numbers.

Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow *only* the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:
coughing or wheezing
difficulty breathing, shortness of breath or chest pain
irregular heartbeats, pounding or fluttering in your chest
increased pain, swelling, redness, or a pus-like discharge where skin is burned
unexplained drowsiness, dizziness, headache, or fainting

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.
[ ] Call for an appointment with Dr. _____ in the practice of _____.
When you call for your appointment, please say that you were treated in the Emergency Department at _____ Hospital by _____ and were advised to be seen again in _____ days.
[ ] Return to the Emergency Department/ _____ Clinic on (date) _____at __ _____ AM/PM for a follow-up examination.
[ ] Do not perform vigorous physical activities for 1 to 2 days.
[ ] You may resume everyday activities including driving and operating machinery.
[ ] Do not return to work for _____ days.
[ ] You may return to work on a limited basis. See instructions below.
[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.
[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.
[ ] Avoid taking the following medications: _____
[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: __
_____
_____
[ ] Other instructions: _____
_____
_____

- Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.

- You or your physician can get more information on the chemical by contacting: _____ _____ or _____, or by checking out the following Internet Web sites: _____; _____.

Signature of patient _____ Date _____

Signature of physician _____ Date _____

Phosgene ($COCl_2$)
CAS 75-44-5; UN 1076

Synonyms include carbonic acid dichloride, carbonic dichloride, carbon oxychloride, carbonyl chloride, and chloroformyl chloride.

Persons exposed only to phosgene gas do not pose substantial risks of secondary contamination. Persons whose clothing or skin is contaminated with liquid phosgene (ambient temperature below 47 °F) can secondarily contaminate response personnel through direct contact or off-gassing vapor.

At room temperature, phosgene is a colorless, nonflammable gas with a suffocating odor like new mown hay. However, odor provides insufficient warning of hazardous concentrations. At high concentrations it is mildly irritating.

Below 47 °F, it is a colorless, fuming liquid; contact with the liquid can cause frostbite. In the presence of water (sweat, saliva, tears), the liquid or gas slowly hydrolyzes to hydrochloric acid, which can irritate and damage cells.

Phosgene is absorbed to some extent by the lungs, but not by intact skin. Systemic damage is usually a secondary result of anoxia caused by loss of lung function. It is corrosive to the lungs and intact skin.

Description

Phosgene is a colorless, fuming liquid below 47 °F (8.2 °C) and a colorless, nonflammable gas above 47 °F. At low concentrations, its odor is similar to that of green corn or new mown hay; at high concentrations, its odor can be sharp and suffocating. Phosgene is slightly soluble in water and is hydrolyzed slowly by moisture to form hydrochloric acid. It is soluble in most liquid hydrocarbons. It is shipped as a liquefied, compressed gas. Large quantities of phosgene should be stored in a dry, cool, well-ventilated, and fireproof room. Phosgene is a combustion product of many household products that contain volatile organochlorine compounds. Therefore, it may contribute to the hazards of smoke inhalation in fire victims and firefighters.

Routes of Exposure

Inhalation

Inhalation is the major route of phosgene exposure. The odor threshold for phosgene is 5 times higher than the OSHA PEL. **Thus, odor provides insufficient warning of hazardous concentrations**. Phosgene's irritating quality can be mild and delayed, which may result in a lack of avoidance leading to exposure for prolonged periods. Phosgene is heavier than air and may cause asphyxiation in poorly ventilated, low-lying, or enclosed spaces.

Children exposed to the same levels of phosgene gas as adults may receive larger doses because they have greater lung surface area:body weight ratios and increased minute volumes:weight ratios. In addition, they may be exposed to higher levels than adults in the same location because of their short stature and the higher levels of phosgene gas found nearer to the ground.

Skin/Eye Contact

When phosgene gas contacts moist or wet skin, it may cause irritation and erythema. High airborne concentrations can also cause corneal inflammation and opacification. Direct contact with liquid phosgene under pressure can cause frostbite as well as severe irritation and corrosive effects.

Children are more vulnerable to toxicants affecting the skin because of their relatively larger surface area:body weight ratio.

Ingestion

Ingestion of phosgene is unlikely because it is a gas at room temperature.

Sources/Uses

Phosgene is produced commercially by chlorinating carbon monoxide. It is a combustion or decomposition by-product of most volatile chlorinated compounds; therefore, household substances such as certain solvents, paint removers, and dry-cleaning fluids can produce phosgene when exposed to heat or fire. Phosgene may also be produced during the welding of metal parts that have been cleaned with chlorinated hydrocarbons. Phosgene is used as an intermediate in the manufacture of many chemicals including isocyanates, polyurethane, polycarbonates, dyes, pesticides, and pharmaceuticals.

Standards and Guidelines

OSHA PEL (permissible exposure limit) = 0.1 ppm (averaged over a 8-hour workshift)

NIOSH IDLH (immediately dangerous to life or health) = 2 ppm

AIHA ERPG-2 (emergency response planning guideline) (maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms which could impair an individual's ability to take protective action) = 0.2 ppm

Physical Properties

Description: Colorless gas with musty odor at room temperature; a fuming liquid below 47 °F (8 °C).

Warning properties: Detectable odor following brief emergency releases; odor threshold 0.4 to 1.5 ppm; slightly irritating in high concentration. **Odor provides inadequate warning of harmful concentrations**.

Molecular weight: 98.9 daltons

Boiling point: (760 mm Hg): 47 °F (8 °C)

Freezing point: -198 °F (-127 °C)

Specific gravity: 1.43 (liquid at 32 °F)

Vapor pressure: 1,215 mm Hg at 68 °F (20 °C)

Gas density: 3.48 (air = 1)

Water solubility: Slight

Flammability: Nonflammable gas

Incompatibilities

Phosgene reacts with moisture (water or alcohols). In water, it slowly decomposes to hydrochloric acid and carbon dioxide. When heated to decomposition, it will produce toxic and corrosive fumes. Phosgene reacts violently with various chemicals (e.g., alkalis, ammonia, amines, copper, aluminum); it attacks many metals in the presence of water and can also attack plastic and rubber.

Health Effects

Phosgene is an irritant to the skin, eyes, and respiratory tract; there may be minimal irritation immediately after exposure, but delayed damage may be severe.

Common initial symptoms include mild irritation of the eyes and throat, with some coughing, choking, feeling of tightness in the chest, nausea and occasional vomiting, headache, and lacrimation.

Phosgene poisoning may cause respiratory and cardiovascular failure, which results from low plasma volume, increased hemoglobin concentration, low blood pressure, and an accumulation of fluid in the lungs. Secondary systemic damage is the result of anoxia.

Acute Exposure

Phosgene directly reacts with amine, sulfhydryl, and alcohol groups in cells, thereby adversely affecting cell macromolecules and cell metabolism. Direct toxicity to the cells leads to an increase in capillary permeability, resulting in large shifts of body fluid, decreasing plasma volume. In addition, when phosgene hydrolyzes, it forms hydrochloric acid, which can also damage surface cells and cause cell death in the alveoli and bronchioles. Hydrochloric acid release into the mucosa triggers a systemic inflammatory response. Phosgene stimulates the synthesis of lipoxygenase-derived leukotrienes, which attract neutrophils and causes their massive accumulation in the lungs; this contributes to the development of pulmonary edema. Following phosgene exposure, a patient may be free of symptoms for 30 minutes to 48 hours before respiratory damage becomes evident; the more severe the exposure, the shorter the latency. If the initial concentration of phosgene was high, rapid onset of direct cytotoxicity and enzymatic poisoning may ensue. Because phosgene is not very water soluble and hydrolysis tends to be slow, victims inhaling low concentrations of the gas may experience no irritation or only mild irritation of the upper airway. Lack of irritation allows victims to inhale the gas more deeply into the lungs and for prolonged periods.

Children do not always respond to chemicals in the same way that adults do. Different protocols for managing their care may be needed.

Respiratory

Inhaling low concentrations of phosgene may cause no signs or symptoms initially, or symptoms may be due only to mild irritation of the airways; these symptoms (dryness and burning of the throat and cough) may cease when the patient is removed from exposure.

However, after an asymptomatic interval of 30 minutes to 48 hours, in those developing severe pulmonary damage, progressive pulmonary edema develops rapidly with shallow rapid respiration, cyanosis, and a painful paroxysmal cough producing large amounts of frothy white or yellowish liquid. Inadequate, labored respiration, during which abnormal chest sounds are evident, may be accompanied by increased distress and apprehension. Insufficient oxygenation of arterial blood, and massive accumulation of fluid in the lungs may be accompanied by cardiovascular and hematological signs.

Exposure to phosgene has been reported to result in Reactive Airway Dysfunction Syndrome (RADS), a chemically- or irritant-induced type of asthma.

Children may be more vulnerable to corrosive agents than adults because of the relatively smaller diameter of their airways. Children may also be more vulnerable because of increased minute ventilation per kg and failure to evacuate an area promptly when exposed.

Cardiovascular

Cardiovascular collapse may occur if the patient is severely hypovolemic and hypoxemic from accumulation of fluid in the lungs. Destruction of red blood cells in the pulmonary circulation can cause capillary plugging that leads to strain on the right side of the heart and death.

Dermal

If the skin is wet or moist, contact with phosgene vapor can cause irritation and redness of the skin. Contact with liquid phosgene under pressure can result in frostbite.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants affecting the skin.

Ocular

High vapor concentrations cause tearing and increased presence of blood in the eye. Contact with liquid phosgene may result in clouding of the cornea and delayed perforation.

Hematologic

In severe cases, phosgene may cause hemolysis that results in the plugging of pulmonary capillaries.

Most hematologic changes (e.g., hemolysis, methemoglobinemia, bone marrow suppression, and anemia) can be detected by standard blood tests.

Hepatic

In cases of high exposures, phosgene may be directly cytotoxic to the liver, causing necrosis and loss of function.

Renal

In cases of high exposures, phosgene may be directly cytotoxic to the kidneys, causing necrosis and loss of function.

Gastrointestinal

Nausea and vomiting may occur following exposure to phosgene.

Potential Sequelae

If the patient survives the initial 48 hours after exposure, recovery is likely. Sensitivity to irritants may persist, causing bronchospasm and chronic inflammation of the bronchioles. Pulmonary tissue destruction and scarring may lead to chronic dilation of the bronchi, lobular emphysema, regions of atelectasis, and increased susceptibility to infection.

Exposure to phosgene has been reported to result in Reactive Airway Dysfunction Syndrome (RADS), a chemically- or irritant-induced type of asthma.

Chronic Exposure

A group of workers who were exposed daily to high levels of phosgene showed an increase in mortality and morbidity from inflammation of the lungs, chronic inflammation of the bronchioles, destruction of alveoli, and impaired pulmonary function. Chronic exposures to low levels of phosgene may lead to chronic pneumonitis, which may resolve or lead to pulmonary edema.

Chronic exposure may be more serious for children because of their potential longer latency period.

Carcinogenicity

Phosgene has not been classified for carcinogenic effects.

Reproductive and Developmental Effects

No information was found pertaining to reproductive or developmental hazards caused by phosgene exposure. Phosgene is not included in *Reproductive and Developmental Toxicants*, a 1991 report published by the U.S. General Accounting Office (GAO) that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences.

Prehospital Management

Victims exposed only to phosgene gas do not pose substantial risks of secondary contamination to personnel outside the Hot Zone. Victims whose clothing or skin is contaminated with liquid phosgene (ambient temperature below 47 °F) can secondarily contaminate response personnel through direct contact or off-gassing vapor.

Rescue personnel should use breathing apparatus and chemical protective clothing if there is a possibility of exposure to unsafe levels of phosgene.

Phosgene is a severe pulmonary irritant. However, serious pulmonary effects may be delayed up to 48 hours.

Systemic effects are largely a secondary effect of anoxia resulting from pulmonary injury. Phosgene is also irritating to the eyes and skin.

There is no antidote for phosgene. Treatment consists of support of respiratory and cardiovascular functions.

Hot Zone

Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if rescuers have not been trained in its use, assistance should be obtained from a local or regional HAZMAT team or other properly equipped response organization.

Rescuer Protection

Phosgene is a severe respiratory tract irritant and skin irritant; contact with the liquid will cause frostbite.

Respiratory Protection: Positive-pressure-demand, self-contained breathing apparatus (SCBA) is recommended in response situations that involve exposure to potentially unsafe levels of phosgene.

Skin Protection: Chemical-protective clothing is recommended because phosgene gas can cause skin irritation and burns. NIOSH recommends protective suites made from Responder™ (Kappler Co.), Tychem 10000™ (DuPont Co.), or Teflon™ (DuPont Co.).

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible.

Victim Removal

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be

removed on backboards or gurneys; if these are not available, carefully carry or drag victims to safety.

Victims should be kept warm and quiet; any activity subsequent to exposure may increase the likelihood of death.

Consider appropriate management of chemically contaminated children, such as measures to reduce separation anxiety if a child is separated from a parent or other adult.

Decontamination Zone

Victims exposed only to phosgene gas who have no evidence of skin or eye irritation may be transferred immediately to the Support Zone. Other patients will require decontamination as described below.

Rescuer Protection

If exposure levels are determined to be safe, decontamination may be conducted by personnel wearing a lower level of protection than that worn in the Hot Zone (described above).

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. Stabilize the cervical spine with a collar and a backboard if trauma is suspected. Administer supplemental oxygen as required. Assist ventilation with a bag-valve-mask device if necessary.

Basic Decontamination

Victims should be kept warm and quiet; any activity subsequent to exposure may increase the likelihood of death.

Victims who are able may assist with their own decontamination. If the exposure involved liquid phosgene (ambient temperature below 47 °F [8 °C]) and if clothing is contaminated, remove and double-bag the clothing.

Flush exposed skin and hair with plain water for 3 to 5 minutes. Wash thoroughly with soap and water. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Flush exposed or irritated eyes with plain water or saline for at least 15 minutes. Remove contact lenses if easily removable without additional trauma to the eye. If a corrosive material is suspected or if pain or injury is evident, continue irrigation while transferring the victim to the Support Zone.

Consider appropriate management of chemically contaminated children at the exposure site. Provide reassurance to the child during decontamination, especially if separation from a parent occurs.

Transfer to Support Zone

As soon as basic decontamination is complete, move the victim to the Support Zone.

Support Zone

Be certain that victims have been decontaminated properly (see *Decontamination Zone* above). Victims who have undergone decontamination or have been exposed only to phosgene gas generally pose no serious risks of secondary contamination. In such cases, Support Zone personnel require no specialized protective gear.

ABC Reminders

Quickly access for a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Ensure adequate respiration and pulse. Administer supplemental oxygen as required and establish intravenous access if necessary. Place on a cardiac monitor. Watch for signs of airway swelling and obstruction such as progressive hoarseness, stridor, or cyanosis.

Additional Decontamination

Continue irrigating exposed skin and eyes, as appropriate.

Advanced Treatment

In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, perform cricothyroidotomy if equipped and trained to do so.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Phosgene poisoning is not known to pose additional risk during the use of bronchial or cardiac sensitizing agents.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Patients who are comatose, hypotensive, or are having seizures or cardiac arrhythmias should be treated according to advanced life support (ALS) protocols.

Transport to Medical Facility

Only decontaminated patients or patients not requiring decontamination should be transported to a medical facility. "Body bags" are not recommended.

Report to the base station and the receiving medical facility the condition of the patient, treatment given, and estimated time of arrival at the medical facility.

Multi-Casualty Triage

Consult with the base station physician or the regional poison control center for advice regarding triage of multiple victims.

Phosgene has relatively little odor or irritating effects at moderately toxic air concentrations; serious health effects may occur without warning or symptoms. Because serious complications may be delayed up to 48 hours after exposure, all patients who have suspected phosgene exposure should be transported to a medical facility for evaluation.

Emergency Department Management

Patients exposed only to phosgene gas do not pose significant risks of secondary contamination to personnel outside the Hot Zone. Victims whose clothing or skin is contaminated with liquid phosgene (ambient temperature below 47°F) can secondarily contaminate hospital personnel by direct contact or through off-gassing vapor.

Rescue personnel should use breathing apparatus and chemical protective clothing if there is a possibility of exposure to unsafe levels of phosgene.

Phosgene is a severe pulmonary irritant. However, serious pulmonary effects may be delayed up to 48 hours.

Systemic effects are largely a secondary effect of anoxia resulting from pulmonary injury. Phosgene is also irritating to the eyes and skin.

There is no antidote for phosgene. Treatment consists of support of respiratory and cardiovascular functions.

Decontamination Area

Unless previously decontaminated, all patients suspected of contact with phosgene liquid and all victims with skin or eye irritation require decontamination as described below. Because contact with liquid phosgene may cause burns, don butyl rubber gloves and apron and eye protection before treating patients. All other patients may be transferred immediately to the Critical Care Area.

Be aware that use of protective equipment by the provider may cause fear in children, resulting in decreased compliance with further management efforts.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants affecting the skin. Also, emergency room personnel should examine children's mouths because of the frequency of hand-to-mouth activity among children.

Victims should be kept warm and quiet; any activity subsequent to exposure may increase the likelihood of death.

ABC Reminders

Evaluate and support airway, breathing, and circulation. Children may be more vulnerable to corrosive agents than adults because of the smaller diameter of their airways. In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, surgically create an airway.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Phosgene poisoning is not known to pose additional risk during the use of bronchial or cardiac sensitizing agents.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Patients who are comatose, hypotensive, or have seizures or ventricular arrhythmias or renal failure should be treated in the conventional manner.

Basic Decontamination

Victims who are able may assist with their own decontamination. If the exposure involved liquid phosgene (ambient temperature below 47°F [8 °C]) and if clothing is contaminated, remove and double-bag the clothing.

Flush exposed skin and hair with plain water for 3 to 5 minutes. Wash thoroughly with soap and water. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Flush exposed or irritated eyes with plain water or saline for at least 15 minutes. Remove contact lenses if easily removable without additional trauma to the eye. If a corrosive material is suspected or if pain or injury is evident, continue eye irrigation while transferring the patient to the Critical Care Area.

An ophthalmic anesthetic, such as 0.5% tetracaine, may be necessary to alleviate blepharospasm, and lid retractors may be required to allow adequate irrigation under the eyelids.

Critical Care Area

Be certain that appropriate decontamination has been carried out (see *Decontamination Area* above).

ABC Reminders

Evaluate and support airway, breathing, and circulation as in ABC Reminders above. Children may be more vulnerable to corrosive

agents than adults because of the relatively smaller diameter of their airways. Establish intravenous access in seriously ill patients if this has not been done previously. Continuously monitor cardiac rhythm.

Patients who are comatose, hypotensive, or have seizures or cardiac arrhythmias should be treated in the conventional manner.

Inhalation Exposure

Administer supplemental oxygen by mask to patients who have respiratory complaints. Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Phosgene poisoning is not known to pose additional risk during the use of bronchial or cardiac sensitizing agents.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Observe patients who are in respiratory distress for up to 48 hours and periodically reexamine their chests and order other appropriate studies. Follow up as clinically indicated.

Corticosteroids are suggested for intense inflammation, especially inflammation of the respiratory epithelium. If the patient experienced severe exposure, consider initiating intravenous steroid therapy while the patient is asymptomatic.

Prophylactic antibiotics are not routinely recommended but may be used based on the results of sputum cultures. Pneumonia can complicate severe pulmonary edema and may cause death up to 48 hours after onset of pulmonary edema.

Diuretics are contraindicated. Pulmonary edema due to phosgene inhalation is not hypervolemic in origin; patients tend to be hypovolemic and hypotensive. Dopamine may be required for treatment of hypotension, bradycardia, or renal failure. Initiate fluid resuscitation as needed.

Skin Exposure

If phosgene was in contact with the skin, chemical burns may result; treat as thermal burns.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants affecting the skin.

Eye Exposure

Continue irrigation for at least 15 minutes. Test visual acuity. Examine the eyes for corneal damage and treat appropriately. Immediately consult an ophthalmologist for patients who have corneal injuries.

Antidotes and Other Treatments

There is no antidote for phosgene. Treatment is supportive.

Laboratory Tests

The diagnosis of acute phosgene toxicity is primarily clinical, based on symptoms of irritation and breathing difficulty. However, laboratory testing is useful for monitoring the patient and evaluating complications. Routine laboratory studies for all exposed patients include CBC, glucose, and electrolyte determinations. ECG monitoring is useful for patients exposed to phosgene. Chest radiography and pulse oximetry (or ABG measurements) are also recommended for severe inhalation exposure. Evidence of pulmonary edema—hilar enlargement, and ill-defined, central-patch infiltrates on chest radiography—is a late finding that may occur 6 to 8 hours after exposure.

Plasma phosgene levels are not clinically useful.

Disposition and Follow-up

Consider hospitalizing all patients who have suspected phosgene exposure. Patients who have respiratory compromise should be admitted to an intensive care unit.

Delayed Effects

Because pulmonary edema may not occur for up to 48 hours after exposure, patients who have known exposure should be observed and reexamined periodically before confirming the absence of toxic effects. Patients who have bronchospasm or pulmonary edema should be watched carefully for signs of impending respiratory failure and should be managed accordingly. Patients who survive for 48 hours usually recover.

Patient Release

Asymptomatic patients who have normal initial examinations and no signs of toxicity after observation for 48 hours may be discharged with instructions to seek medical care promptly if symptoms develop (see the *Phosgene—Patient Information Sheet* below).

Follow-up

Obtain the name of the patient's primary care physician so that the hospital can send a copy of the ED visit to the patient's doctor.

Patients may have long term damage to the lungs and increased susceptibility to infection. Sensitivity to irritants may persist, causing bronchospasm, chronic inflammation of the bronchioles and

Reactive Airway Dysfunction Syndrome (RADS), a chemically- or irritant-induced type of asthma.

Patients who have corneal injuries should be reexamined in 24 hours.

Reporting

If a work-related incident has occurred, you may be legally required to file a report; contact your state or local health department.

Other persons may still be at risk in the setting where this incident occurred. If the incident occurred in the workplace, discussing it with company personnel may prevent future incidents. If a public health risk exists, notify your state or local health department or other responsible public agency. When appropriate, inform patients that they may request an evaluation of their workplace from OSHA or NIOSH. See Appendices III and IV for a list of agencies that may be of assistance.

Phosgene
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to phosgene.

What is phosgene?
At room temperature, phosgene is a colorless gas. At high concentrations, it has a suffocating odor; at low concentrations, it smells like green corn or new mown hay. It is not flammable. Phosgene is used in the manufacture of many chemicals. It is also produced when chlorine-containing chemicals burn or break down.

What immediate health effects can result from exposure to phosgene?
Most exposures to phosgene occur from breathing the gas. Exposure to small amounts usually causes eye, nose, and throat irritation. However, the irritating effects can be so mild at first that the person does not leave the area of exposure. Generally, the higher the exposure, the more severe the symptoms. Extended exposure can cause severe breathing difficulty, which may lead to chemical pneumonia and death. Severe breathing problems may not develop for as long as 48 hours after exposure.

Can phosgene poisoning be treated?
There is no antidote for phosgene, but its effects can be treated, and most exposed persons get well. Persons who have experienced serious symptoms may need to be hospitalized.

Are any future health effects likely to occur?
A single small exposure from which a person recovers quickly is not likely to cause delayed or long-term effects. After a serious exposure, some symptoms may take a few days to develop. Some persons who have had serious exposures have developed permanent breathing difficulty and tend to develop lung infections easily.

What tests can be done if a person has been exposed to phosgene?
Specific tests for the presence of phosgene in blood or urine generally are not useful to the doctor. If a severe exposure has occurred, chest x-rays, blood and urine analyses and other tests may show whether the lungs or other organs have been injured. Because effects may take several days to develop, immediate and follow-up testing of lung function should be done in all cases of suspected exposure to phosgene.

Where can more information about phosgene be found?
More information about phosgene can be obtained from your regional poison control center; your state, county, or local health department; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in occupational and environmental health. If the exposure happened at work, you may wish to discuss it with your employer, the Occupational Safety and Health Administration (OSHA), or the National Institute for Occupational Safety and Health (NIOSH). Ask the person who gave you this form for help in locating these telephone numbers.

Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow *only* the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:

coughing or wheezing
difficulty breathing or shortness of breath
increased pain or a discharge from exposed skin or eyes
chest pain or tightness

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.
[ ] Call for an appointment with Dr. _____ in the practice of _____. When you call for your appointment, please say that you were treated in the Emergency Department at _____ Hospital by _____ and were advised to be seen again in _____ days.
[ ] Return to the Emergency Department/ _____ Clinic on (date) _____at __ _____ AM/PM for a follow-up examination.
[ ] Do not perform vigorous physical activities for 1 to 2 days.
[ ] You may resume everyday activities including driving and operating machinery.
[ ] Do not return to work for _____ days.
[ ] You may return to work on a limited basis. See instructions below.
[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.
[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.
[ ] Avoid taking the following medications: _____
[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: __ _____
_____
[ ] Other instructions: _____
_____
_____

- Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.

- You or your physician can get more information on the chemical by contacting: _____ _____ or _____, or by checking out the following Internet Web sites: _____; _____.

Signature of patient _____ Date _____

Signature of physician _____ Date _____

Phosphine (PH_3)
CAS 7803-51-2; UN 2199
Also: Aluminum Phosphide (CAS 20859-73-B; UN 1397) and Zinc Phosphide (CAS 1314-84-7; UN 1714)

Synonyms of phosphine include hydrogen phosphide, phosphorus hydride, phosphorus trihydride, and phosphoretted hydrogen.

Persons exposed only to phosphine gas do not pose substantial risks of secondary contamination; however, persons exposed to solid phosphides may present such risks. Metallic phosphides on clothes, skin, or hair can react with water or moisture to generate phosphine gas. Vomitus containing phosphides can also off-gas phosphine.

Phosphine is extremely flammable and explosive; it may ignite spontaneously on contact, with air. Phosphine has a fish- or garlic-like odor, but may not provide adequate warning of hazardous concentrations. When phosphine burns it produces a dense white cloud of phosphorus pentoxide, P_2O_5 fume. This fume is a severe respiratory tract irritant due to the rapid formation of orthophosphoric acid, H_3PO_4, on contact with water.

- **Phosphine is a respiratory tract irritant that attacks primarily the cardiovascular and respiratory systems causing peripheral vascular collapse, cardiac arrest and failure, and pulmonary edema.**

Most phosphine exposures occur by inhalation of the gas or ingestion of metallic phosphides, but dermal exposure to phosphides can also cause systemic effects.

Description

Phosphine is a colorless, flammable, and toxic gas with an odor of garlic or decaying fish. It can ignite spontaneously on contact with air. The gas is shipped as a liquefied, compressed gas.

Aluminum phosphide (Celphos, Phostoxin, Quick Phos) and zinc phosphide are solids used as grain fumigants and as a rodenticide, respectively. Zinc phosphide is often mixed with bait food such as cornmeal, which can be a danger to pets and children. When phosphides are ingested or exposed to moisture, they release phosphine gas. Phosphine gas may also be released when acetylene is made by the action of water on calcium carbide which is contaminated with calcium phosphide as is commonly the case.

Routes of Exposure

Inhalation

Inhalation is the major route of phosphine toxicity. **Odor is not an adequate indicator of phosphine's presence and may not provide reliable warning of hazardous concentrations.** The OSHA PEL of 0.3 ppm is within the range of reported odor thresholds. Phosphine is heavier than air and may cause asphyxiation in enclosed, poorly ventilated, or low-lying areas.

Children exposed to the same levels of phosphine as adults may receive a larger dose because they have greater lung surface area:body weight ratios and increased minute volumes:weight ratios. In addition, they may be exposed to higher levels than adults in the same location because of their short stature and the higher levels of phosphine found nearer to the ground.

Skin/Eye Contact

Phosphides may be absorbed dermally, especially through broken skin, and can cause systemic toxicity by this route. Phosphine gas produces no adverse effects on the skin or eyes, and contact does not result in systemic toxicity. Contact with liquefied or compressed phosphine gas may cause frostbite.

Ingestion

Ingestion of phosphine is unlikely because it is a gas at room temperature. Ingestion of metallic phosphides can produce phosphine intoxication when the solid phosphide contacts gastric acid.

Sources/Uses

Phosphine is produced when metallic phosphides (e.g., aluminum, calcium, or zinc phosphides) react with water or acid. Both aluminum and zinc phosphides are used as rodenticides. Phosphine may be produced during the generation of acetylene gas. Phosphine is used in the semiconductor industry to introduce phosphorus into silicon crystals as an intentional impurity. Phosphine is also used as a fumigant and a polymerization initiator.

Standards and Guidelines

OSHA PEL (permissible exposure limit) = 0.3 ppm (averaged over an 8-hour workshift)

NIOSH IDLH (immediately dangerous to life or health) = 50 ppm

ERPG-2 (Emergency Response Planning Guideline) (maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious adverse health effects or symptoms that could impair an individuals's ability to take protective action) = 0.5 ppm

Physical Properties

Description: Colorless gas; odor of garlic or decaying fish

Warning properties: Inadequate; nonirritating and garlic-like or fishy odor at 1 to 3 ppm.

Molecular weight: 34.0 daltons

Melting point: -209 °F (-134 °C)

Boiling point (760 mm Hg): = -126 °F (- 87.7 °C)

Vapor pressure: >760 mm Hg at 68 °F (20 °C)

Gas density: 1.17 (air = 1)

Water solubility: Slightly water soluble (0.3% at 68 °F) (20 °C)

Flammability: Extremely flammable and explosive; may ignite spontaneously on contact with air.

Incompatibilities

Phosphine reacts with air, oxidizers, chlorine, acids, moisture, halogenated hydrocarbons, and copper.

Health Effects

Symptoms of phosphine intoxication are primarily related to the cardiovascular and pulmonary systems and may include restlessness, irritability, drowsiness, tremors, vertigo, diplopia, ataxia, cough, dyspnea, retrosternal discomfort, abdominal pain, and vomiting.

The same symptoms may occur after ingestion of phosphide salts. Multiple signs may be seen representing various stages of cardiovascular collapse.

Phosphine interferes with enzymes and protein synthesis, primarily in the mitochondria of heart and lung cells. As a result, effects may include hypotension, reduction in cardiac output, tachycardia, oliguria, anuria, cyanosis, pulmonary edema, tachypnea, jaundice, hepatosplenomegaly, ileus, seizures, and diminished reflexes.

Acute Exposure

Phosphine interferes with enzymes and protein synthesis, primarily in the mitochondria of heart and lung cells. Metabolic changes in heart muscle cause cation disturbances that alter transmembrane potentials. Ultimately, cardiac arrest, peripheral vascular collapse and pulmonary edema can occur. Pulmonary edema and pneumonitis are believed to result from direct cytotoxicity to the pulmonary cells. In fatal cases, centrilobular necrosis of the liver has also been reported.

Most deaths occur within the first 12 to 24 hours after exposure and are cardiovascular in origin. If the patient survives the initial 24 hours, the ECG typically returns to normal, indicating that heart damage is reversible. Deaths after 24 hours are usually due to liver failure.

Children do not always respond to chemicals in the same way that adults do. Different protocols for managing their care may be needed.

CNS

Phosphine is a CNS depressant. Initial effects may include headache, restlessness, dizziness, loss of feeling, impaired gait, trembling of the extremities during movement, and double vision. Severe exposure can cause seizures and coma.

Respiratory

Toxicity that occurs after inhalation is characterized by chest tightness, cough, and shortness of breath. Severe exposure can cause accumulation of fluid in the lungs, which may have a delayed onset of 72 hours or more after exposure. Pulmonary symptoms can

also result from ingestion of metallic phosphides (e.g., aluminum or zinc phosphide).

Children may be more vulnerable because of relatively increased minute ventilation per kg and failure to evacuate an area promptly when exposed.

Cardiovascular

Cardiovascular manifestations include hypotension, reduction in cardiac output, tachycardia, irregular heart beat, or cardiac arrest. Laboratory tests may reveal abnormal myocardial enzymes. Phosphine affects the small peripheral vessels, causing a profound decrease in systemic vascular resistance. Vascular changes may lead to marked low blood pressure that does not respond well to pressor agents.

Gastrointestinal

Gastrointestinal symptoms are usually the first to occur after exposure. Symptoms may include nausea, vomiting, abdominal pain, and diarrhea.

Hepatic

Typically, liver injury does not become evident until 48 to 72 hours after exposure. Findings may include jaundice, enlarged liver, elevated serum transaminases, and increased bilirubin in the blood.

Renal

Blood and protein in the urine, and acute kidney failure can occur.

Electrolyte

Analysis of blood gases may reveal combined respiratory and metabolic acidosis. Also, there have been reports of significant hypomagnesemia and hypermagnesemia associated with massive focal myocardial damage.

Potential Sequelae

Although most survivors of acute phosphine exposure show no permanent disabilities, damage due to insufficient blood supply to the heart and brain have been reported. Subacute poisoning resulting from exposure for a few days may cause reactive airways dysfunction syndrome (RADS) months later.

Chronic Exposure

Chronic exposure to very low concentrations may result in anemia, bronchitis, gastrointestinal disturbances, and visual, speech, and motor disturbances. Chronic exposure may be more serious for children because of their potential longer latency period.

Carcinogenicity

The EPA has determined that phosphine is not classifiable as to its human carcinogenicity.

Reproductive and Developmental Effects

Phosphine is not contained in the TERIS or Reprotext databases, nor is it mentioned in *Shepards Catalog of Teratogenic Agents.* Phosphine is not included in *Reproductive and Developmental Toxicants,* a 1991 report published by the U.S. General Accounting Office (GAO) that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences.

No teratogenic effects form acute exposure are known.

Prehospital Management

Victims exposed only to phosphine gas do not pose substantial risks of secondary contamination to personnel outside the Hot Zone. Victims exposed to solid phosphides, which react with moisture to produce phosphine, can pose such risks if phosphides are on clothes, skin, or hair. Protect personnel through the use of rubber gloves and aprons.

Phosphine is a multisystem toxicant that can cause pulmonary irritation, CNS depression, and cardiovascular collapse.

There is no antidote for phosphine poisoning. Treatment consists of support of respiratory and cardiovascular functions.

Hot Zone

Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if rescuers have not been trained in its use, assistance should be obtained from a local or regional HAZMAT team or other properly equipped response organization.

Rescuer Protection

Phosphine is a highly toxic systemic poison and a severe respiratory tract irritant.

Respiratory Protection: Positive-pressure, self-contained breathing apparatus (SCBA) is recommended in response situations that involve exposure to potentially unsafe levels of phosphine.

Skin Protection: Chemical-protective clothing is not generally required because phosphine gas is not absorbed through the skin, and skin irritation is unlikely. Use rubber gloves and aprons with victims exposed to phosphides.

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible.

Brush powder from the skin, hair, and clothes of victims before leaving the Hot Zone.

Victim Removal

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be removed on backboards or gurneys; if these are not available, carefully carry or drag victims to safety.

Consider appropriate management of chemically contaminated children, such as measures to reduce separation anxiety if a child is separated from a parent or other adult.

Decontamination Zone

Victims exposed only to phosphine gas do not need decontamination. They may be transferred immediately to the Support Zone. Victims exposed to metallic phosphides will require decontamination as described below.

Rescuer Protection

If exposure levels are determined to be safe, decontamination may be conducted by personnel wearing a lower level of protection than that worn in the Hot Zone (described above).

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. Stabilize the cervical spine with a collar and a backboard if trauma is suspected. Administer supplemental oxygen as required. Assist ventilation with a bag-valve-mask device if necessary.

Basic Decontamination

Victims who are able may assist with their own decontamination. Brush all visible particles from clothes, skin, and hair. Remove and double-bag contaminated clothing and personal belongings.

Thoroughly flush exposed skin and hair with water for 3 to 5 minutes, then wash with mild soap. Rinse thoroughly with water. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

If phosphides have been ingested, **do not induce emesis**. Phosphides will release phosphine in the stomach; therefore, watch for signs similar to those produced by phosphine inhalation. Administer a slurry of activated charcoal at 1 gm/kg (usual adult dose 60–90 g, child dose 25–50 g). A soda can and a straw may be of assistance when offering charcoal to a child.

Consider appropriate management of chemically contaminated children at the exposure site. Also, provide reassurance to the child during decontamination, especially if separation from a parent occurs. If possible, seek assistance from a child separation expert.

Transfer to Support Zone

As soon as basic decontamination is complete, move the victim to the Support Zone.

Support Zone

Be certain that victims exposed to metallic phosphides have been decontaminated properly (see *Decontamination Zone* above). Victims who have been exposed only to phosphine gas or who have

undergone decontamination pose no serious risks of secondary contamination. Support Zone personnel require no specialized protective gear in such cases.

ABC Reminders

Quickly access for a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Ensure adequate respiration and pulse. Administer supplemental oxygen as required and establish intravenous access if necessary. Place on a cardiac monitor.

Additional Decontamination

Continue irrigating exposed skin and eyes, as appropriate.

If phosphides have been ingested, **do not induce emesis**. If it has not been given previously and the patient is alert and able to swallow, administer a slurry of activated charcoal at 1 gm/kg (usual adult dose 60–90 g, child dose 25–50 g). A soda can and a straw may be of assistance when offering charcoal to a child. Phosphides will release phosphine in the stomach; therefore, watch for signs similar to those produced by phosphine inhalation.

Advanced Treatment

In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, perform cricothyroidotomy if equipped and trained to do so.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly).

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Patients who are comatose, hypotensive, or having seizures or cardiac arrhythmias should be treated according to advanced life support (ALS) protocols.

If evidence of shock or hypotension is observed begin fluid administration. For adults, bolus 1,000 mL/hour intravenous saline or lactated Ringer's solution if blood pressure is under 80 mm Hg; if systolic pressure is over 90 mm Hg, an infusion rate of 150 to 200 mL/hour is sufficient. For children with compromised perfusion administer a 20 mL/kg bolus of normal saline over 10 to 20 minutes, then infuse at 2 to 3 mL/kg/hour.

Transport to Medical Facility

Only decontaminated patients or patients not requiring decontamination should be transported to a medical facility. "Body bags" are not recommended.

Report to the base station and the receiving medical facility the condition of the patient, treatment given, and estimated time of arrival at the medical facility.

If metallic phosphides have been ingested, prepare the ambulance in case the victim vomits toxic material. Have ready several towels and open plastic bags to quickly clean up and isolate vomitus.

Multi-Casualty Triage

Consult with the base station physician or the regional poison control center for further advice regarding triage of multiple victims.

Because it is difficult to determine at the scene which patients have had the most serious inhalation exposure, and because some systemic symptoms may be delayed for up to 72 hours after exposure, all patients who have potentially significant exposures should be transported to a medical facility for evaluation. Those who have had massive exposures and those who have experienced a garlic- or fish-like odor should be transported first.

All patients who have ingested phosphides should be transported to a medical facility without delay.

Emergency Department Management

Victims exposed only to phosphine gas do not pose substantial risks of secondary contamination to personnel outside the Hot Zone. However, solid phosphides, which react with moisture to produce phosphine, may present secondary contamination risks on clothes, skin, or hair.

Phosphine is a multisystem toxicant that causes acute pulmonary irritation, CNS depression, and cardiovascular collapse. Fatal outcomes after the initial 24 hours are usually due to hepatic or renal failure.

There is no antidote for phosphine poisoning. Treatment consists of support of respiratory and cardiovascular functions.

Decontamination Area

Previously decontaminated patients and patients exposed only to phosphine gas may be transferred immediately to the Critical Care Area. Other patients will require decontamination as described below.

Be aware that use of protective equipment by the provider may cause fear in children, resulting in decreased compliance with further management efforts. Rubber gloves and aprons should be used with non-decontaminated victims exposed to phosphides.

Emergency room personnel should examine children's mouths because of the frequency of hand-to-mouth activity among children.

ABC Reminders

Evaluate and support airway, breathing, and circulation. In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, surgically create an airway.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly).

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Patients who are comatose, hypotensive, or have seizures or ventricular arrhythmias should be treated in the conventional manner.

Correct acidosis in the patient who has coma, seizures or cardiac dysrhythmias by administering intravenously sodium bicarbonate (adult dose = 1 ampule; pediatric dose = 1 Eq/kg). Further bicarbonate therapy should be guided by ABG measurements.

Basic Decontamination

Patients who are able may assist with their own decontamination. If the patient has been exposed to solid phosphides, brush the powder from skin, hair, and clothes. Remove and double-bag the patient's clothing and personal belongings. Flush the skin and hair with water (preferably under a shower). Remove contact lenses if easily removable without additional trauma to the eye. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

In cases of phosphide ingestion, **do not induce emesis.** If activated charcoal has not been given previously, administer a slurry of it at 1 gm/kg (usual adult dose 60–90 g, child dose 25–50 g). Phosphides will release phosphine in the stomach; therefore, watch for signs similar to those produced by phosphine inhalation. (More information is provided in *Ingestion Exposure* under *Critical Care Area* below).

Critical Care Area

Be certain that patients who have ingested solid phosphides have been decontaminated as described above. Decontamination is not necessary for patients exposed only to phosphine gas.

ABC Reminders

Evaluate and support airway, breathing, and circulation as in *ABC Reminders* above. Watch for signs of airway compromise. Monitor cardiac rhythm.

Hypotension may develop and may respond poorly to pressor agents.

Patients who are comatose or have seizures should be treated in the conventional manner. Correct acidosis in the patient who has coma, seizures or cardiac dysrhythmias by administering intravenously sodium bicarbonate (adult dose = 1 ampule; pediatric dose = 1 Eq/kg).

Inhalation Exposure

Symptomatic patients should receive supplemental oxygen for dyspnea and should be observed for at least 72 hours with repeated

chest examinations and other appropriate studies. Follow-up as clinically indicated.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly).

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Ingestion Exposure

Remove phosphides from the stomach as soon as possible because most phosphides release phosphine gas on contact with water or acids. Administer a slurry of activated charcoal at 1 gm/kg (usual adult dose 60–90 g, child dose 25–50 g), if it has not been given previously. A mineral oil cathartic (100 mL) is recommended rather than a saline cathartic. Watch for signs and symptoms similar to those produced by inhalation exposure; treat accordingly.

Gastric lavage with a potassium permanganate solution (1:10,000) is recommended if ingestion occurred. Permanganate oxidizes phosphine in the stomach to form phosphate, thus reducing the available phosphine.

Antidotes and Other Treatments

There is no antidote for phosphine poisoning. Treatment consists of supportive measures. Hemodialysis is recommended only if renal failure develops. The effectiveness of exchange transfusions is questionable. The value of steroids for phosphine-exposed patients who develop acute pulmonary symptoms has not been proven.

Laboratory Tests

Routine laboratory studies for all exposed patients include CBC, glucose, and electrolyte determinations. Additional studies for patients exposed to phosphine include ECG monitoring, renal function tests, and liver-function tests. Chest radiography, pulse oximetry (or ABG measurements), and PFl3 are recommended to establish baseline for pulmonary status. Serial myocardial enzyme levels may also be helpful.

Phosphine is metabolized to phosphite and hypophosphite, which are excreted in the urine. Although analysis for these metabolites is not clinically useful in an emergency setting, urine samples can be collected and frozen for future analysis, particularly if questions on the nature or extent of exposure are likely.

Disposition and Follow-up

Decisions to admit or discharge a patient should be based on exposure history, physical examination, and test results.

Delayed Effects

Because onset of pulmonary edema and liver damage may be delayed for 72 hours or more after exposure, all patients who have significant exposure should be admitted and observed carefully.

Patient Release

Asymptomatic patients who have normal initial examinations, minimal exposure, and no signs of toxicity after observation for 4 to 6 hours may be discharged with instructions to return to the ED if symptoms develop (see the *Phosphine—Patient Information Sheet* below).

Follow-up

Obtain the name of the patient's primary care physician so the hospital can send a copy of the ED visit to the patient's doctor.

Patients exposed to phosphine should be monitored for pulmonary dysfunction.

Reporting

If a work-related incident has occurred, you may be legally required to file a report; contact your state or local health department.

Other persons may still be at risk in the setting where this incident occurred. If the incident occurred in the workplace, discussing it with company personnel may prevent future incidents. If a public health risk exists, notify your state or local health department or other responsible public agency. When appropriate, inform patients that they may request an evaluation of their workplace from OSHA or NIOSH. See Appendices III and IV for a list of agencies that may be of assistance.

Phosphine
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to phosphine or phosphides.

What is phosphine? How are phosphides related?
Phosphine is a toxic gas that has no color and smells like garlic or fish. A serious exposure to phosphine could occur, however, even if a person does not smell it. Phosphine is used widely in the semiconductor industry. Phosphine may be encountered in grain storage silos where it has been used as a fumigant, or zinc phosphide has been put down as a rat poison.

Certain pesticides containing zinc phosphide or aluminum phosphide can release phosphine when they come in contact with water or acid. The phosphine formed in the stomach when these solid phosphides are swallowed can result in phosphine poisoning.

What immediate health effects can be caused by exposure to phosphine?
Exposure to even small amounts of phosphine can cause headache, dizziness, nausea, vomiting, diarrhea, drowsiness, cough, and chest tightness. More serious exposure can cause shock, convulsions, coma, irregular heartbeat, and liver and kidney damage. Generally, the more serious the exposure, the more severe the symptoms.

Can phosphine poisoning be treated?
There is no antidote for phosphine, but its effects can be treated, and most exposed persons get well. Persons who have experienced serious symptoms may need to be hospitalized.

Are any future health effects likely to occur?
A single small exposure from which a person recovers quickly is not likely to cause delayed or long-term effects. After a severe exposure, symptoms usually begin immediately but might not appear for 72 hours or more.

Some severely exposed persons have experienced long-term brain, heart, lung, and liver injury.

What tests can be done if a person has been exposed to phosphine?
There are no specific blood or urine tests for phosphine itself. Breakdown products of phosphine can be measured in urine, but the result of this test is generally not useful to the doctor. If a severe exposure has occurred, blood and urine analyses and other tests may also show whether the brain, lungs, heart, liver, or kidneys have been damaged. Testing is not needed in every case.

Where can more information about phosphine be found?
More information about phosphine and phosphides can be obtained from your regional poison control center; your state, county, or local health department; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in occupational and environmental health. If the exposure happened at work, you may wish to discuss it with your employer, the Occupational Safety and Health Administration (OSHA), or the National Institute for Occupational Safety and Health (NIOSH). Ask the person who gave you this form for help in locating these telephone numbers.

Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow *only* the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:
coughing or wheezing
difficulty breathing or shortness of breath
chest pain or tightness
headache, dizziness, tremor, or double vision
difficulty walking
nausea, vomiting, diarrhea, or stomach pain

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.
[ ] Call for an appointment with Dr. _____ in the practice of _____.
When you call for your appointment, please say that you were treated in the Emergency Department at _____ Hospital by _____ and were advised to be seen again in _____ days.
[ ] Return to the Emergency Department/ _____ Clinic on (date) _____at __ _____ AM/PM for a follow-up examination.
[ ] Do not perform vigorous physical activities for 1 to 2 days.
[ ] You may resume everyday activities including driving and operating machinery.
[ ] Do not return to work for _____ days.
[ ] You may return to work on a limited basis. See instructions below.
[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.
[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.
[ ] Avoid taking the following medications: _____
[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: __
_____
_____
[ ] Other instructions: _____
_____
_____

- Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.

- You or your physician can get more information on the chemical by contacting: _____ _____ or _____, or by checking out the following Internet Web sites: _____; _____.

Signature of patient _____ Date _____

Signature of physician _____ Date _____

Phosgene Oxime ($CHCl_2NO$)
CAS 1794-86-1

Synonyms include dichloroformoxime; CX.

Persons whose clothing or skin is contaminated with liquid or solid phosgene oxime can cause secondary contamination by direct contact or through off-gassing vapor. Persons exposed only to phosgene oxime vapor pose no risk of secondary contamination.

Phosgene oxime is a colorless, crystalline solid or a yellowish-brown liquid with a disagreeable penetrating odor. The solid can vaporize at ambient temperatures.

Phosgene oxime is readily absorbed by the skin causing an immediate corrosive lesion. Ocular and pulmonary exposure may cause incapacitating inflammation,

Description

Phosgene oxime is an urticant or nettle agent. It is one of the least well studied chemical warfare agents; therefore, specific information is limited. Pure phosgene oxime is a colorless, crystalline solid; however, the munitions grade compound is a yellowish-brown liquid. The solid material can release enough vapor to cause symptoms. Post World War II studies indicate that concentrations below 8% cause no or inconsistent effects.

Routes of Exposure

Inhalation

Inhaled phosgene oxime is extremely irritating to the upper airways and causes pulmonary edema. Irritation occurs with exposures to 0.2 mg-min/m^3 and becomes unbearable at 3 mg-min/m^3. The estimated LCt_{50} (the product of concentration times time that is lethal to 50% of the exposed population by inhalation) is 1,500 to 2,000 mg-min/m^3.

Skin/Eye Contact

Pain and local tissue destruction occur immediately on contact with skin, eyes and mucous membranes. Phosgene oxime is rapidly absorbed from the skin and eyes and may result in systemic toxicity. The LD_{50} for skin exposure is estimated as 25 mg/kg.

Ingestion

No human data are available. Animal studies suggest phosgene oxime may induce hemorrhagic inflammatory lesions in the gastrointestinal tract.

Sources/Uses

Phosgene oxime was developed as a potential chemical warfare agent but has never been known to be used on the battlefield.

Standards and Guidelines No standards are available.

Physical Properties

Table 1. Physical Properties of Phosgene Oxime

Property	Agent Phosgene Oxime
Description	Colorless solid or yellowish-brown liquid
Warning properties	No data
Molecular weight	113.93 daltons
Boiling point	(760 mm Hg) = 128 °C
Melting point	95 to 104 °F (35 to 40 °C)
Freezing point	No data
Vapor pressure	11.2 mm Hg at 25 °C (solid); 13 mm Hg at 40 °C (liquid)
Vapor density	<3.9
Liquid density	No data
Flash point	No data
Solubility in water	70% in water; highly soluble in most organic solvents
Volatility	1,800 mg/m^3 (20 °C)
NAERG#	153

Incompatibilities It decomposes when in contact with many metals, but it also is corrosive to most metals.

Health Effects

- **Direct contact with phosgene oxime results in immediate pain, irritation, and tissue necrosis. Inhalation and systemic absorption may result in pulmonary edema, necrotizing bronchiolitis, and pulmonary thrombosis.**
- **Phosgene oxime is known to cause more severe tissue damage than vesicants and other urticants but it has not been well studied and the mechanism of action is unknown.**

Acute Exposure

Phosgene oxime is an urticant or nettle agent capable of producing erythema, wheals, and urticaria. It is considered a corrosive agent because it causes extensive tissue damage. The skin effects are similar to those caused by strong acids; however, the mechanism of action is unknown.

Ocular

Contact with the eyes may result in severe pain, conjunctivitis, and keratitis.

Dermal

Direct skin exposure to any form of phosgene oxime causes immediate pain and blanching with an erythematous ring. After 30 minutes a wheal occurs followed by necrosis. Extreme pain may persist for days. Absorption through the skin can cause pulmonary edema.

Respiratory

Phosgene oxime produces immediate irritation to the upper respiratory tract. Inhalation and systemic absorption may cause pulmonary edema, necrotizing bronchiolitis and pulmonary thrombosis.

Gastrointestinal

There are no human data; however, animal studies suggest that hemorrhagic inflammatory lesions may occur throughout the gastrointestinal tract.

Chronic Exposure

There are no data regarding potential effects of chronic exposure to phosgene oxime.

Carcinogenicity

No data exist.

Reproductive and Developmental Effects

No data exist.

Prehospital Management

- **Victims whose skin or clothing is contaminated with liquid phosgene oxime can contaminate rescuers by direct contact or through off-gassing vapor.**
- **Phosgene oxime is extremely toxic and may cause immediate pain and necrotic lesions of the eyes, skin, and respiratory tract.**
- **There is no antidote for phosgene oxime toxicity. Treatment consists of supportive measures.**

Hot Zone

Responders should be trained and appropriately attired before entering the Hot Zone. If the proper personal protective equipment (PPE) is not available, or if the rescuers have not been trained in its use, call for assistance in accordance with local Emergency Operational Guides (EOG). Sources of such assistance include local HAZMAT teams, mutual aid partners, the closest metropolitan strike system (MMRS) and the U.S. Soldier and Biological Chemical Command (SBCCOM)-Edgewood Research Development and Engineering Center SBCCOM may be contacted (from 0700-1630 EST call 410-671-4411 and from 1630-0700 EST call 410-278-5201), ask for the Staff Duty Officer.

Rescuer Protection

Phosgene oxime is readily absorbed by inhalation and by dermal and ocular contact. It causes immediate irritation and pain.

Respiratory Protection: Pressure-demand, self-contained breathing apparatus (SCBA) is recommended in response situations that involve exposure to any level of phosgene oxime vapor.

Skin/Ocular Protection: Personal Protective Equipment (PPE) and butyl rubber gloves must be worn at all times when skin contact with any form of the material is possible because lesions and dermal absorption may occur. Phosgene oxime may attack the butyl rubber in the butyl rubber gloves and boots, which nevertheless, are expected to protect against field concentrations of phosgene oxime until they can be exchanged for fresh gloves and boots.

Multi-Casualty Triage

Chemical casualty triage is based on walking feasibility, respiratory status, age, and additional conventional injuries. The triage officer must know the natural course of a given injury, the medical resources immediately available, the current and likely casualty flow, and the medical evacuation capabilities. General

principles of triage for chemical exposures are presented in the box on the following page. There are four triage categories: immediate (priority 1), delayed (priority 2), minimal (priority 3), and expectant (priority 4).

Before transport, all casualties must be decontaminated. If needed, consult with the base station physician or the regional poison control center for advise concerning management of multiple casualties.

General principals of triage for chemical exposures are as follows:

- Check triage tag/card for any previous treatment or triage.
- Survey for evidence of associated traumatic/blast injuries.
- Observe for sweating, labored breathing, coughing/vomiting, secretions.
- Severe casualty triaged as immediate if assisted breathing is required.
- Blast injuries or other trauma, where there is question whether there is chemical exposure, victims must be tagged as immediate in most cases. Blast victims evidence delayed effects such as ARDS, etc.
- Mild/moderate casualty: self/buddy aid, triaged as delayed or minimal and release is based on strict follow up and instructions.
- If there are chemical exposure situations which may cause delayed but serious signs and symptoms, then overtriage is considered appropriate to the proper facilities that can observe and manage any delayed onset symptoms. *For phosgene oxime, effects are immediate. No overtriage would be anticipated.*
- Expectant categories in multi-casualty events are those victims who have experienced a cardiac arrest, respiratory arrest, or continued seizures immediately. Resources should not be expended on these casualties if there are large numbers of casualties requiring care and transport with minimal or scant resources available.

1. *Immediate:* casualties who require lifesaving care within a short time, when that care is available and of short duration. This care may be a procedure that can be done within minutes at an emergency treatment station (e.g., relief of an airway obstruction, administering antidotes) or may be acute lifesaving surgery.

2. *Delayed:* casualties with severe injuries who are in need of major or prolonged surgery or other care and who will require hospitalization, but delay of this care will not adversely affect the outcome of the injury (e.g., fixation of a stable fracture).

3. *Minimal:* casualties who have minor injuries, can be helped by nonphysician medical personnel, and will not require hospitalization.

4. *Expectant:* casualties with severe life-threatening injuries who would not survive with optimal medical care, or casualties whose injuries are so severe that their chance of survival does not justify expenditure of limited resources. As circumstances permit, casualties in this category may be reexamined an possibly be retriaged to a higher category.

ABC Reminders

Quickly ensure that the victim has a patent airway. Maintain adequate circulation. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Apply direct pressure to stop arterial bleeding, if present.

Victim Removal

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be removed on backboards or gurneys. If these are not available, carefully carry or drag victims to safety.

Decontamination Zone

Decontamination or self-aid immediately after skin and ocular exposure is the only means for preventing or decreasing tissue damage since phosgene oxime is absorbed within seconds. Decontaminable gurneys and back boards should be used if available when managing casualties in a contaminated area. Decontaminable gurneys are made of a monofilament polypropylene fabric that allows drainage of liquids, does not absorb chemical agents, and is easily decontaminated. Fiberglass back boards have been developed specifically for use in HAZMAT incidents. These are nonpermeable and readily decontaminated. The **Chemical Resuscitation Device** is a bag-valve mask equipped with a chemical agent cannister that can be used to ventilate casualties in a contaminated environment.

Rescuer Protection

Personnel should continue to wear the same level of protection as required in the Hot Zone (see *Rescuer Protection* under *Hot Zone*, above).

ABC Reminders

Quickly ensure that the victim has a patent airway. Maintain adequate circulation. Stabilize the cervical spine with a decontaminable collar and a backboard if trauma is suspected. Administer supplemental oxygen if cardiopulmonary compromise is suspected. Assist ventilation with a bag-valve-mask device equipped with a cannister or air filter if necessary. Direct pressure should be applied to control bleeding, if present.

Basic Decontamination

The eyes and skin must be decontaminated immediately after exposure because the agent is absorbed from the skin within seconds. Flush the eyes immediately with water for about 5 to 10 minutes by tilting the head to the side, pulling eyelids apart with fingers, and pouring water slowly into eyes. Do not cover eyes with bandages.

If exposure to liquid is suspected, victims should remove all clothing and wash skin with soap and water. If shower areas are available, showering with water alone will be adequate. However, in those cases where water is in short supply, and showers are not available, an alternative form of decontamination is to use 0.5% sodium hypochlorite solution or absorbent powders such as flour, talcum powder, or Fuller's earth. If exposure to vapor only is certain, remove outer clothing and wash with soap and water or 0.5% solution of sodium hypochlorite. Place contaminated clothes and personal belongings in a sealed double bag.

In cases of ingestion, **do not induce emesis**.

Transfer to Support Zone

As soon as basic decontamination is complete, move the victim to the Support Zone.

Support Zone

Be certain that victims have been decontaminated properly (see *Decontamination Zone* above). Victims who have undergone decontamination or have been exposed only to phosgene oxime vapor pose no serious risk of secondary contamination to rescuers. In such cases, Support Zone personnel require no specialized protective gear.

ABC Reminders

Quickly ensure that the victim has a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Ensure adequate respiration; administer supplemental oxygen if cardiopulmonary compromise is suspected. Maintain adequate circulation. Establish intravenous access if necessary. Attach a cardiac monitor. Direct pressure should be applied to stop bleeding, if present.

Additional Decontamination

Continue irrigating exposed skin and eyes, as appropriate.

In cases of ingestion, **do not induce emesis**. If the victim is alert and able to swallow, give 4 to 8 ounces of milk or water to drink. There are no data regarding the efficacy of activated charcoal.

Advanced Treatment

Intubate the trachea in cases of respiratory compromise. When the patient's condition precludes endotracheal intubation, perform cricothyrotomy if equipped and trained to do so.

Treat patients who have bronchospasm with bronchodilators.

Patients who are comatose or hypotensive, or have seizures or ventricular dysrhythmias due to other exposures or trauma should be treated according to advanced life support (ALS) protocols.

Transport to Medical Facility

Report the condition of the patient, treatment given, and estimated time of arrival at the medical facility to the base station and the receiving medical facility.

Multi-Casualty Triage

Consult with the base station physician, closest Metropolitan Medical Response System, or the regional poison control center for advice regarding triage of multiple victims.

Patients who have sustained skin, eye, or respiratory lesions and those who have ingested phosgene oxime should be transported to a medical facility for evaluation.

Patients who have no symptoms may be discharged from the scene, after their names, addresses, and telephone numbers have been recorded. They should be advised to rest and to seek medical care promptly if additional symptoms develop (see *Follow-up Instructions*, included with the *Phosgene Oxime Patient Information Sheet* below).

Emergency Department Management

- **Patients whose skin or clothing is contaminated with liquid or solid phosgene oxime can contaminate rescuers by direct contact or through off-gassing vapor.**
- **Phosgene oxime is extremely toxic and may cause immediate pain and necrotic lesions of the eyes, skin, and respiratory tract.**
- **There is no antidote for phosgene oxime toxicity. Treatment consists of supportive measures.**

Decontamination Area

Previously decontaminated patients may be transferred immediately to the Treatment Area. Others require decontamination as described below.

ABC Reminders

Evaluate and support the airway, breathing, and circulation. Intubate the trachea in cases of respiratory compromise. If the patient's condition precludes intubation, surgically create an airway.

Treat patients who have bronchospasm with bronchodilators.

Patients who are comatose or hypotensive, or have seizures or ventricular dysrhythmias due to other exposures or trauma should be treated in the conventional manner.

Personal Protection

If contaminated patients arrive at the Emergency Department, they must be decontaminated before being allowed to enter the facility. Decontamination can take place inside the hospital only if there is a decontamination facility with negative air pressure and floor drains to contain contamination. Personnel should wear the same level of protection required in the Hot Zone (see *Rescuer Protection* under Hot Zone, above).

Basic Decontamination

Flush the eyes with water for about 5 to 10 minutes. Do not cover eyes with bandages; if necessary, use dark or opaque goggles to relieve discomfort from photophobia.

If a liquid splash is suspected, clothing must be removed and the patient showered using soap and water. Showering should be accomplished using cool water and enough water pressure to quickly reduce the potential for agent penetration of the skin. If the patient was exposed to vapor only, remove outer clothing and wash exposed skin with soap and water. Place contaminated clothes and personal belongings in a sealed double bag.

In cases of ingestion, **do not induce emesis**. If the patient is alert and able to swallow, give 4 to 8 ounces of milk or water to drink if not already administered.

Treatment Area

Be certain that appropriate decontamination has been carried out (see *Decontamination Area* above).

ABC Reminders

Evaluate and support the airway, breathing, and circulation (as in *ABC Reminders*, previous page). Establish intravenous access and continuously monitor cardiac rhythm in seriously ill patients.

Patients who are comatose, hypotensive, or who have seizures or ventricular dysrhythmias due to other exposures or trauma should be treated in the conventional manner.

Triage

Patients arriving at the emergency department directly from the scene of potential exposure (within 30-60 minutes) will have pain or irritation if they were exposed. If they have no pain or irritation, they can safely be sent home and told to return with the onset of symptoms. Patients with skin or eye lesions or with respiratory symptoms should undergo decontamination and be admitted. Those with large burns or with shortness of breath should be admitted to the Critical Care Unit following appropriate decontamination. Patients with other symptoms should be observed for at least 6 hours.

Airway Exposure

Patients with minor upper-respiratory symptoms (nose, sinus, pharyngitis) should be admitted to a routine care ward for treatment. Pulmonary edema may develop several hours after exposure. Patients with symptoms or signs of severe respiratory injury should be admitted to the Critical Care Unit for treatment in a conventional manner for non-cardiac pulmonary edema.

Skin Exposure

If the skin was in contact with phosgene oxime, treat tissue damage in the same manner as for any corrosive lesion. If the burned area is large, the patient should be transferred to a Burn Unit with reverse isolation. Most burns are second degree although third degree burns may occur after liquid exposure. The denuded area should be irrigated two or three times a day using a whirlpool if the lesion is large (the patient should be given ample amounts of a systemic analgesic beforehand). This should be followed by liberal application of a topical antibiotic. Skin lesions may take many months to heal. Systemic antibiotics should be used when there are signs of infection and a culture indicates the responsible organism.

Eye Exposure

Mild conjunctivitis beginning more than 12 hours after exposure is unlikely to progress to a severe lesion. The patient should have a thorough eye examination (including a test for visual acuity), treatment with a soothing eye solution such as Visine or Murine, and be advised to return if there is worsening. Conjunctivitis beginning earlier and other effects such as lid swelling and signs/symptoms of inflammation indicate need for inpatient care and observation.

Lesions more severe than conjunctivitis may be treated with a topical mydriatic (e.g., atropine), topical antibiotics, and vaseline or similar substance applied to the lid edges several times a day. Consult an ophthalmologist for patients with severe corneal injuries. Topical analgesics should be used only for an initial examination (including slit lamp and a test of visual acuity), but not after. Pain may be controlled with systemic analgesics. Once the lid edema and blepharospasm subside and the eyes are open, dark glasses may reduce the discomfort of photophobia.

Ingestion Exposure

Do not induce emesis. Treat nausea and vomiting with antiemetics.

Antidotes and Other Treatments

There is no antidote for phosgene oxime. Treatment is supportive.

Laboratory Tests

Routine laboratory studies should be done for all patients requiring admission. These include CBC, glucose, serum electrolytes, liver enzymes, and kidney function tests. Chest X-ray and pulse oximetry (or ABG measurements) are recommended for inhalation exposures.

Disposition and Follow-up

Patients with moderate to severe exposures will require hospitalization, as discussed above.

Patient Release

Patients with no symptoms may be discharged. Discharged patients should be advised to rest and to seek medical care promptly if symptoms develop (see *Follow-up Instructions*, included with the *Phosgene Oxime Patient Information Sheet* below).

Follow-up

Patients who have mild skin burns should be reexamined within 24 hours.

Reporting

Other persons may still be at risk in the setting where this incident occurred. If a public health risk exists, notify your state or local health department or other responsible public agency.

Phosgene Oxime ($CHCl_2NO$)
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to phosgene oxime.

What is phosgene oxime?
Phosgene oxime is a colorless, crystalline solid or a yellowish-brown liquid. It is classified as a urticant or nettle chemical warfare agent; however, it has not been used on the battlefield.

What immediate health effects can be caused by exposure to phosgene oxime?
Phosgene oxime causes immediate and painful skin and eye lesions. Inhalation causes fluid to accumulate in the lungs and severe bronchitis.

Can phosgene oxime poisoning be treated?
There is no antidote for phosgene oxime. Its effects can be treated in the same way as burns from other causes (e.g., strong acids). Exposed persons may need to be hospitalized.

Are any future health effects likely to occur?
There is no information evaluating future health effects.

What tests can be done if a person has been exposed to phosgene oxime?
There are no specific tests to confirm exposure.

Where can more information about phosgene oxime be found?
Phosgene oxime is one of the least well studied chemical warfare agents; therefore, specific information is limited. More information about phosgene oxime may be obtained from your regional poison control center; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in toxicology or occupational and environmental health. Ask the person who gave you this form for help locating these telephone numbers.

Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow *only* the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:

- coughing, wheezing, or shortness of breath
- increased pain or discharge from injured eyes
- increased redness, pain, or a pus-like discharge from injured skin

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.
[ ] Call for an appointment with Dr. _____ in the practice of _____. When you call for your appointment, please say that you were treated in the Emergency Department at _____ Hospital by _____ and were advised to be seen again in _____ days.
[ ] Return to the Emergency Department/ _____ Clinic on (date) _____ at _____ AM/PM for a follow-up examination.
[ ] Do not perform vigorous physical activities for 1 to 2 days.
[ ] You may resume everyday activities including driving and operating machinery.
[ ] Do not return to work for _____ days.
[ ] You may return to work on a limited basis. See instructions below.
[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.
[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.
[ ] Avoid taking the following medications: _____
[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: _____
_____
_____
[ ] Other instructions: _____
_____
_____

- Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.

- You or your physician can get more information on the chemical by contacting: _____ _____ or _____, or by checking out the following Internet Web sites: _____; _____.

Signature of patient _____ Date _____

Signature of physician _____ Date _____

Selenium Hexafluoride (SeF_6)
CAS 7783-79-1; UN 2194

Synonyms include selenium fluoride and selenium (VI) fluoride.

- **Persons exposed only to selenium hexafluoride gas do not pose secondary contamination risks.**
- **At room temperature, selenium hexafluoride is a colorless gas. It is not highly flammable, but when heated to high temperatures, it may decompose to produce toxic fumes (fluoride and selenium). Vapors from the liquified gas are initially heavier than air and spread along the ground. The odor of selenium hexafluoride may not provide adequate warning of hazardous concentrations.**
- **Selenium hexafluoride is absorbed by the lungs. Exposure causes inflammation and irritation of the skin, respiratory tract, and mucous membranes. Pulmonary edema may also occur after inhalation. Contact with the liquified gas may cause burns, severe injury, or frostbite.**

Description

Selenium hexafluoride is a colorless gas at room temperature. It is corrosive and highly toxic. Selenium hexafluoride should be stored in a cool, fireproof building with ventilation along the floor. Selenium hexafluoride is insoluble in water.

Routes of Exposure

Inhalation

Inhaled selenium hexafluoride is a highly toxic, corrosive, and irritating gas. It is absorbed from the lungs and is irritating to the upper respiratory tract even at low concentrations. No data as to odor threshold were located; **odor may not provide an adequate warning of potentially hazardous concentrations**. Selenium hexafluoride vapor is heavier than air, and asphyxiation in enclosed, poorly ventilated, or low-lying areas is possible.

Children exposed to the same levels of selenium hexafluoride vapor as adults may receive a larger dose because they have greater lung surface area:body weight ratios and higher minute volume:weight ratios. In addition, they may be exposed to higher levels than adults in the same location because of their short stature and the higher levels of selenium hexafluoride vapor found nearer to the ground.

Skin/Eye Contact

Direct contact with selenium hexafluoride gas causes rapid and severe eye and skin irritation or burns. Exposure to the liquified gas may produce burns, severe injury or frostbite.

Children are more vulnerable to toxicants affecting the skin because of their relatively larger surface area:body weight ratio. In addition, they may be exposed to higher levels than adults in the same location because of their short stature and the higher levels of selenium hexafluoride found nearer to the ground.

Ingestion

Selenium hexafluoride is a gas at room temperature and ingestion is therefore unlikely.

Sources/Uses

Selenium hexafluoride is prepared by passing gaseous fluoride over finely divided selenium in a copper vessel.

Selenium hexafluoride is used as a gaseous electrical insulator.

Standards and Guidelines

OSHA PEL (permissible exposure limit) = 0.05 ppm, as selenium.

NIOSH IDLH (immediately dangerous to life or health) = 2 ppm.

Physical Properties

Description: Colorless gas.

Warning properties: none

Molecular weight: 192.95 daltons

Boiling point (760 mm Hg): sublimes at -51.88 °F (-46.6 °C)

Freezing point: - 59.44 °F (-50.8 °C)

Vapor pressure: 651.2 mm Hg at -55.66 °F (-48.7 °C)

Gas density: 6.7 (air = 1)

Specific gravity: 3.25 at -28 °C (water = 1)

Water solubility: insoluble

Flammability: not flammable

Flammable range: not flammable

Incompatibilities

Selenium hexafluoride reacts with water. Selenium hexafluoride also reacts with ammonia gas at 200 °C to give selenium, nitrogen, and hydrogen fluoride.

Health Effects

- **Selenium hexafluoride gas is corrosive and severely irritating to skin, eyes, and mucous membranes. Inhalation of selenium hexafluoride results in respiratory distress and pulmonary edema. Contact with the skin or eyes produces irritation and lacrimation, and can result in chemical burns, permanent tissue damage, or blindness. Contact with the liquified gas may cause burns, severe injury, or frostbite.**

- **Selenium hexafluoride decomposes into selenium and hydrofluoric acid on contact with moisture. No information was found as to whether the health effects of selenium hexafluoride in children are different than in adults. Exposure to selenium hexafluoride produces severe respiratory problems and individuals with pre-existing breathing difficulties or skin disease may be more susceptible to its effects.**

Acute Exposure

Selenium hexafluoride decomposes into selenium and hydrofluoric acid on contact with moisture. Onset of irritation is immediate, but pulmonary edema may be delayed several hours. Burns and damage to the eyes are progressive while any unneutralized fluoride ion remains.

Children do not always respond to chemicals in the same way that adults do. Different protocols for managing their care may be needed.

Respiratory

Selenium hexafluoride produces irritation of the respiratory-tract, and can lead to pulmonary edema and death.

Children may be more vulnerable to corrosive agents because of the smaller diameter of their airways.

Children may be more vulnerable because of relatively higher minute ventilation per kg and failure to evacuate an area promptly when exposed.

Dermal

Selenium hexafluoride is a skin irritant. Contact with the liquified gas may cause burns, severe injury or frostbite. Burns are progressive while any unneutralized fluoride ion remains.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants affecting the skin.

Ocular/Ophthalmic

Selenium hexafluoride gas can cause eye irritation and damage to the cornea, exposure to the liquified gas can cause severe damage or blindness. Damage to the eyes is progressive while any unneutralized fluoride ion remains.

Potential Sequelae

Tissue damage may be permanent; damage to the eyes may cause blindness. Exposure to selenium hexafluoride may result in electrolyte imbalance Selenium hexafluoride may trigger electrolyte imbalance similar to that elicited by hydrogen fluoride, since selenium hexafluoride readily decomposes to selenium and hydrogen fluoride upon contact with moisture. Refer to the Medical Management Guidelines for hydrogen fluoride for additional information.

Chronic Exposure

Repeated contact with low concentrations of selenium hexafluoride may cause dermatitis, systemic toxicity characteristic of chronic selenium exposure, or fluorosis, a degenerative bone condition.

Chronic exposure may be more serious for children because of their potential longer latency period.

Carcinogenicity

Selenium hexafluoride has not been classified for carcinogenicity.

Reproductive and Developmental Effects

No studies were located that address reproductive or developmental effects of selenium hexafluoride in humans. Selenium hexafluoride is not included in *Reproductive and Developmental Toxicants*, a 1991 report published by the U.S. General Accounting Office (GAO) that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences.

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Prehospital Management

- **Victims exposed only to selenium hexafluoride gas do not pose contamination risks to rescuers.**
- **Selenium hexafluoride is corrosive and irritating to mucous membranes, skin, eyes, and the respiratory system. Acute inhalation exposure may lead to respiratory distress and noncardiogenic pulmonary edema.**
- **There is no antidote for selenium hexafluoride. Treatment consists of respiratory and cardiovascular support.**

Hot Zone

Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if rescuers have not been trained in its use, assistance should be obtained from a local or regional HAZMAT team or other properly equipped response organization.

Rescuer Protection

Selenium hexafluoride is a highly toxic gas, it is corrosive and severely irritating to the eyes, mucous membranes, respiratory tract, and skin. Selenium hexafluoride is not flammable, but when heated, decomposes to produce irritating, corrosive, and/or toxic gases.

Respiratory Protection: Positive-pressure, self-contained breathing apparatus (SCBA) is recommended in response situations that involve exposure to potentially unsafe levels of selenium hexafluoride.

Skin Protection: Chemical-protective clothing is recommended because selenium hexafluoride can cause skin irritation and burns. Fully encapsulating, vapor protective clothing should be worn to deal with spills or leaks with no fire.

ABC Reminders

Quickly establish a patent airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible.

Victim Removal

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be removed on backboards or gurneys; if these are not available, carefully carry or drag victims to safety.

Consider appropriate management of anxiety in victims with chemically-induced acute disorders, especially children who may suffer separation anxiety if separated from a parent or other adult.

Decontamination Zone

Patients exposed only to selenium hexafluoride vapor who have no skin or eye irritation may be transferred immediately to the Support Zone. Other patients will require decontamination as described below.

Rescuer Protection

If exposure levels are determined to be safe, decontamination may be conducted by personnel wearing a lower level of protection than that worn in the Hot Zone (described above).

ABC Reminders

Quickly establish a patent airway, ensure adequate respiration and pulse. Stabilize the cervical spine with a collar and a backboard if trauma is suspected. Administer supplemental oxygen as required. Assist ventilation with a bag-valve-mask device if necessary.

Basic Decontamination

Victims who are able may assist with their own decontamination. Decontamination is important as burns and damage to the eyes are progressive while any unneutralized fluoride ion remains.

Flush exposed skin and hair with copious amounts of water. Wash with soap and rinse thoroughly with water. Use caution to avoid hypothermia when decontaminating victims, particularly children or the elderly. Use blankets or warmers after decontamination as needed.

Flush exposed or irritated eyes with tepid water for 15 minutes. Remove contact lenses if easily removable without additional trauma to the eye. Continue eye irrigation during other basic care and transport. If pain or injury is evident, continue irrigation while transferring the victim to the Support Zone.

Consider appropriate management of chemically contaminated children at the exposure site. Provide reassurance to the child during decontamination, especially if separation from a parent occurs.

Transfer to Support Zone

As soon as basic decontamination is complete, move the victim to the Support Zone.

Support Zone

Be certain that victims have been decontaminated properly (see *Decontamination Zone*, above). Victims who have undergone decontamination or have been exposed only to vapor pose no

serious risks of secondary contamination to rescuers. In such cases, Support Zone personnel require no specialized protective gear.

ABC Reminders

Quickly establish a patent airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Administer supplemental oxygen as required and establish intravenous access if necessary. Place on a cardiac monitor, if available.

In cases of contact with liquid (compressed gas), gently wash frosted skin with water; gently remove clothing from affected area. Dry with clean towels and keep victim warm and quiet.

Additional Decontamination

Continue irrigating exposed skin and eyes, as appropriate.

Advanced Treatment

Treat cases of respiratory compromise, coma, or excessive pulmonary secretions with respiratory support using protocols and techniques available and within the scope of training. Some cases may necessitate procedures such as endotracheal intubation or cricothyroidotomy by properly trained and equipped personnel.

Treat patients who have bronchospasm with an aerosolized bronchodilator such as albuterol. Administer corticosteroids as indicated to patients who have persistent wheezing or hypersensitivity pneumonitis.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Patients who are comatose, hypotensive, or having seizures or cardiac arrhythmias should be treated according to advanced life support (ALS) protocols.

Transport to Medical Facility

Only decontaminated patients or patients not requiring decontamination should be transported to a medical facility. “Body bags” are not recommended.

Report to the base station and the receiving medical facility the condition of the patient, treatment given, and estimated time of arrival at the medical facility.

Multi-Casualty Triage

Consult with the base station physician or the regional poison control center for advice regarding triage of multiple victims.

Patients who are seriously symptomatic (as in cases of chest tightness or wheezing), and patients who have histories or evidence of significant exposure should be transported to a medical facility for evaluation. Others may be discharged at the scene after their names, addresses, and telephone numbers are recorded. Those discharged should be advised to seek medical care promptly if symptoms develop (see *Patient Information Sheet* below).

Emergency Department Management

- **Patients do not pose a contamination risk to hospital personnel.**
- **Selenium hexafluoride is corrosive and irritating to mucous membranes, skin, eyes, and the respiratory tract. Acute inhalation exposure may lead to respiratory distress and noncardiogenic pulmonary edema.**
- **There is no antidote for selenium hexafluoride. Treatment consists of respiratory and cardiovascular support.**

Decontamination Area

Unless previously decontaminated, all victims with skin or eye irritation require decontamination as described below. All other patients may be transferred immediately to the Critical Care Area.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants absorbed through the skin. Also emergency room personnel should examine children's mouths because of the frequency of hand-to-mouth activity among children.

ABC Reminders

Treat cases of respiratory compromise, coma, or excessive pulmonary secretions with respiratory support using protocols and techniques available and within the scope of training. Some cases may necessitate procedures such as endotracheal intubation or cricothyroidotomy by properly trained and equipped personnel.

Treat patients who have bronchospasm with an aerosolized bronchodilator such as albuterol. Administer corticosteroids as indicated to patients who have persistent wheezing or hypersensitivity pneumonitis.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Patients who are comatose, hypotensive, or have seizures or ventricular arrhythmias should be treated in the conventional manner.

Basic Decontamination

Patients who are able may assist with their own decontamination. Decontamination is important as burns and damage to the eyes are progressive while any unneutralized fluoride ion remains.

Flush exposed skin and hair with water for 2 to 3 minutes (preferably under a shower), then wash thoroughly with mild soap. Rinse thoroughly with water. In case of frostbite injury, irrigate with lukewarm (42 °C) water according to standard treatment. Use caution to avoid hypothermia when decontaminating victims, particularly children or the elderly. Use blankets or warmers after decontamination as needed.

Flush exposed eyes with plain tepid water for at least 15 minutes. Remove contact lenses if easily removable without additional trauma to the eye. If pain or injury is evident, continue irrigation while transporting the patient to the Critical Care Area.

Critical Care Area

Be certain that appropriate decontamination has been carried out (see *Decontamination Area* above).

ABC Reminders

Evaluate and support airway, breathing, and circulation as in ABC Reminders above under *Decontamination Zone*. Establish intravenous access in seriously ill patients if this has not been done previously. Continuously monitor cardiac rhythm.

Patients who are comatose, hypotensive, or have seizures or cardiac arrhythmias should be treated in the conventional manner.

Inhalation Exposure

Administer supplemental oxygen by mask to patients who have respiratory symptoms. Treat patients who have bronchospasm with an aerosolized bronchodilator such as albuterol. Administer corticosteroids as indicated to patients who have persistent wheezing or hypersensitivity pneumonitis.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Skin Exposure

If the skin was in contact with selenium hexafluoride gas chemical burns may occur; treat as thermal burns. Flush exposed skin for at least 20 minutes. Contact with the liquified gas may produce frostbite. In case of frostbite injury, irrigate with lukewarm (42 °C) water according to standard treatment. Burns may be treated with

a calcium gluconate gel or slurry in water or glycerine to remove fluoride ions and relieve pain.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants affecting the skin.

Eye Exposure

Continue irrigation for at least 15 minutes. In case of frostbite injury, ensure that thorough warming with lukewarm water or saline has been completed. Test visual acuity. Examine the eyes for corneal damage and treat appropriately. Immediately consult an ophthalmologist for patients who have corneal injuries.

Antidotes and Other Treatments

There is no antidote for selenium hexafluoride. Treatment is supportive of respiratory and cardiovascular functions.

Laboratory Tests

Routine laboratory studies for all exposed patients include CBC, glucose, and electrolyte determinations. An EKG should be performed if significant exposure is suspected. Patients who have respiratory complaints may require pulse oximetry (or ABG measurements), chest radiography, and peak-flow spirometry.

Disposition and Follow-up

Consider hospitalizing patients who have histories of significant inhalation exposure and are symptomatic (e.g., chest tightness or wheezing).

Delayed Effects

Pulmonary edema may be delayed for several hours after inhalation exposure. Burns and damage to the eyes are progressive while any unneutralized fluoride ion remains.

Patient Release

Patients who remain asymptomatic for 24 hours after exposure may be discharged with instructions to seek medical care promptly if symptoms develop (see the *Selenium hexafluoride—Patient Information Sheet* below).

Follow-up

Obtain the name of the patient's primary care physician so that the hospital can send a copy of the ED visit to the patient's doctor.

If significant inhalation or skin contact has occurred, monitor pulmonary function.

Patients who have corneal injuries should be reexamined within 24 hours.

Reporting

If a work-related incident has occurred, you may be legally required to file a report; contact your state or local health department.

Other persons may still be at risk in the setting where this incident occurred. If the incident occurred in the workplace, discussing it with company personnel may prevent future incidents. If a public health risk exists, notify your state or local health department or other responsible public agency. When appropriate, inform patients that they may request an evaluation of their workplace from OSHA or NIOSH. See Appendix III for a list of agencies that may be of assistance.

Selenium hexafluoride
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to selenium hexafluoride.

What is selenium hexafluoride?
Selenium hexafluoride is a corrosive, colorless gas. Selenium hexafluoride is used as a gaseous electrical insulator.

What immediate health effects can be caused by exposure to selenium hexafluoride?
Low levels of selenium hexafluoride in the air can irritate the eyes, nose, throat, and lungs and cause cough, chest tightness, and shortness of breath. Higher levels can cause a build-up of fluid in the lungs, which may cause death. If the liquified gas comes in contact with the skin or eyes, it can cause severe burns or frostbite. Generally, the more serious the exposure, the more severe the symptoms.

Can selenium hexafluoride poisoning be treated?
There is no antidote for selenium hexafluoride, but its effects can be treated and most exposed persons get well. Seriously exposed persons may need to be hospitalized.

Are any future health effects likely to occur?
In rare cases, after exposure to selenium hexafluoride, certain persons can develop allergies in which even small exposures to selenium hexafluoride or other irritants can trigger skin irritation. Therefore, it is important to tell your doctor that you have been exposed to selenium hexafluoride.

What tests can be done if a person has been exposed to selenium hexafluoride?
Specific tests for the presence of selenium hexafluoride in blood are not available. If a severe exposure has occurred, respiratory function tests and a chest x-ray may show whether damage has been done to the lungs. Testing is not needed in every case.

Where can more information about selenium hexafluoride be found?
More information about selenium hexafluoride can be obtained from your regional poison control center; your state, county, or local health department; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor, or a clinic in your area that specializes in occupational and environmental health. If the exposure happened at work, you may wish to discuss it with your employer, the Occupational Safety and Health Administration (OSHA), or the National Institute for Occupational Safety and Health (NIOSH). Ask the person who gave you this form for help in locating these telephone numbers.

Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow *only* the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:

- coughing, wheezing, difficulty breathing, shortness of breath, or chest pain
- increased pain or a discharge from your eyes
- increased redness or pain or a pus-like discharge in the area of a skin burn

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.
[ ] Call for an appointment with Dr. _____ in the practice of _____. When you call for your appointment, please say that you were treated in the Emergency Department at _____ Hospital by _____ and were advised to be seen again in _____ days.
[ ] Return to the Emergency Department/ _____ Clinic on (date) _____at _____ AM/PM for a follow-up examination.
[ ] Do not perform vigorous physical activities for 1 to 2 days.
[ ] You may resume everyday activities including driving and operating machinery.
[ ] Do not return to work for _____ days.
[ ] You may return to work on a limited basis. See instructions below.
[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.
[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.
[ ] Avoid taking the following medications: _____
[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: ___
_____
_____
[ ] Other instructions: _____
_____
_____

- Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.

- You or your physician can get more information on the chemical by contacting: _____ _____ or _____, or by checking out the following Internet Web sites: _____; _____.

Signature of patient _____ Date _____

Signature of physician _____ Date _____

Sodium Hydroxide (NaOH)
CAS 1310-73-2; UN 1823 (solid); UN 1824 (solution)

Synonyms include caustic soda, lye, soda lye, and sodium hydrate.

Persons whose clothing or skin is contaminated with solid sodium hydroxide or its solutions can secondarily contaminate rescuers by direct contact.

Sodium hydroxide is a white, noncombustible solid that absorbs moisture from the air. When the solid is in contact with water, it may generate sufficient heat to ignite combustible materials. The solid and its solutions are corrosive. Sodium hydroxide is odorless; thus, odor provides no warning of hazardous concentrations.

Sodium hydroxide does not produce systemic toxicity, but is very CORROSIVE and can cause severe burns in all tissues that it comes in contact with. Sodium hydroxide poses a particular threat to the eyes, since it can hydrolyze protein, leading to severe eye damage.

Description

At room temperature, anhydrous sodium hydroxide is a white crystalline, odorless solid that absorbs moisture from the air. It is produced as flakes, pellets, sticks, and cakes. When dissolved in water or neutralized with acid, it liberates substantial heat, which may be sufficient to ignite combustible materials. Sodium hydroxide is caustic and is one of several alkaline compounds referred to as "lye." It is generally used commercially as either the solid or as a 50% aqueous solution and should be stored in a cool, dry, well ventilated location separate from organic and oxidizing materials, acids, and metal powders.

Routes of Exposure

Inhalation

Inhalation of sodium hydroxide dust, mist, or aerosol may cause irritation of the mucous membranes of the nose, throat, and respiratory tract. Sodium hydroxide is odorless; thus, **odor provides no warning of hazardous concentrations**. Mucous membrane irritation occurs at the OSHA PEL (2 mg/m^3) and is generally an adequate warning property for acute exposure to sodium hydroxide. However, workers exposed to prolonged or recurrent mists or aerosols of sodium hydroxide can become somewhat tolerant of the irritant effects. Sodium hydroxide of sufficient strength can hydrolyze proteins in tissues and can kill cells in tissues.

Children exposed to the same levels of sodium hydroxide in air as adults may receive a larger dose because they have greater lung

surface area:body weight ratios and increased minute volumes:weight ratios. In addition, they may be exposed to higher levels than adults in the same location because of their short stature and the higher levels of sodium hydroxide in air found nearer to the ground.

Skin/Eye Contact

Exposure to sodium hydroxide solid or solution can cause skin and eye irritation. Direct contact with the solid or with concentrated solutions causes thermal and chemical burns leading to deep-tissue injuries. Very strong solutions of sodium hydroxide can hydrolyze proteins in the eyes, leading to severe burns and eye damage or, in extreme cases, blindness.

Children are more vulnerable to toxicants affecting the skin because of their relatively larger surface area: body weight ratio.

Ingestion

Ingestion of sodium hydroxide can cause **severe corrosive injury** to the lips, tongue, oral mucosa, esophagus, and stomach.

Sources/Uses

Sodium hydroxide is produced by the electrolysis of aqueous solutions of sodium chloride (brine) or by reacting naturally occurring sodium carbonate with calcium hydroxide.

Sodium hydroxide is used to manufacture soaps, rayon, paper, explosives, dyestuffs, and petroleum products. It is also used in processing cotton fabric, laundering and bleaching, metal cleaning and processing, electroplating, oxide coating, and electrolytic extracting. It is commonly present in commercial drain and oven cleaners.

Standards and Guidelines

OSHA PEL (permissible exposure limit) = 2 mg/m^3 (averaged over an 8-hour workshift)

NIOSH IDLH (immediately dangerous to life or health) = 10 mg/m^3

AIHA ERPG-2 (emergency response planning guideline) (maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms which could impair an individual's ability to take protective action) = 5 mg/m^3

Physical Properties

Description: Colorless-to-white, odorless, solid that absorbs moisture from the air.

Warning properties: Inadequate; no odor. Mucous membrane irritation at 2 mg/m^3.

Molecular weight: 40.0 daltons

Boiling point (760 mm Hg): 2,534 °F (1,390 °C)

Freezing point: 605 °F (318 °C)

Specific gravity: 2.13 (water = 1)

Vapor pressure: 0 mm Hg at 68 °F (20 °C)

Water solubility: 111% at 68 °F (20 °C)

Flammability: Noncombustible solid, but when in contact with water, it may generate enough heat to ignite combustible materials.

Incompatibilities

Sodium hydroxide dissolves easily in water generating a great deal of heat. It reacts with acids (also generating a lot of heat); halogenated organic compounds; metals such as aluminum, tin, and zinc; and nitromethane. Sodium hydroxide is corrosive to most metals.

Health Effects

- **Sodium hydroxide is strongly irritating and corrosive. It can cause severe burns and permanent damage to any tissue that it comes in contact with. Sodium hydroxide can cause hydrolysis of proteins, and hence can cause burns in the eyes which may lead to permanent eye damage.**
- **Inhaled sodium hydroxide can cause swelling of the larynx and an accumulation of fluid in the lungs.**
- **Stridor, vomiting, drooling, and abdominal pain are early symptoms of sodium hydroxide ingestion. Ingestion may lead to perforation of the gastrointestinal tract and shock.**
- **Sodium hydroxide does not produce systemic toxicity; its health effects are due to its corrosive nature.**

Acute Exposure

Sodium hydroxide is strongly irritating and corrosive. It can cause severe burns and permanent damage to any tissue that it comes in contact with. The extent of damage to the gastrointestinal tract may not be clear until several hours after ingestion. Inhaled sodium hydroxide can cause swelling of the larynx and an accumulation of fluid in the lungs. Contact with 25–50% solutions produces immediate irritation, while after contact with solutions of 4% or less, irritation may not develop for several hours. It may not be possible to correctly ascertain the degree of damage to eyes for up to 72 hours after exposure.

Children do not always respond to chemicals in the same way that adults do. Different protocols for managing their care may be needed.

Respiratory

Inhalation of sodium hydroxide is immediately irritating to the respiratory tract. Swelling or spasms of the larynx leading to upper-airway obstruction and asphyxia can occur after high-dose inhalation. Inflammation of the lungs and an accumulation of fluid in the lungs may also occur.

Children may be more vulnerable to corrosive agents than adults because of the relatively smaller diameter of their airways.

Children may be more vulnerable because of relatively increased minute ventilation per kg and failure to evacuate an area promptly when exposed.

People with asthma or emphysema may be more susceptible to the toxicity of this agent.

Dermal

Skin contact with solid sodium hydroxide or its concentrated solutions can cause severe burns with deep ulcerations. Burns appear soft and moist and are very painful. Although contact with concentrated solutions causes pain and irritation within 3 minutes, contact with dilute solutions may not cause symptoms for several hours.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants affecting the skin.

Ocular

Eye exposure may produce diffuse or localized blood vessel clots and an accumulation of fluid in the eye. Softening, sloughing, and ulcerations of the cornea may occur. Ulcerations may continue to progress for many days. Severe injury can lead to clouding of the eye surface and blindness.

Gastrointestinal

Ingestion of sodium hydroxide can cause spontaneous vomiting, chest and abdominal pain, and difficulty swallowing with drooling. Corrosive injury to the mouth, throat, esophagus, and stomach is extremely rapid and may result in perforation, hemorrhage, and narrowing of the gastrointestinal tract.

Potential Sequelae

Cataracts, glaucoma, adhesion of the eyelid to the cornea, blindness, and loss of the eye may occur after eye exposure.

Cancer of the esophagus has been reported 15 to 40 years after the formation of corrosion-induced strictures. However, it is believed that these cancers were the result of tissue destruction and scar formation rather than a direct cancer-causing action of sodium hydroxide.

Severe inhalation injuries may cause persistent hoarseness and reactive airways dysfunction syndrome (RADS), a chemically- or irritant-induced type of asthma.

Chronic Exposure

Chronic exposure to dusts or mists of sodium hydroxide may lead to ulceration of the nasal passages. Chronic skin exposures can lead to dermatitis. Ingestion may lead to perforation of the gastrointestinal tract or stricture formation.

Chronic exposure may be more serious for children because of their potential longer latency period.

Carcinogenicity

Sodium hydroxide has not been classified for carcinogenic effects. See *Potential Sequelae* above.

Reproductive and Developmental Effects

Sodium hydroxide dissociates within the body and would not reach the reproductive organs in an unchanged state. No data were located concerning reproductive endpoints in humans exposed to sodium hydroxide. Sodium hydroxide is not teratogenic in rats. Sodium hydroxide is not included in *Reproductive and Developmental Toxicants,* a 1991 report published by the U.S. General Accounting Office (GAO) that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences.

Prehospital Management

Victims whose clothing or skin is contaminated with sodium hydroxide solid or solutions can secondarily contaminate response personnel by direct contact. Victims do not pose risks of secondary contamination after clothing is removed and the skin is washed.

Sodium hydroxide is corrosive to tissues. When mists or aerosols of sodium hydroxide are inhaled, laryngeal edema and noncardiogenic pulmonary edema can result. Extensive skin burns or gastrointestinal-tract injury from ingestion may compromise fluid balance, causing shock; early clinical appearance may not predict this event. Stridor, vomiting, painful swallowing, drooling, and abdominal pain are early symptoms of sodium hydroxide ingestion.

There is no antidote for sodium hydroxide. Treatment consists of respiratory and cardiovascular support.

Hot Zone

Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if rescuers have not been trained in its use, assistance should be obtained from a local or regional HAZMAT team or other properly equipped response organization.

Rescuer Protection

Sodium hydroxide is a severe respiratory-tract and skin irritant.

Respiratory Protection: Positive-pressure, self-contained breathing apparatus (SCBA) is recommended in response situations that involve exposure to potentially unsafe levels of sodium hydroxide.

Skin Protection: Chemical-protective clothing is recommended because sodium hydroxide can cause irritation or skin burns.

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible.

Victim Removal

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be removed on backboards or gurneys; if these are not available, carefully carry or drag victims to safety.

Consider appropriate management of chemically contaminated children, such as measures to reduce separation anxiety if a child is separated from a parent or other adult.

Decontamination Zone

All victims require decontamination as described below.

Rescuer Protection

If exposure levels are determined to be safe, decontamination may be conducted by personnel wearing a lower level of protection than that worn in the Hot Zone (described above).

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. Stabilize the cervical spine with a collar and a backboard if trauma is suspected. Administer supplemental oxygen as required. Assist ventilation with a bag-valve-mask device if necessary.

Basic Decontamination

Rapid decontamination is critical. Victims who are able may assist with their own decontamination. Rescuers should wear protective clothing and gloves while treating patients whose skin is contaminated with sodium hydroxide.

Immediately brush any solid material from clothes, skin, or hair while protecting the victim's eyes. Quickly remove contaminated clothing and flush exposed areas with water for at least 15 minutes. Double-bag contaminated clothing and personal belongings. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Flush exposed or irritated eyes with plain water or saline for at least 30 minutes. Remove contact lenses if easily removable without additional trauma to the eye, otherwise sodium hydroxide trapped beneath the lens will continue to damage the eye. If pain or injury is evident, continue irrigation while transferring the victim to the Support Zone.

In cases of ingestion, **do not induce emesis**. **Do not administer activated charcoal or attempt to neutralize stomach contents**.

Victims who are conscious and able to swallow can be given 4 to 8 ounces of milk or water; if the patient is symptomatic, delay decontamination until other emergency measures have been instituted.

Consider appropriate management of chemically contaminated children at the exposure site. Provide reassurance to the child

during decontamination, especially if separation from a parent occurs.

Transfer to Support Zone

As soon as basic decontamination is complete, move the victim to the Support Zone.

Support Zone

Be certain that victims have been decontaminated properly (see *Decontamination Zone* above). Victims who have undergone decontamination pose no serious risks of secondary contamination to rescuers. In such cases, Support Zone personnel require no specialized protective gear.

ABC Reminders

Quickly access for a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Ensure adequate respiration and pulse. Administer supplemental oxygen as required and establish intravenous access if necessary. Place on a cardiac monitor.

Additional Decontamination

Continue irrigating exposed skin and eyes, as appropriate.

In cases of ingestion, **do not induce emesis**. **Do not administer activated charcoal or attempt to neutralize stomach contents**.

Victims who are conscious and able to swallow can be given 4 to 8 ounces of milk or water if this has not been given previously; if the patient is symptomatic, delay decontamination until other emergency measures have been instituted.

Advanced Treatment

In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, perform cricothyroidotomy if equipped and trained to do so. Avoid blind nasotracheal intubation or the use of an esophageal obturator. Use direct visualization to intubate.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Sodium hydroxide poisoning is not known to pose additional risk during the use of bronchial or cardiac sensitizing agents.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Patients who are comatose, hypotensive, or are having seizures or cardiac arrhythmias should be treated according to advanced life support (ALS) protocols.

Transport to Medical Facility

Only decontaminated patients should be transported to a medical facility. "Body bags" are not recommended.

Report to the base station and the receiving medical facility the condition of the patient, treatment given, and estimated time of arrival at the medical facility.

If a chemical has been ingested, prepare the ambulance in case the victim vomits toxic material. Have ready several towels and open plastic bags to quickly clean up and isolate vomitus.

Multi-Casualty Triage

Consult with the base station physician or the regional poison control center for advice regarding triage of multiple victims.

Patients with evidence of ingestion or substantial inhalation exposure or who have evidence of eye or skin burns should be transported to a medical facility for evaluation. Others may be discharged from the scene after their names, addresses, and telephone numbers are recorded. Those discharged should be advised to seek medical care promptly if symptoms develop (see *Patient Information Sheet* below).

Emergency Department Management

Patients who have sodium hydroxide solid or solution on their skin or clothing can secondarily contaminate hospital personnel by direct contact. Patients do not pose risks of secondary contamination after clothing is removed and the skin is washed.

Sodium hydroxide is corrosive to tissues. The severity of sodium hydroxide burns may not be readily apparent until 24 to 48 hours after exposure.

Stridor, vomiting, drooling, and abdominal pain are early symptoms of sodium hydroxide ingestion. Patients who have ingested sodium hydroxide may progress to shock. Patients who have inhaled mists or aerosols of sodium hydroxide may experience laryngeal edema and noncardiogenic pulmonary edema.

There is no antidote for sodium hydroxide. Treatment consists of respiratory and cardiovascular support.

Decontamination Area

Unless previously decontaminated, all patients suspected of contact with solid sodium hydroxide or its solutions and all victims with skin or eye irritation require decontamination as described below. Because sodium hydroxide is extremely corrosive, hospital personnel should don rubber gloves, rubber aprons, and eye protection before treating contaminated patients. All other patients may be transferred to the Critical Care area.

Be aware that use of protective equipment by the provider may cause fear in children, resulting in decreased compliance with further management efforts.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants affecting the skin. Also, emergency room personnel should examine children's mouths because of the frequency of hand-to-mouth activity among children.

ABC Reminders

Evaluate and support airway, breathing, and circulation. Children may be more vulnerable to corrosive agents than adults because of the smaller diameter of their airways. Administer 100% humidified supplemental oxygen to patients who have hypoxemia. In cases of respiratory compromise secure airway and respiration via endotracheal intubation. Because of possible corrosive injury, intubation should be done carefully. If not possible, surgically create an airway.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Sodium hydroxide poisoning is not known to pose additional risk during the use of bronchial or cardiac sensitizing agents.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Patients who are comatose, hypotensive, or have seizures or ventricular arrhythmias should be treated in the conventional manner.

Basic Decontamination

Rapid decontamination is critical. Patients who are able may assist with their own decontamination.

Immediately brush any solid material from clothes, skin, or hair while protecting the victim's eyes. Quickly remove contaminated clothing and flush exposed areas with water for at least 15 minutes. Double-bag contaminated clothing and personal belongings. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Flush exposed or irritated eyes with plain water or saline for at least 30 minutes. Remove contact lenses if easily removable without additional trauma to the eye. If a corrosive material is suspected or if pain or injury is evident, continue irrigation while transferring the victim to the Critical Care Area.

In cases of ingestion, **do not induce emesis**. **Do not administer activated charcoal or attempt to neutralize stomach contents**.

Victims who are conscious and able to swallow can be given 4 to 8 ounces of milk or water if this has not been given previously (see *Critical Care Area* below for more information on ingestion exposure).

Critical Care Area

Be certain that appropriate decontamination has been carried out (see *Decontamination Area* above).

ABC Reminders

Evaluate and support airway, breathing, and circulation as in *ABC Reminders* above. Children may be more vulnerable to corrosive agents than adults because of the smaller diameter of their airways. Establish intravenous access in seriously ill patients if this has not been done previously. Continuously monitor cardiac rhythm.

Patients who are comatose, hypotensive, or have seizures or cardiac arrhythmias should be treated in the conventional manner.

Inhalation Exposure

Administer supplemental oxygen by mask to patients who have respiratory symptoms. Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Sodium hydroxide poisoning is not known to pose additional risk during the use of bronchial or cardiac sensitizing agents.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Skin Exposure

Skin burns from sodium hydroxide should be irrigated frequently with normal saline for 24 hours. Consider early (within 1 hour of exposure) institution of continuous hydrotherapy. Neutralizing substances should not be used. Fluid resuscitation should be provided as for comparable thermal burns; keeping in mind that the full extent of the sodium hydroxide burn may not be accurately assessed for 24 to 48 hours and may be underestimated initially.

Because of their relatively larger surface area:body weight ratio children are more vulnerable to toxicants affecting the skin.

Eye Exposure

Continue eye irrigation until the pH of the conjunctival sac is neutral (pH 7). The pH of the conjunctiva should be checked every 30 minutes for 2 hours after irrigation is stopped to ensure that the measured pH is that of the tissue and not the irrigating fluid. Ensure that any particulate matter has been removed. A mydriatic-cycloplegic medication such as homatropine should be used to prevent synechiae. Examine the eyes for conjunctival or corneal damage and treat appropriately. Immediately consult an ophthalmologist for patients who have eye exposure.

Ingestion Exposure

In cases of ingestion, **do not induce emesis**. **Do not administer activated charcoal or attempt to neutralize stomach contents**.

Victims who are conscious and able to swallow can be given 4 to 8 ounces of milk or water if this has not been given previously.

Extreme throat swelling may require endotracheal intubation or cricothyroidotomy. Gastric lavage is useful in certain circumstances to remove caustic material and prepare for endoscopic examination. Consider gastric lavage with a small nasogastric tube if: (1) a large dose has been ingested; (2) the patient's condition is evaluated within 30 minutes; (3) the patient has oral lesions or persistent esophageal discomfort; and (4) the lavage can be administered within one hour of ingestion. Placement of the gastric tube should be guided by endoscopy because blind gastric-tube placement may further injure the chemically damaged esophagus or stomach.

Endoscopic evaluation is essential in cases of sodium hydroxide ingestion, and surgical consultation is recommended for patients who have suspected perforation. Signs and symptoms do not provide an accurate guide to the extent of injury. All patients suspected of significant caustic ingestion must have early endoscopy to assess injury to the esophagus, stomach and duodenum, and to guide subsequent management. Severe esophageal burns have occurred even in cases where burns of the mouth or oropharynx were not seen. The ingestion of large amounts of sodium hydroxide may also result in shock. Endoscopy may be contraindicated in cases where the patient is unstable, has upper airway compromise, evidence of perforation, or ingestion took place more than 48 hours previously.

Perforation almost always requires surgical repair.

Because children do not ingest large amounts of corrosive materials, and because of the risk of perforation from NG intubation, lavage is discouraged in children unless performed under endoscopic guidance.

Toxic vomitus or gastric washings should be isolated (e.g., by attaching the lavage tube to isolated wall suction or another closed container).

Antidotes and Other Treatment

There is no antidote for sodium hydroxide. Various treatments to decrease stricture formation have been proposed (including administration of ascorbic acid and steroids), but are not recommended.

Laboratory Tests

The diagnosis of acute sodium hydroxide toxicity is primarily clinical, based on symptoms of corrosive injury. However, laboratory testing is useful for monitoring the patient and evaluating complications. Routine laboratory studies for all exposed patients include CBC, glucose, and electrolyte determinations. Patients who have respiratory complaints may require chest radiography and pulse oximetry (or ABG measurements). Patients with symptoms of severe burns or perforation may require renal function tests and blood typing.

Disposition and Follow-up

Consider hospitalizing patients who have ingested sodium hydroxide or who have eye or serious skin burns or histories of significant inhalation exposure. Patients with signs of perforation may require emergency surgery. Those with significant dermal injury should be admitted to the burn unit and patients with significant ingestion may need admission to the intensive care unit.

Delayed Effects

Injury may continue to progress in severity for up to 48 hours after exposure. Patients may develop upper airway obstruction, perforation, and shock.

Severe inhalation injuries may cause persistent hoarseness and reactive airways dysfunction syndrome (RADS), a chemically- or irritant-induced type of asthma.

Patient Release

Patients who have minimal skin exposure or patients who show no progressive symptoms 6 to 12 hours after a mild-to-moderate inhalation exposure may be discharged with instructions to seek medical care promptly if symptoms develop (see the *Sodium Hydroxide—Patient Information Sheet* below).

Follow-up

Obtain the name of the patient's primary care physician so that the hospital can send a copy of the ED visit to the patient's doctor.

For patients who have ingested sodium hydroxide, esophagoscopy should be performed within 48 hours of ingestion to assess severity of injury; a flexible instrument should be used. If perforation has not occurred, consider follow-up endoscopy or a barium swallow 10 days to 3 weeks after the initial burn to further assess the injury.

Patients who have corneal, conjunctival, scleral, or lid lesions should be reexamined within 24 hours.

Reporting

If a work-related incident has occurred, you may be legally required to file a report; contact your state or local health department.

Other persons may still be at risk in the setting where this incident occurred. If the incident occurred in the workplace, discussing it with company personnel may prevent future incidents. If a public health risk exists, notify your state or local health department or other responsible public agency. When appropriate, inform patients that they may request an evaluation of their workplace from OSHA or NIOSH. See Appendices III and IV for a list of agencies that may be of assistance.

Sodium Hydroxide
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to sodium hydroxide.

What is sodium hydroxide?
Sodium hydroxide is a white, solid material that picks up moisture from the air. If put in water, it produces a large amount of heat. Both the solid and its solutions are very corrosive and can cause severe burns. Sodium hydroxide is a member of a group of chemical compounds also known as bases or alkalies, which can neutralize and are neutralized by, acids, releasing a lot of heat.

What immediate health effects can be caused by exposure to sodium hydroxide?
Solid sodium hydroxide or strong solutions produce immediate pain when they come in contact with any part of the body. Weak solutions may not produce pain for several hours, but serious burns can result even from weak solutions if they are not washed off quickly. Spilling sodium hydroxide over large areas of the skin or swallowing sodium hydroxide may cause shock and even death. Sodium hydroxide can break down proteins and generates heat when dissolving in water. Contact with sensitive tissues, such as the eyes, is particularly dangerous and can cause permanent damage or even blindness.

Can sodium hydroxide exposure be treated?
There is no antidote for sodium hydroxide, but the burns and shock it can cause can be treated. Patients who develop serious symptoms need to be hospitalized.

Are any future health effects likely to occur?
A single small exposure from which a person recovers quickly is not likely to cause delayed or long-term effects. After a serious exposure to large areas of the skin, scarring may occur that will require skin grafts. A serious eye exposure can result in blindness. If sodium hydroxide mist was breathed, permanent injury to the lungs may result. If a solution was swallowed, damage to the mouth, throat, and esophagus may cause permanent scarring, making swallowing difficult.

What tests can be done if a person has been exposed to sodium hydroxide?
Specific tests for the presence of sodium hydroxide in blood or urine are not available. If a severe exposure has occurred, blood and urine analyses and other tests may show whether the lungs, eyes, or stomach has been injured. Testing is not needed in every case.

Where can more information about sodium hydroxide be found?
More information about sodium hydroxide can be obtained from your regional poison control center; your state, county, or local health department; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in occupational and environmental health. If the exposure happened at work, you may wish to discuss it with your employer, the Occupational Safety and Health Administration (OSHA), or the National Institute for Occupational Safety and Health (NIOSH). Ask the person who gave you this form for help in locating these telephone numbers.

Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow *only* the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:
drooling or difficulty swallowing
stomach pain or vomiting
coughing, wheezing, or hoarseness
difficulty breathing, shortness of breath, or chest pain
increased pain or a discharge from exposed eyes
increased redness or pain or a pus-like discharge in the area of a skin burn

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.
[ ] Call for an appointment with Dr. _____ in the practice of _____.
When you call for your appointment, please say that you were treated in the Emergency Department at _____ Hospital by _____ and were advised to be seen again in _____ days.
[ ] Return to the Emergency Department/ _____ Clinic on (date) _____at __ _____ AM/PM for a follow-up examination.
[ ] Do not perform vigorous physical activities for 1 to 2 days.
[ ] You may resume everyday activities including driving and operating machinery.
[ ] Do not return to work for _____ days.
[ ] You may return to work on a limited basis. See instructions below.
[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.
[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.
[ ] Avoid taking the following medications: _____
[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: __
_____
_____
[ ] Other instructions: _____
_____
_____

- Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.

- You or your physician can get more information on the chemical by contacting: _____ _____ or _____, or by checking out the following Internet Web sites: _____; _____.

Signature of patient _____ Date _____

Signature of physician _____ Date _____

Sulfur Dioxide (SO_2)
CAS 7446-09-5; UN 1079

Synonyms include sulfur oxide, sulfurous acid anhydride, sulfurous anhydride, and sulfurous oxide.

- **Persons exposed only to sulfur dioxide gas pose no risk of secondary contamination. Persons whose skin or clothing is contaminated with liquid sulfur dioxide can secondarily contaminate rescuers by direct contact or through off-gassing of vapor.**
- **At room temperature, sulfur dioxide is a nonflammable, colorless gas that is heavier than air. Its strong, pungent odor and irritating properties usually provide adequate warning of its presence.**
- **Sulfur dioxide is readily absorbed through the upper respiratory tract; no data were located regarding dermal absorption. Sulfur dioxide is present in some foods; therefore, oral ingestion, although insignificant, is possible.**

Description

At room temperature, sulfur dioxide is a nonflammable, colorless gas with a very strong, pungent odor. Most people can smell sulfur dioxide at levels of 0.3 to 1 ppm. It is handled and transported as a liquefied compressed gas. It easily dissolves in water. The liquid is heavier than water. Although sulfur dioxide does not burn in air, cylinders of compressed liquid can explode in the heat of a fire.

Routes of Exposure

Inhalation

Inhalation is the major route of exposure to sulfur dioxide. The odor threshold is 5 times lower than the OSHA PEL (5 ppm). Most exposures are due to air pollution, and this has both short-term and chronic health consequences for people with lung disease. Inhaled sulfur dioxide readily reacts with the moisture of mucous membranes to form sulfurous acid (H_2SO_3), which is a severe irritant. People with asthma can experience increased airway resistance with sulfur dioxide concentrations of less than 0.1 ppm when exercising. Healthy adults experience increased airway resistance at 5 ppm, sneezing and coughing at 10 ppm, and bronchospasm at 20 ppm. Respiratory protection is required for exposures at or above 20 ppm. Exposures of 50 to 100 ppm may be tolerated for more than 30 to 60 minutes, but higher or longer exposures can cause death from airway obstruction. Sulfur dioxide is heavier than air; thus, exposure in poorly ventilated, enclosed, or low-lying areas can result in asphyxiation.

Children exposed to the same levels of sulfur dioxide as adults may receive a larger dose because they have greater lung surface

area:body weight ratios and increased minute volumes:weight ratios. In addition, they may be exposed to higher levels than adults in the same location because of their short stature and the higher levels of sulfur dioxide found nearer to the ground and because they are slow to leave the site of an exposure.

Skin/Eye Contact

Exposures of 10 to 20 ppm cause irritation to mucous membranes. Direct contact with escaping compressed gas or liquid sulfur dioxide can produce severe corneal damage and frostbite injury to the skin. No data were located regarding dermal absorption.

Ingestion

Ingestion of sulfur dioxide is unlikely because it is a gas at room temperature. Sulfur dioxide is used in small amounts as a food and wine preservative. Highly sensitive asthmatic individuals can develop bronchospasm after eating foods or drinking wine preserved with sulfur dioxide or other sulfur preservatives.

Sources/Uses

Sulfur dioxide gas is released primarily from the combustion of fossil fuels (75% to 85% of the industrial sources), the smelting of sulfide ores, volcanic emissions, and several other natural sources. It is a U.S. Environmental Protection Agency (EPA) priority air pollutant, but has many industrial and agricultural uses. It is sometimes added as a warning marker and fire retardant to liquid grain fumigants. Approximately 300,000 tons are used each year to manufacture hydrosulfites and other sulfur-containing chemicals (40%); to bleach wood pulp and paper (20%); to process, disinfect, and bleach food (16%); for waste and water treatment (10%); in metal and ore refining (6%); and in oil refining (4%). Toxic amounts of sulfur dioxide can be released from the preservative chemical metabisulfite in the presence of water and acid.

Standards and Guidelines

OSHA PEL (permissible exposure limit) = 5 ppm (averaged over an 8-hour workshift)

NIOSH IDLH (immediately dangerous to life or health) = 100 ppm

AIHA ERPG-2 (maximum airborne concentration below which it is believed that nearly all persons could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action) = 3 ppm

Physical Properties

Description: colorless gas at room temperature, colorless liquid when pressurized or cooled.

Warning properties: pungent odor is usually adequate to warn of acute exposure. Most people can detect sulfur dioxide at levels of 1 to 3 ppm (1 ppm is equivalent to 2.62 mg/m^3).

Molecular weight: 64.06 daltons

Boiling point (760 mm Hg): 14.0 °F (-10.0 °C)

Freezing point: -99.4 °F (-72.7 °C)

Vapor pressure: 2,538 mm Hg at 70.0°F (21.1 °C)

Vapor density: 1.43 g/mL (water = 1.00)

Water solubility: soluble in water (11.3 g/100 mL at 68 °F [20 °C])

Flammability: nonflammable

Incompatibilities

Sulfur dioxide dissolves in water or steam to form sulfurous acid. Liquid sulfur dioxide corrodes iron, brass, copper, and some forms of plastic and rubber. Many metals, including zinc, aluminum, cesium, and iron, incandesce and/or ignite in unheated sulfur dioxide. Sulfur dioxide reacts explosively when it comes in contact with sodium hydride. Sulfur dioxide ignites when it is mixed with lithium acetylene carbide diamino or lithium acetylide ammonia.

Health Effects

- **Sulfur dioxide is severely irritating to the eyes, mucous membranes, skin, and respiratory tract. Bronchospasm, pulmonary edema, pneumonitis, and acute airway obstruction can occur.**
- **Inhalation exposure to very low concentrations of sulfur dioxide can aggravate chronic pulmonary diseases, such as asthma and emphysema. Certain highly sensitive asthmatics may develop bronchospasm when exposed to sulfur dioxide or sulfite-preserved foods.**
- **Sulfur dioxide reacts with water in the upper airway to form hydrogen, bisulfite, and sulfite, all of which induce irritation. As a result, reflex bronchoconstriction increases airway resistance.**

Acute Exposure

Sulfur dioxide dissolves in the moisture on skin, eyes, and mucous membranes to form sulfurous acid, an irritant and inhibitor of mucociliary transport. Most of the inhaled sulfur dioxide is detoxified by the liver to sulfates and excreted in the urine. The bisulfite ion produced when sulfur dioxide reacts with water is likely to be the main initiator of sulphur dioxide-induced bronchoconstriction.

Children do not always respond to chemicals in the same way that adults do. Different protocols for managing their care may be needed.

Respiratory

Sulfur dioxide respiratory irritation induces symptoms such as sneezing, sore throat, wheezing, shortness of breath, chest tightness, and a feeling of suffocation. Reflex laryngeal spasm and edema can cause acute airway obstruction. Bronchospasm, pneumonitis, and pulmonary edema can occur.

Some individuals are very susceptible to the presence of sulfur dioxide and overreact to concentrations which, in most people, elicit a much milder response. This hyperreactive response occurs the first time the individual is exposed and is therefore not an acquired immune or “hypersensitivity” response.

Acclimatization (a physiological adjustment of the individual to environmental changes) may also occur in up to 80% of exposed individuals. This is not necessarily beneficial although exposure may become less subjectively objectionable upon continuous or repeated exposure.

Asthmatics who are sensitive to sulfites in food can develop bronchospasm or an anaphylactoid reaction. Sulfur dioxide, along with other components of air pollution, can exacerbate chronic cardiopulmonary disease.

Exposure to high concentrations of sulfur dioxide can lead to Reactive Airway Dysfunction Syndrome (RADS), a chemically- or irritant-induced type of asthma.

Children may be more vulnerable to corrosive agents than adults because of the relatively smaller diameter of their airways. Children also may be more vulnerable because of relatively increased minute ventilation per kg and failure to evacuate an area promptly when exposed.

Dermal

Sulfur dioxide is a severe skin irritant causing stinging pain, redness, and blisters, especially on mucous membranes. Skin contact with escaping compressed gas or liquid sulfur dioxide can cause frostbite and irritation injury.

Because of their relatively larger surface area: body weight ratio, children are more vulnerable to toxicants that affect the skin.

Ocular

Conjunctivitis and corneal burns can result from the irritant effect of sulfur dioxide vapor or escaping compressed gas, and from direct exposure to the liquid.

Gastrointestinal

Nausea, vomiting, and abdominal pain have been reported after inhalation exposure to moderate to high doses of sulfur dioxide.

Potential Sequelae

High-level acute exposures have resulted in pulmonary fibrosis, chronic bronchitis, and chemical bronchopneumonia with bronchiolitis obliterans. Bronchospasm can be triggered in individuals who have underlying lung disease, especially those who have asthma and emphysema. Rarely, new onset airway hyperreactivity, known as reactive airways dysfunction syndrome (RADS), develops in patients without prior bronchospasm.

Chronic Exposure

Chronic exposure can result in an altered sense of smell (including increased tolerance to low levels of sulfur dioxide), increased susceptibility to respiratory infections, symptoms of chronic bronchitis, and accelerated decline in pulmonary function. Chronic exposure may be more serious for children because of their potential longer life span.

Carcinogenicity

The International Agency for Research on Cancer (IARC) assigned sulfur dioxide to Group 3, not classifiable as to its carcinogenicity to humans.

Reproductive and Developmental Effects

Sulfur dioxide is not included in *Reproductive and Developmental Toxicants*, a 1991 report published by the U.S. General Accounting Office (GAO) that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences. There are no known reproductive or developmental effects of sulfur dioxide alone by any route of exposure. There is no conclusive evidence that sulfur dioxide is a genotoxin in humans.

Prehospital Management

- **Persons exposed only to sulfur dioxide gas pose no risk of secondary contamination to rescuers. Persons whose skin or clothing is contaminated with liquid sulfur dioxide can secondarily contaminate response personnel by direct contact or through off-gassing of vapor.**
- **Sulfur dioxide is severely irritating to the eyes, mucous membranes, skin, and respiratory tract. Exposure to high levels can cause pulmonary edema, bronchial inflammation and laryngeal spasm and edema with possible airway obstruction.**
- **There is no antidote for sulfur dioxide. Treatment consists of support of respiratory and cardiovascular functions.**

Hot Zone

Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if the rescuers have not been trained in its use, call for assistance from a local or regional hazardous materials (HAZMAT) team or other properly equipped response organization.

Rescuer Protection

Inhaled sulfur dioxide vapor is readily absorbed and is a potent respiratory tract irritant, causing mild irritation even at low doses. Escaping compressed gas or liquid sulfur dioxide on the skin or eyes can cause frostbite injury and irritation. Dermal absorption is negligible.

Respiratory protection: Positive-pressure, self-contained breathing apparatus (SCBA) is recommended in response situations that involve exposure to potentially unsafe levels of sulfur dioxide gas.

Skin protection: Fully encapsulated chemical-protective clothing is recommended because sulfur dioxide can cause skin irritation and burns.

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. Maintain adequate circulation. Provide supplemental oxygen if cardiopulmonary compromise is suspected. If trauma is suspected, manually maintain cervical immobilization and apply a cervical collar and a backboard when feasible. Apply direct pressure to stop any heavy bleeding.

Victim Removal

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk should be removed on backboards or gurneys. If these are not available, carefully carry or drag victims to safety.

Consider appropriate management of chemically contaminated children, such as measures to reduce separation anxiety if a child is separated from a parent or other adult.

Decontamination Zone

Patients exposed only to sulfur dioxide gas who have no eye or skin irritation do not need decontamination. They may be transferred immediately to the Support Zone. Other patients will require decontamination as described below.

Rescuer Protection

If exposure levels are determined to be safe, decontamination may be conducted by personnel wearing a lower level of protection than that required in the Hot Zone (described above).

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. Maintain adequate circulation. Provide supplemental oxygen if cardiopulmonary compromise is suspected. If trauma is suspected, manually maintain cervical immobilization and apply a cervical collar and a backboard when feasible. Administer supplemental oxygen as required. Assist ventilation with a bag-valve-mask device if necessary. Apply direct pressure to control any heavy bleeding.

Basic Decontamination

Rapid skin decontamination is critical. Victims who are able may assist with their own decontamination. Remove contaminated clothing and personal belongings and place them in double plastic bags.

Gently wash exposed skin and hair with copious amounts of water (preferably under a shower). Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Irrigate exposed eyes with plain water or saline for at least **5 minutes**. Remove contact lenses if they are easily removable without additional trauma to the eye. If pain or injury is evident, continue irrigation while transferring the victim to the Support Zone.

Consider appropriate management of chemically contaminated children at the exposure site. Also, provide reassurance to the child during decontamination, especially if separation from a parent occurs. If possible, seek assistance from a child separation expert.

Transfer to Support Zone

As soon as basic decontamination is complete, move the victim to the Support Zone.

Support Zone

Be certain that victims have been decontaminated properly (see *Decontamination Zone*, above). Victims who have undergone decontamination or have been exposed only to sulfur dioxide gas pose no serious risk of secondary contamination to rescuers. In such cases, Support Zone personnel require no specialized protective gear.

ABC Reminders

Quickly access for a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Ensure adequate respiration and pulse. Administer supplemental oxygen as required and establish intravenous access if necessary. Place on a cardiac monitor.

Additional Decontamination

Continue irrigating exposed skin and eyes, as appropriate.

Advanced Treatment

In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, perform cricothyroidotomy if equipped and trained to do so.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Sulfur dioxide poisoning is not known to pose additional risk during the use of bronchial or cardiac sensitizing agents.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Patients who are comatose, hypotensive, or having seizures or cardiac arrhythmias should be treated according to advanced life support (ALS) protocols.

If evidence of shock or hypotension is observed begin fluid administration. For adults, bolus 1,000 mL/hour intravenous saline or lactated Ringer's solution if blood pressure is under 80 mm Hg; if systolic pressure is over 90 mm Hg, an infusion rate of 150 to 200 mL/hour is sufficient. For children with compromised perfusion administer a 20 mL/kg bolus of normal saline over 10 to 20 minutes, then infuse at 2 to 3 mL/kg/hour.

Transport to Medical Facility

Only decontaminated patients or patients not requiring decontamination should be transported to a medical facility. "Body bags" are not recommended.

Report the condition of the patient, treatment given, and estimated time of arrival at the medical facility to the base station and the receiving medical facility.

Multi-Casualty Triage

Consult with the base station physician or the regional poison control center for advice regarding triage of multiple victims.

Patients who have histories or evidence suggesting significant exposure (e.g., severe or persistent cough or dyspnea, or chemical burns) should be transported to a medical facility for evaluation. Patients who have a history of chronic pulmonary disease should be clinically evaluated for airflow obstruction.

Patients who have symptoms of mild or transient skin, nose, or eye irritation may be discharged from the scene after their names, addresses, and telephone numbers are recorded. They should be advised to rest and to seek medical care promptly if symptoms develop or recur (see *Patient Information Sheet* below).

Emergency Department Management

- **Persons exposed only to sulfur dioxide gas pose no risk of secondary contamination to rescuers. Persons whose skin or clothing is contaminated with liquid sulfur dioxide can secondarily contaminate response personnel by direct contact or through off-gassing of vapor.**
- **Sulfur dioxide is a severe irritant to the respiratory tract, eyes, mucous membranes, and skin. Exposure to high doses can cause pulmonary edema, bronchial inflammation, and laryngeal spasm and edema with possible airway obstruction.**
- **There is no antidote for sulfur dioxide. Treatment consists of support of respiratory and cardiovascular functions.**

Decontamination Area

Previously decontaminated patients and those exposed only to sulfur dioxide gas who have no skin or eye irritation may be transferred immediately to the Critical Care Area. Others require decontamination as described below.

Be aware that use of protective equipment by the provider may cause fear in children, resulting in decreased compliance with further management efforts.

Emergency room personnel should examine children's mouth because of the frequency of hand-to-mouth activity among children.

ABC Reminders

Evaluate and support the airways, breathing, and circulation. Children may be more vulnerable to corrosive agents than adults because of the relatively smaller diameter of their airways. Provide supplemental oxygen if cardiopulmonary compromise is suspected. In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, surgically create an airway.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Sulfur dioxide poisoning is not known to pose additional risk during the use of bronchial or cardiac sensitizing agents.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Patients who are comatose, hypotensive, or are having seizures or cardiac arrhythmias should be treated in the conventional manner.

Basic Decontamination

Patients who are able may assist with their own decontamination.

Because sulfur dioxide can cause burns, ED staff should don chemical-resistant jumpsuits (e.g., of Tyvek or Saranex) or butyl rubber aprons, rubber gloves, and eye protection if the patient's clothing or skin is wet. After the patient has been decontaminated, no special protective clothing or equipment is required for ED personnel.

Quickly remove contaminated clothing while gently washing the skin with water (preferably under a shower). Double-bag the contaminated clothing and personal belongings. Sulfur dioxide reacts with body moisture to form sulfurous and sulfuric acids; therefore, chemical burns are likely. Handle burned skin with caution.

Flush exposed or irritated eyes with plain water or saline for at least **5 minutes**. Remove contact lenses if easily removable without additional trauma to the eye. If pain or injury is evident, continue irrigation while transferring the victim to the Critical Care Area. An ophthalmic anesthetic, such as 0.5% tetracaine, might be necessary to alleviate blepharospasm, and lid retractors might be required to allow adequate irrigation under the eyelids.

Critical Care Area

Be certain that appropriate decontamination has been carried out (see *Decontamination Area*, above).

ABC Reminders

Evaluate and support the airways, breathing, and circulation as in *ABC Reminders* above. Children may be more vulnerable to corrosive agents than adults because of the relatively smaller diameter of their airways. Establish intravenous access in seriously ill patients. Continuously monitor cardiac rhythm.

Patients who are comatose, hypotensive, or are having seizures or cardiac arrhythmias should be treated in the conventional manner.

Inhalation Exposure

Administer supplemental oxygen by mask to patients who have respiratory complaints. Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Sulfur dioxide poisoning is not known to pose additional risk during the use of bronchial or cardiac sensitizing agents.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Use of steroids to prevent or treat chemical pneumonitis and pulmonary edema is controversial. Antibiotics should be used as indicated to control infection. Damaged lower respiratory tissue might be more susceptible to infection.

Skin Exposure

Escaping compressed gas or liquid sulfur dioxide can cause frostbite. If frostbite is present, treat affected areas by rewarming in a water bath at a temperature of 104 to 107.6 °F (40 to 42 °C) for 20 to 30 minutes and continue until a flush has returned to the affected area. If chemical burns are present, treat as thermal burns.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants that affect the skin.

Eye Exposure

Continue irrigation for at least 15 minutes or until the pH of the conjunctival fluid has returned to normal. Test visual acuity. Examine the eyes for conjunctival or corneal damage and treat appropriately. Immediately consult an ophthalmologist for patients who have suspected severe corneal injuries.

Antidotes and Other Treatments

There is no antidote for sulfur dioxide. Treatment is supportive of respiratory function.

Laboratory Tests

Routine laboratory studies include chest radiography and pulse oximetry (or ABG measurements).

Disposition and Follow-up

Consider hospitalizing symptomatic patients who have evidence of respiratory distress or significant skin burns.

Pulmonary injury might continue to evolve over 18 to 24 hours. Patients exposed by inhalation who are initially symptomatic should be observed carefully and reexamined periodically. Patients who develop pulmonary edema should be admitted to an intensive care unit.

Delayed Effects

Reactive airways dysfunction syndrome (RADS) is a non-immune-mediated asthma-like syndrome that can develop after exposure to sulfur dioxide. Once established, this non-specific bronchial hyperreactivity might diminish over a few weeks or persist for years. Bronchospasm might be triggered in people who have chronic pulmonary diseases, such as asthma and emphysema.

Patient Release

Patients who become totally asymptomatic in terms of pulmonary complaints in a 6- to 8-hour observation period are not likely to develop complications. They may be released and advised to rest and to seek medical care promptly if symptoms develop (see the *Sulfur Dioxide—Patient Information Sheet* below). Cigarette smoking can exacerbate pulmonary injury and should be discouraged for 72 hours after exposure.

Follow-up

Obtain the name of the patient's primary care physician so that the hospital can send a copy of the ED visit to the patient's doctor.

Follow-up evaluation of respiratory function should be arranged for severely exposed patients. Patients who have skin or corneal lesions should be reexamined within 24 hours.

Reporting

If a work-related incident has occurred, you might be legally required to file a report; contact your state or local health department.

Other persons might still be at risk in the setting where this incident occurred. If the incident occurred in the workplace, discussing it with company personnel might prevent future incidents. If a public health risk exists, notify your state or local health department or other responsible public agency. When appropriate, inform patients that they may request an evaluation of their workplace form the Occupational Safety and Health Administration (OSHA) or the National Institute for Occupational Safety and Health (NIOSH).

Sulfur Dioxide (SO_2)
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to sulfur dioxide.

What is sulfur dioxide?
Sulfur dioxide is a colorless gas that has a strong, stinging odor. It has many industrial and agricultural uses. Most sulfur dioxide comes from burning fossil fuels containing sulfur and is a major part of air pollution. It is shipped and handled as a compressed gas in a special container. Some foods and wines are preserved with small amounts of sulfur dioxide that are safe for most people.

What immediate health effects can be caused by exposure to sulfur dioxide?
Inhaling sulfur dioxide causes irritation to the nose, eyes, throat, and lungs. Typical symptoms include sore throat, runny nose, burning eyes, and cough. Inhaling high levels can cause swollen lungs and difficulty breathing. Skin contact with sulfur dioxide vapor can cause irritation or burns. Liquid sulfur dioxide is very cold and can severely injure the eyes or cause frostbite if it touches the skin. Some people with asthma who are sensitive to sulfites might have an asthma attack if they eat foods preserved with sulfur dioxide or other sulfur-containing chemicals.

Can sulfur dioxide poisoning be treated?
There is no antidote for sulfur dioxide, but its effects can be treated and most exposed persons recover completely. Persons who have inhaled large amounts of sulfur dioxide might need to be hospitalized.

Are any future health effects likely to occur?
A single, small exposure from which a person recovers quickly is not likely to cause delayed or long-term effects. After a serious exposure, damage to the lungs can occur, causing asthma, pneumonia, and bronchitis. Permanent damage to the lungs is possible.

What tests can be done if a person has been exposed to sulfur dioxide?
Specific tests for the presence of sulfur dioxide in blood or urine are not generally useful. If a severe exposure has occurred, blood analyses, x-rays, and breathing tests might show whether the lungs have been injured. Testing is not needed in every case.

Where can more information about sulfur dioxide be found?
If the exposure happened at work, you might be required to contact your employer and the Occupational Safety and Health Administration (OSHA).

Employees may request a Health Hazard Evaluation from the National Institute for Occupational Safety and health (NIOSH).

More information about sulfur dioxide can be obtained from your regional poison control center; your state, county, or local health department; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in occupational and environmental health. Ask the person who gave you this form for help locating these telephone numbers.

Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow *only* the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:

- eye, nose, throat irritation
  coughing or wheezing
  difficulty breathing or shortness of breath
  chest pain or tightness
  nausea, vomiting, diarrhea, or stomach pain

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.
[ ] Call for an appointment with Dr. _____ in the practice of _____.
When you call for your appointment, please say that you were treated in the Emergency Department at _____ Hospital by _____ and were advised to be seen again in _____ days.
[ ] Return to the Emergency Department/ _____ Clinic on (date) _____at __ _____ AM/PM for a follow-up examination.
[ ] Do not perform vigorous physical activities for 1 to 2 days.
[ ] You may resume everyday activities including driving and operating machinery.
[ ] Do not return to work for _____ days.
[ ] You may return to work on a limited basis. See instructions below.
[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.
[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.
[ ] Avoid taking the following medications: _____
[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: __
_____
_____
[ ] Other instructions: _____
_____
_____

- Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.

- You or your physician can get more information on the chemical by contacting: _____ _____ or _____, or by checking out the following Internet Web sites: _____; _____.

Signature of patient _____ Date _____

Signature of physician _____ Date _____

Tetrachloroethylene ($Cl_2C=CCl_2$)
CAS 127-18-4; UN 1897

Synonyms include carbon bichloride, carbon dichloride, ethylene tetrachloride, PCE, perc, perchlor, perchloroethylene, Perclene, perk, 1,1,2,2-tetrachloroethylene, and tetrachloroethene.

- **Persons exposed only to tetrachloroethylene vapor pose no risk of secondary contamination. Persons whose skin or clothing is contaminated with liquid tetrachloroethylene can contaminate rescuers by direct contact or through off-gassing vapor.**
- **Tetrachloroethylene is a colorless, volatile, nonflammable liquid with a sharp, sweet odor. The vapor is heavier than air and can collect in toxic levels in poorly ventilated spaces. While the odor threshold is low, tetrachloroethylene quickly desensitizes olfactory responses; therefore, odor may not be an adequate warning of toxic levels.**
- **Tetrachloroethylene is readily absorbed if inhaled or ingested. Dermal exposure to the liquid can cause burns and irritation, but absorption across intact skin is slow. Exposure by any route can cause systemic effects.**

Description

At room temperature, tetrachloroethylene is a colorless, nonviscous, nonflammable liquid. It evaporates easily and has a sweet odor. The vapors are heavier than air. Tetrachloroethylene is slightly soluble in water, and is miscible with most organic solvents and oils. Although it is considered to be quite stable, at temperatures greater than 600 °F (316 °C), it breaks down to form the poisonous gas, phosgene, and hydrogen chloride, which are potent pulmonary irritants. Tetrachloroethylene is stored in mild steel tanks equipped with breathing vents and chemical driers in cool, dry, well-ventilated locations, away from any area where fire hazard may be acute, or in glass containers.

Routes of Exposure

Inhalation

Inhalation is the most important route of exposure, and tetrachloroethylene is absorbed readily through the lungs. Most people can smell tetrachloroethylene in the air at levels of 5 to 50 ppm (OSHA PEL is 100 ppm). **Odor is an adequate warning for high-dose acute exposures, but might not be adequate for prolonged exposures because olfactory fatigue can occur.** The vapors are heavier than air and can collect to toxic levels in poorly ventilated or low-lying areas and cause asphyxiation. Levels of 75 to 100 ppm can cause mild ocular irritation and levels of 216 ppm or more produce respiratory tract irritation. Central nervous system (CNS) effects, including sleepiness, headache, and loss of coordination, have been observed at exposures of 100 to 300 ppm.

During exposures of 1,000 to 1,500 ppm for less than 2 hours, people have experienced mood changes, slight ataxia, faintness, and dizziness. Exposure to higher concentrations or for longer periods of time can lead to collapse, coma, or death.

Children exposed to the same levels of tetrachloroethylene vapor as adults may receive a larger dose because they have greater lung surface area:body weight ratios and increased minute volumes:weight ratios. In addition, they may be exposed to higher levels than adults in the same location because of their short stature and the higher levels of tetrachloroethylene vapor found nearer to the ground.

Skin/Eye Contact

Exposure to high levels of tetrachloroethylene vapor causes ocular irritation. Direct contact with the liquid can cause skin and eye irritation and burns. Absorption across intact skin is slow. Thus, systemic toxicity is unlikely unless liquid on the skin is prevented from evaporating by heavy clothing or other impermeable covering.

Children are more vulnerable to toxicants absorbed through the skin because of their relatively larger surface:body weight ratio.

Ingestion

Ingested tetrachloroethylene is rapidly absorbed and can cause systemic effects similar to those seen with inhalation exposure.

Sources/Uses

Tetrachloroethylene is made by direct chlorination or oxychlorination of certain hydrocarbons. Tetrachloroethylene is used as a chemical intermediate, as solvent for metal cleaning and vapor degreasing, and for dry-cleaning and textile processing. It is found in many household products, including paint removers, water repellents, silicone lubricants, spot removers, adhesives, wood cleaners, and many products used by hobbyists. Tetrachloroethylene may still be employed as grain fumigant. It was formerly used as a deworming medicine in humans. It has been intentionally abused for its CNS-intoxicating effect. With improved recovery and recycling efforts, production has declined from about 500 million pounds in the 1980s to about 250 million pounds in the 1990s.

Standards and Guidelines

OSHA PEL (permissible exposure limit) = 100 ppm (averaged over an 8-hour workshift)

OSHA Ceiling for 15-minute exposure = 200 ppm; 5-minute maximum peak in any 3 hours = 300 ppm

NIOSH IDLH (immediately dangerous to life or health) = 150 ppm; potential occupational carcinogen

AIHA ERPG-2 (maximum airborne concentration below which it is believed that nearly all persons could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action) = 200 ppm.

Physical Properties

Description: colorless, nonviscous, nonflammable liquid

Warning properties: sweet, chloroform-like odor detectable at 5 to 50 ppm; adequate for acute exposures, but might be inadequate for chronic exposure because olfactory fatigue can occur.

Molecular weight: 165.83 daltons

Boiling point (760 mm Hg): 250.16 °F (121.20 °C)

Freezing point: -8.14 °F (-22.3 °C)

Specific gravity: 1.623 at 68 °F (20 °C) (water = 1.000)

Vapor pressure: 15.8 mm Hg at 71.6 °F (22 °C)

Vapor density: 5.83 (air = 1.00)

Water solubility: negligible (0.015% at 68 °F [20 °C])

Flammability: nonflammable liquid; vapors do not readily ignite; at temperatures >600 °F (>316 °C), tetrachloroethylene oxidizes to form hydrogen chloride, phosgene, and carbon monoxide.

Incompatibilities

Tetrachloroethylene reacts with strong oxidizers such as nitric acid or nitrogen tetroxide and strong alkali such as sodium hydroxide or potassium carbonate, but only at elevated temperatures. Tetrachloroethylene reacts with metals very slowly at 25 °C, but will react explosively with molten potassium and possibly with other reactive metals such as barium or lithium at elevated temperatures. Tetrachloroethylene does not react with water at ordinary temperatures, but with strong aqueous alkali at higher temperatures, tetrachloroethylene will form dichloroacetic acid and hydrochloric acid.

Health Effects

- **Inhalation or ingestion of tetrachloroethylene can cause CNS depression and cardiovascular effects. At high concentrations, the vapor is irritating to the eyes, mucous membranes, and respiratory tract. The liquid is irritating to the skin and can cause chemical burns.**

- **Tetrachloroethylene effects on the CNS are thought to be caused by interaction of the parent compound with neural membranes; other effects as well as liver cancer in animals are thought to be caused by tetrachloroethylene metabolites, but the exact mechanisms are not known.**

Acute Exposure

Tetrachloroethylene probably depresses the CNS through a solvent effect on lipids and protein components of neural membranes. It defats the skin, causing redness, blistering, and scaling. Organ damage, primarily liver and kidney, may occasionally be seen. CNS effects appear immediately during and following exposure, while organ damage may be delayed for hours to days. Most inhaled or ingested tetrachloroethylene leaves the body unchanged in exhaled air. Only 1% to 3% is metabolized (though there is considerable individual variation), and residual organ damage is not commonly observed.

Children do not always respond to chemicals in the same way that adults do. Different protocols for managing their care may be needed.

CNS

Tetrachloroethylene causes dose-related CNS and respiratory depression, but transient initial CNS excitation can also occur. Symptoms can include irritability, impaired coordination, lightheadedness, headache, slurred speech, malaise, nausea, ataxia, sedation, coma, and death. Sublethal CNS effects generally resolve quickly when the victim is removed from further exposure, but may be delayed due to fat uptake. CNS effects can also be prolonged following ingestion exposure.

Cardiovascular

Tetrachloroethylene can lower the myocardial threshold to the dysrhythmogenic effects of catecholamines and can predispose exposed people to dysrhythmias, although this appears to be much less likely with this chemical than with other related chemicals.

Respiratory

Upper respiratory tract irritation can occur following inhalation of high concentrations of tetrachloroethylene.

Exposure to certain chemicals can lead to Reactive Airway Dysfunction Syndrome (RADS), a chemically- or irritant-induced type of asthma.

Children may be more vulnerable because of relatively increased minute ventilation per kg and failure to evacuate an area promptly when exposed.

Gastrointestinal

Ingestion or inhalation of tetrachloroethylene can cause nausea and vomiting.

Hepatic

Exposure to high levels of tetrachloroethylene can cause transient hepatocellular damage manifested as hepatomegaly, icterus, and elevated serum levels of liver enzymes. Liver injury might not develop until several days after exposure.

Renal

Proteinuria, hematuria, and oliguric renal failure can occur following exposure to very high levels of tetrachloroethylene.

Dermal

Direct skin exposure to liquid tetrachloroethylene can cause irritation and blistering. Prolonged contact can result in second- and third-degree chemical burns.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants that affect the skin.

Ocular

High concentrations of tetrachloroethylene vapor or direct contact with the liquid can cause intense conjunctival and scleral irritation, pain, swelling, lacrimation, and photophobia.

Potential Sequelae

Survivors of severe acute exposures that induced coma or respiratory arrest might suffer brain or heart damage from decreased levels of oxygen to these organs. Dermal exposure may result in dermal hypersensitivity.

Chronic Exposure

Prolonged exposure to tetrachloroethylene can result in memory and concentration impairment, vision disturbances, dizziness, irritability, ataxia, sleep disturbances, and peripheral neuropathy. Chronic exposure can cause liver and kidney abnormalities. Chronic skin exposure can cause irritant contact dermatitis.

Carcinogenicity

The U.S. Department of Health and Human Services (DHHS) has determined that tetrachloroethylene is reasonably anticipated to be a human carcinogen based on adequate evidence from experimental animals (hepatocellular adenomas and carcinomas in male mice and hepatocellular carcinomas in female mice and mononuclear cell leukemia in rats). The International Agency for Research on Cancer

(IARC) has classified tetrachloroethylene as probably carcinogenic to humans (Group 2A) based on limited evidence in humans and adequate evidence from experimental animals.

Reproductive and Developmental Effects

Tetrachloroethylene is not included in *Reproductive and Developmental Toxicants*, a 1991 report published by the U.S. General Accounting Office (GAO) that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences. There is no conclusive evidence that tetrachloroethylene has adverse reproductive or developmental effects in humans. In animal studies, high level exposures of pregnant females caused behavioral and neurochemical changes in the offspring.

Tetrachloroethylene has been detected in human breast milk.

Prehospital Management

- **Victims exposed only to tetrachloroethylene vapor pose no risk of secondary contamination to rescuers. Victims whose skin or clothing is contaminated with liquid tetrachloroethylene can contaminate rescuers by direct contact or through off-gassing of vapor. Vomitus from patients who have ingested tetrachloroethylene might also off-gas the vapor.**
- **Inhalation or ingestion of tetrachloroethylene can cause CNS depression, respiratory irritation, and cardiovascular effects. At high concentrations, the vapor is irritating to the eyes, mucous membranes, and respiratory tract. The liquid is irritating to the skin and can cause chemical burns.**
- **There is no antidote for tetrachloroethylene poisoning. Treatment consists of support of respiratory and cardiovascular functions.**

Hot Zone

Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if the rescuers have not been trained in its use, assistance should be obtained from a local or regional HAZMAT team or other properly equipped response organization.

Rescuer Protection

Inhaled tetrachloroethylene vapor is readily absorbed and can irritate the respiratory tract. The liquid is a skin and eye irritant with slow skin absorption.

Respiratory protection: Positive-pressure, self-contained breathing apparatus (SCBA) is recommended in response situations that involve exposure to any level of tetrachloroethylene vapor.

Skin protection: to prevent possible skin irritation and dermal absorption (a slow process), chemical-protective clothing is recommended when skin contact with the liquid is expected.

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. Provide supplemental oxygen if cardiopulmonary compromise is suspected. If trauma is suspected, manually maintain cervical immobilization and apply a cervical collar and a backboard when feasible. Apply direct pressure to stop any heavy bleeding. Maintain adequate circulation.

Victim Removal

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk should be removed on backboards or gurneys. If these are not available, carefully carry or drag victims to safety.

Consider appropriate management of chemically contaminated children, such as measures to reduce separation anxiety if a child is separated from a parent or other adult.

Decontamination Zone

Victims exposed only to tetrachloroethylene vapor who have no eye or skin irritation do not need decontamination. They may be transferred immediately to the Support Zone. All others require decontamination as described below.

Rescuer Protection

If exposure levels are determined to be safe, decontamination may be conducted by personnel wearing a lower level of protection than that required in the Hot Zone (described above).

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. If trauma is suspected, manually maintain cervical immobilization and apply a cervical collar and a backboard when feasible. Administer supplemental oxygen as required. Assist ventilation with a bag-valve-mask device if necessary. Apply direct pressure to control heavy bleeding.

Basic Decontamination

Victims who are able may assist with their own decontamination. Remove and double-bag contaminated clothing and all personal belongings.

Wash exposed skin and hair with mild soap and water (preferably under a shower). Rinse thoroughly with water. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Irrigate exposed eyes with copious amounts of tepid water or saline for at least **15 minutes**. Remove contact lenses if present and easily removable without additional trauma to the eye. If pain or injury is evident, continue irrigation while transferring the victim to the Support Zone.

In cases of ingestion, **do not induce emesis**. If the victim is alert, asymptomatic, and has a gag reflex, administer a slurry of activated charcoal at 1 gm/kg (usual adult dose 60–90 g, child dose 25–50 g). A soda can and straw may be of assistance when offering charcoal to a child.

Consider appropriate management of chemically contaminated children at the exposure site. Also, provide reassurance to the child during decontamination, especially if separation from a parent occurs. If possible, seek assistance from a child separation expert.

Transfer to Support Zone

As soon as basic decontamination is complete, move the victim to the Support Zone.

Support Zone

Be certain that victims have been decontaminated properly (see *Decontamination Zone* above). Victims who have undergone decontamination or have been exposed only to tetrachloroethylene vapor pose no serious risk of secondary contamination to rescuers. In such cases, Support Zone personnel require no specialized protective gear.

ABC Reminders

Quickly access for a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Ensure adequate respiration and pulse. Administer supplemental oxygen as required and establish intravenous access if necessary. Place on a cardiac monitor.

Additional Decontamination

Continue irrigating exposed skin and eyes, as appropriate.

In cases of ingestion, **do not induce emesis**. If the victim is alert, asymptomatic, and has a gag reflex, administer a slurry of activated charcoal at 1 gm/kg (usual adult dose 60–90 g, child dose 25–50 g), if not previously given. A soda can and straw may be of assistance when offering charcoal to a child.

Advanced Treatment

In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, perform cricothyroidotomy if equipped and trained to do so.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Epinephrine or other beta-adrenergic agents should be used only with caution and only when clearly indicated. Careful EKG monitoring for the possible induction of arrhythmias should be done, and resuscitation medications and equipment should be readily available.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Patients who are comatose, hypotensive, or seizing or have cardiac dysrhythmias should be treated according to advanced life support (ALS) protocols, observing the precautions for catecholamines described above.

Transport to Medical Facility

Only decontaminated patients or patients not requiring decontamination should be transported to a medical facility. "Body bags" are not recommended.

Report the condition of the patient, treatment given, and estimated time of arrival at the medical facility to the base station and the receiving medical facility.

If tetrachloroethylene has been ingested, prepare the ambulance in case the victim vomits toxic material. Prepare several towels and open double-sealable plastic bags to quickly clean up and isolate vomitus, if necessary.

Multi Casualty Triage

Consult with the base station physician or the regional poison control center for advice regarding triage of multiple victims.

Patients who have histories or evidence suggesting significant exposure, such as incoordination, disorientation, or difficulty breathing, and patients who have ingested tetrachloroethylene should be transported to a medical facility for evaluation.

Patients who have mild or transient symptoms may be discharged form the scene after their names, addresses, and telephone numbers are recorded. They should be advised to rest and to seek medical care promptly if symptoms develop or recur (see *Patient Information Sheet* below).

Emergency Department Management

- **Patients exposed only to tetrachloroethylene vapor pose no risk of secondary contamination to rescuers. Patients who skin or clothing is contaminated with liquid tetrachloroethylene can contaminate rescuers by direct contact or through off-gassing of vapor. Vomitus from patients who have ingested tetrachloroethylene can also off-gas the vapor.**
- **Inhalation or ingestion of tetrachloroethylene can cause CNS depression, respiratory irritation, and cardiovascular effects. At high concentrations, the vapor is irritating to the eyes, mucous membranes, and respiratory tract. The liquid is irritating to the skin and can cause chemical burns.**
- **There is no antidote for tetrachloroethylene poisoning. Treatment consists of support of respiratory and cardiovascular functions.**

Decontamination Area

Previously decontaminated patients and those exposed only to tetrachloroethylene vapor and who have no skin or eye irritation may be transferred immediately to the Critical Care Area. All others require decontamination as described below.

Be aware that use of protective equipment by the provider may cause fear in children, resulting in decreased compliance with further management efforts.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants absorbed through the skin. Also, emergency room personnel should examine children's mouths for signs of irritation because of the frequency of hand-to-mouth activity among children.

ABC Reminders

Evaluate and support the airways, breathing, and circulation. Children may be more vulnerable to corrosive agents than adults because of the relatively smaller diameter of their airways. Provide supplemental oxygen if cardiopulmonary compromise is suspected. In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, surgically create an airway.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents

after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Epinephrine or other beta-adrenergic agents should be used only with caution and only when clearly indicated. Careful EKG monitoring for the possible induction of arrhythmias should be done, and resuscitation medications and equipment should be readily available.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Patients who are comatose, hypotensive, or having seizures or have ventricular arrhythmias should be treated in the conventional manner, observing the precautions for catecholamines described above. Arrhythmias might respond to beta-adrenergic blockers (e.g., propranolol, esmolol) if lidocaine is ineffective.

Basic Decontamination

Patients who are able may assist with their own decontamination. Remove and double-bag contaminated clothing and all personal belongings.

Wash exposed skin and hair with mild soap and water (preferably under a shower). Rinse thoroughly with water.Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Flush exposed or irritated eyes with plain water or saline for at least **15 minutes**. Remove contact lenses if easily removable without additional trauma to the eye. If pain or injury is evident, continue irrigation while transferring the patient to the Critical Care Area.

In cases of ingestion, **do not induce emesis**. Give activated charcoal at 1 gm/kg (usual adult dose 60–90 g, child dose 25–50 g), if available and not previously given. A soda can and straw may be of assistance when offering charcoal to a child.

Critical Care Area

Be certain that appropriate decontamination has been carried out (see *Decontamination Area*, above).

ABC Reminders

Evaluate and support the airways, breathing, and circulation (as in *ABC Reminders* above. Children may be more vulnerable to corrosive agents than adults because of the relatively smaller diameter of their airways. Establish intravenous access in seriously ill patients. Continuously monitor cardiac rhythm.

Patients who are comatose, hypotensive, or seizing or have ventricular arrhythmia should be treated in the conventional manner, observing all precautions for catecholamines described below. Arrhythmias might respond to beta-adrenergic blockers (e.g., propranolol, esmolol) if lidocaine is ineffective.

Inhalation Exposure

Administer supplemental oxygen by mask to patients who have respiratory complaints. Treat patients who have bronchospasm with aerosolized bronchodilators. **Use these and all other catecholamines only when clearly indicated and when no alternatives are available. Administer the lowest effective doses. Monitor for cardiac arrhythmia and be prepared to treat as indicated.** Also consider the health of the myocardium before choosing which type of bronchodilator should be administered.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Skin Exposure

If the skin was in prolonged contact with liquid tetrachloroethylene, chemical burns might be present; treat these as thermal burns.

Eye Exposure

Ensure that adequate eye irrigation has been completed. Test visual acuity. Examine the eyes for conjunctival or corneal damage and treat appropriately. Immediately consult an ophthalmologist for patients who have corneal injuries.

Ingestion Exposure

Do not induce emesis. If the patient is alert and able to swallow and activated charcoal has not been given previously, administer a slurry of activated charcoal at 1 gm/kg (usual adult dose 60–90 g, child dose 25–50 g). A soda can and straw may be of assistance when offering charcoal to a child.

Consider endoscopy to evaluate the extent of gastrointestinal-tract injury. Extreme throat swelling may require endotracheal intubation or cricothyroidotomy. Consider gastric lavage with a small nasogastric tube if: (1) a large dose has been ingested; (2) the patient's condition is evaluated within 30 minutes; (3) the patient has oral lesions or persistent esophageal discomfort; and (4) the lavage can be administered within 1 hour of ingestion. Care must be taken when placing the gastric tube because blind gastric tube placement may further injure the chemically damaged esophagus or stomach.

Because children do not ingest large amounts of corrosive materials, and because of the risk of perforation from NG

intubation, lavage is discouraged in children unless intubation is performed under endoscopic guidance.

Toxic vomitus or gastric washings should be isolated (e.g., by attaching the lavage tube to isolated wall suction or another closed container).

Antidotes and Other Treatments

There is no antidote for tetrachloroethylene poisoning. Treatment is supportive. Controlled hyperventilation to enhance respiratory elimination of tetrachloroethylene has been reported, but is not a proven treatment method.

Laboratory Tests

Routine laboratory studies for all seriously exposed patients include CBC, glucose, electrolytes, liver enzymes, and kidney function tests. Chest radiography and pulse oximetry (or ABG measurements) are recommended in cases of severe inhalation exposure. Abdominal radiography may be useful in evaluating the severity of ingestion exposure and in assessing decontamination. Since hepatic and renal effects following acute tetrachloroethylene exposure may be delayed, serial testing over 1 to 3 days should be performed.

Tetrachloroethylene levels in blood or expired air are not clinically useful but can be used to document an exposure. Exposure to tetrachloroethylene is also suggested by detection of trichloroacetic acid in blood or urine; however, these tests are not specific for tetrachloroethylene.

Disposition and Follow-Up

Consider hospitalizing patients who have had significant inhalation exposure (e.g., with loss of consciousness) and patients who have ingested significant amounts of tetrachloroethylene.

Delayed Effects

Skin injury can develop several hours after exposure. Dermal hypersensitivity may also develop. Hepatic or renal injury can develop a few days after exposure, depending on the magnitude of the exposure.

Patient Release

Patients who have not experienced alterations in mental status or respiratory difficulty may be discharged. Patients who initially had mild symptoms, but who are asymptomatic 6 to 8 hours after exposure, may also be discharged. Discharged patients should be advised to rest and to seek medical care promptly if symptoms develop or recur (see the *Tetrachloroethylene—Patient Information Sheet* below).

Follow-up

Obtain the name of the patient's primary care physician so that the hospital can send a copy of the ED visit to the patient's doctor.

Follow-up laboratory evaluation of hepatic and renal function should be arranged for severely exposed patients. Neurologic examination for post-hypoxic injury is recommended in cases of CNS or respiratory depression. Patients who have skin burns or corneal lesions should be reexamined within 24 hours.

Reporting

If a work-related incident has occurred, you might be legally required to file a report; contact your state or local health department.

Other persons might still be at risk at the place where this incident occurred. If the incident occurred in the workplace, discussing it with company personnel might prevent future incidents. If a public health risk exists, notify your state or local health department or other responsible public agency. When appropriate, inform patients that they may request an evaluation of their workplace form the Occupational Safety and Health Administration (OSHA) or the National Instituted for Occupational Safety and Health (NIOSH). See Appendices III and IV for a list of agencies that may be of assistance.

Tetrachloroethylene
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to tetrachloroethylene.

What is tetrachloroethylene?
Tetrachloroethylene is a colorless liquid with a sweet smell. It is used to make other chemicals, to degrease metal parts, to dry-clean fabric and in fabric processing. It is also used as a solvent in printing inks, paints, lacquers, varnishes, and adhesives. It is found in many products used in the average home, such as spot removers, adhesives, paint removers, water repellants, wood cleaners, and silicone sprays. Sometimes people intentionally inhale it to get "high".

What immediate health effects can be caused by exposure to tetrachloroethylene?
Breathing or swallowing tetrachloroethylene can cause lightheadedness, dizziness, clumsiness, nausea, and vomiting. Very large amounts can cause sleepiness, coma, and even death. It can damage the liver and kidneys. If the liquid spills on the skin or eyes, it can cause irritation or burns. Vapors in the air can cause burning eyes.

Can tetrachloroethylene poisoning be treated?
There is no antidote for tetrachloroethylene poisoning, but its effects can be treated and most exposed persons recover completely. People who have been exposed to large amounts of tetrachloroethylene might need to be hospitalized.

Are any future health effects likely to occur?
A single small exposure form which a person recovers quickly is not likely to cause delayed or long-term effects. An exposure that occurs over many years can affect the brain, skin, liver, and kidneys and can increase the risk of certain types of cancer.

What tests can be done if a person has been exposed to tetrachloroethylene?
Specific tests for the presence of tetrachloroethylene breakdown products in blood and urine are available, but they are not generally useful to your doctor. If a severe exposure has occurred, blood and other tests might show whether the heart, lungs, liver, or kidneys have been affected. Testing is not needed in every case.

Where can more information about tetrachloroethylene be found?
More information about tetrachloroethylene can be obtained from your regional poison control center; your state, county, or local health department; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in occupational and environmental health. Ask the person who gave you this form for help locating these telephone numbers. If the exposure happened at work, you may wish to discuss it with your employer, the Occupational Safety and Health Administration (OSHA), or the National Instituted for Occupational Safety and Health (NIOSH). Ask the person who gave you this form for help in locating these telephone numbers.

Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow *only* the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:

- dizziness or clumsiness
- nausea or vomiting
- loss of appetite
- difficulty breathing

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.
[ ] Call for an appointment with Dr. _____ in the practice of _____. When you call for your appointment, please say that you were treated in the Emergency Department at _____ Hospital by _____ and were advised to be seen again in _____ days.
[ ] Return to the Emergency Department/ _____ Clinic on (date) _____at __ _____ AM/PM for a follow-up examination.
[ ] Do not perform vigorous physical activities for 1 to 2 days.
[ ] You may resume everyday activities including driving and operating machinery.
[ ] Do not return to work for _____ days.
[ ] You may return to work on a limited basis. See instructions below.
[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.
[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.
[ ] Avoid taking the following medications: _____
[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: __ _____
_____
[ ] Other instructions: _____
_____
_____

- Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.

- You or your physician can get more information on the chemical by contacting: _____ _____ or _____, or by checking out the following Internet Web sites: _____; _____.

Signature of patient _____ Date _____

Signature of physician _____ Date _____

Toluene ($C_6H_5CH_3$)
CAS 108-88-3; UN 1294

Synonyms include methyl benzene, methyl benzol, phenyl methane, and toluol.

Persons exposed only to toluene vapor do not pose substantial risks of secondary contamination. Persons whose clothing or skin is contaminated with liquid toluene can cause secondary contamination by direct contact or through off-gassing vapor.

Toluene is a colorless liquid with a sweet, pungent, benzene-like odor which provides an adequate warning of hazardous concentrations. Toluene is volatile, readily producing flammable and toxic concentrations at room temperature. Its vapor is heavier than air and may accumulate in low-lying areas.

Toluene is absorbed rapidly after inhalation and ingestion. It is absorbed slowly through intact skin; however, percutaneous absorption may contribute to total body burden. Exposure by ingestion or inhalation can cause systemic effects. No information was found to suggest that the pharmacokinetics of toluene in children is different than in adults. Toluene crosses the placenta and is excreted in breast milk.

Description

Toluene is a clear, colorless, volatile liquid with a sweet, pungent, benzene-like odor. It is flammable at temperatures greater than 40 °F (4.4 °C); therefore, it is a significant fire hazard at room temperature. Toluene mixes readily with many organic solvents, but is poorly soluble in water. Toluene is less dense than water and will float on the surface of water. Toluene should be stored indoors in a standard flammable liquids room or cabinet that is separate from oxidizing materials.

Routes of Exposure

Inhalation

Toluene is readily absorbed from the lungs, and most exposures to toluene occur by inhalation. Toluene's odor is discernable at a concentration of 8 ppm, which is 25 times less than the OSHA PEL (200 ppm); therefore, odor generally provides adequate warning of acutely hazardous concentrations. Its vapor is heavier than air and may cause asphyxiation in enclosed, poorly ventilated, or low-lying areas.

Children exposed to the same levels of toluene vapor as adults may receive a larger dose because they have greater lung surface area:body weight ratios and increased minute volumes:weight ratios. In addition, they may be exposed to higher levels than adults in the same location because of their short stature and the higher levels of toluene vapor found nearer to the ground.

Skin/Eye Contact

Toluene vapor is only mildly irritating to mucous membranes; however, liquid toluene splashed in the eyes can result in corneal injury. Repeated or prolonged skin contact with liquid toluene can defat the skin, causing it to crack and peel. Percutaneous absorption is slow through intact skin; however, toluene absorbed through the skin may contribute to total body burden.

Children are more vulnerable to toxicants absorbed through the skin because of their relatively larger surface area:body weight ratio.

Ingestion

Acute systemic toxicity can result from ingestion of toluene.

Sources/Uses

Toluene is among the most abundantly produced chemicals in the United States. It is obtained primarily by distillation from crude petroleum. Toluene is an excellent solvent for paints, lacquers, thinners, and adhesives. It is used extensively in the rubber, chemical, paint, dye, glue, printing, and pharmaceutical industries.

Standards and Guidelines

OSHA PEL (permissible exposure limit) = 200 ppm (averaged over an 8-hour workshift)

OSHA ceiling = 300 ppm

OSHA STEL (short-term exposure limit) = 500 ppm (10-minute exposure)

NIOSH IDLH (immediately dangerous to life or health) = 500 ppm

ACGIH TLV (threshold limit value) = 50 ppm (averaged over an 8-hour workshift)

AIHA ERPG-2 (emergency response planning guideline) (maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms which could impair an individual's ability to take protective action) = 300 ppm

Physical Properties

Description: Clear, colorless liquid

Warning properties: Adequate; sweet, aromatic odor at 8 ppm

Molecular weight: 92.1 daltons

Boiling point (760 mm Hg): 232 °F (110.6 °C)

Freezing point: -139 °F (-9 °C)

Specific gravity: 0.87 (water = 1)

Vapor pressure: 21 mm Hg at 68 °F (20 °C)

Gas density: 3.2 (air = 1)

Water solubility: Slightly water soluble (0.07% at 74 °F) (23 °C)

Flammability: 40 °F (4.4 °C); vapors may travel to a source of ignition and flash back.

Flammable range: 1.2% to 7.1% (concentration in air)

Incompatibilities

Toluene reacts with strong oxidizers.

Health Effects

Toluene is irritating to the skin, eyes, and respiratory tract. It can cause systemic toxicity by ingestion or inhalation and is slowly absorbed through the skin. The most common route of exposure is via inhalation. Symptoms of toluene poisoning include CNS effects (headache, dizziness, ataxia, drowsiness, euphoria, hallucinations, tremors, seizures, and coma), ventricular arrythmias, chemical pneumonitis, respiratory depression, nausea, vomiting, and electrolyte imbalances.

The mechanism by which toluene produces systemic toxicity is not known. No information was found to suggest that the health effects of toluene in children are different than in adults. Toluene crosses the placenta and is excreted in breast milk.

Acute Exposure

The mechanism by which toluene produces systemic toxicity is not known. CNS toxicity may be due to the liposolubility of toluene in the neuronal membrane. It has been suggested that toluene interferes with the normal function of neuronal proteins. It has also been suggested that the toxicity of toluene may be due to some of its metabolic intermediates. CNS toxicity is generally discernable within a short time of exposure, but pulmonary effects may not appear for up to 6 hours after exposure. No information was found to suggest that the health effects of toluene in children are different than in adults.

Children do not always respond to chemicals in the same way that adults do. Different protocols for managing their care may be needed.

CNS

Generally, symptoms of CNS toxicity are apparent immediately after inhalation of high toluene concentrations and 30 to 60 minutes after ingestion. Mild CNS effects include headache, lightheadedness, dizziness, confusion, nausea, impaired judgment, impaired gait, and blurred vision. More severe effects include loss of consciousness, coma, and death. Coma may be prolonged, although most victims regain consciousness rapidly after they are removed from exposure.

Respiratory

Acute exposure to toluene vapor can irritate the mucous membranes of the respiratory tract. With massive exposure, accumulation of fluid in the lungs and respiratory arrest may ensue. Pulmonary aspiration of toxic vomitus or ingested liquid toluene may cause chemical pneumonitis.

Exposure to certain chemicals can lead to Reactive Airway Dysfunction Syndrome (RADS), a chemically- or irritant-induced type of asthma.

Children may be more vulnerable because of relatively increased minute ventilation per kg and failure to evacuate an area promptly when exposed.

Hydrocarbon pneumonitis may be a problem in children.

Cardiovascular Massive doses of toluene can cause cardiac abnormalities. Toluene may lower the threshold of the heart to the effects of epinephrine, potentially disrupting the heart rhythm. Irregular heart rhythm leading to cardiac arrest has been described in solvent abusers, often immediately after intense physical activity.

Renal Blood and protein in the urine can occur after massive inhalation. These effects are usually reversible if exposure is terminated.

Metabolic After high-level exposure, toluene may cause an acid-base imbalance. In solvent abusers, electrolyte and acid-base disturbances have resulted in renal tubular acidosis, deficiency of potassium, and deficiency of phosphate. Ethanol or aspirin may prolong the half-life of toluene in the body.

Because of their relatively higher metabolic rates, children may be more vulnerable to toxicants interfering with basic metabolism.

Dermal Liquid toluene can cause irritation and defatting after prolonged or repeated contact with the skin. Redness and blisters may occur.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants absorbed through the skin.

Hepatic Liver damage has been reported in solvent abusers.

Ocular Eye irritation from toluene vapor begins at concentrations of about 300 ppm. Inflammation is generally slight. When splashed in the eyes, toluene may cause burning pain, blepharospasm, conjuctivitis, and keratinitis.

Gastrointestinal If swallowed, toluene can irritate the stomach, causing nausea, vomiting, and diarrhea.

Potential Sequelae During recovery, exposed persons may continue to experience ataxia, depressed level of consciousness, dilated and poorly responsive pupils, and decreased or absent deep tendon reflexes.

Anxiety, fatigue, and insomnia may last several days. No long-term effects due to acute toluene exposure have been reported.

Chronic Exposure

Chronic toluene exposures at less than 200 ppm have been associated with headache, fatigue, and nausea. Workers repeatedly exposed at 200 to 500 ppm have reported loss of coordination, memory loss, and loss of appetite. Some workers have developed reversible disorders of the optic nerves after chronic exposure in the workplace.

Chronic exposure due to solvent abuse can result in permanent neuropsychiatric effects. Disorders of the muscles, cardiovascular effects, renal tubular damage, and sudden death have occurred in chronic abusers of toluene.

Chronic exposure may be more serious for children because of their potential longer latency period.

Carcinogenicity

The International Agency for Research on Cancer has determined that toluene is not classifiable as to its carcinogenicity to humans. The EPA has determined that toluene is not classifiable as to its human carcinogenicity.

Developmental and Reproductive Effects

Toluene has not been confirmed as a human reproductive hazard. However, toluene is known to cross the placenta and is excreted in breast milk. In animal studies toluene has been shown to be fetotoxic, but not teratogenic. *Shepards Catalog of Teratogenic Agents* reports five cases of children whose mothers regularly used toluene recreationally while pregnant. These children were born with small heads (microcephaly); CNS dysfunction; and minor head, face, and limb anomalies. Several of the mothers had also abused alcohol during pregnancy. Toluene is included in *Reproductive and Developmental Toxicants,* a 1991 report published by the U.S. General Accounting Office (GAO) that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences.

Prehospital Management

Victims exposed only to toluene vapor do not pose substantial risks of secondary contamination to rescuers outside the Hot Zone. Victims whose clothing or skin is contaminated with liquid toluene can secondarily contaminate response personnel by direct contact or through off-gassing vapor. Toluene vapor may also off-gas from the toxic vomitus of victims who have ingested toluene.

Toluene is irritating to the skin, eyes, and respiratory tract. It can cause systemic toxicity by ingestion or inhalation. The most common route of exposure is via inhalation. Symptoms of toluene poisoning include CNS effects (headache, dizziness, ataxia, drowsiness, euphoria, hallucinations, tremor, seizures, and coma), ventricular arrythmias, chemical pneumonitis, respiratory depression, nausea, vomiting, and electrolyte imbalances.

There is no antidote for toluene. Treatment consists of support of respiratory and cardiovascular functions.

Hot Zone

Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if rescuers have not been trained in its use, assistance should be obtained from a local or regional HAZMAT team or other properly equipped response organization.

Rescuer Protection

Toluene vapor is absorbed well by inhalation and is a mild respiratory-tract irritant. The liquid is a mild skin and eye irritant with slow skin absorption.

Respiratory Protection: Positive-pressure, self-contained breathing apparatus (SCBA) is recommended in response situations that involve exposure to potentially unsafe levels of toluene vapor.

Skin Protection: Chemical-protective clothing is not generally required when only vapor exposure is expected because toluene vapor is neither irritating nor absorbed well through the skin.

Chemical-protective clothing should be worn when repeated or prolonged contact with the liquid is anticipated because skin irritation and dermal absorption may occur.

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible.

Victim Removal

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be removed on backboards or gurneys; if these are not available, carefully carry or drag victims to safety.

Consider appropriate management of chemically contaminated children, such as measures to reduce separation anxiety if a child is separated from a parent or other adult.

Decontamination Zone

Patients exposed only to toluene vapor who have no skin or eye irritation may be transferred immediately to the Support Zone. Other patients will require decontamination (as described below).

Rescuer Protection

If exposure levels are determined to be safe, decontamination may be conducted by personnel wearing a lower level of protection than that worn in the Hot Zone (described above).

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. Stabilize the cervical spine with a collar and a backboard if trauma is suspected. Administer supplemental oxygen as required. Assist ventilation with a bag-valve-mask device if necessary.

Basic Decontamination

Victims who are able may assist with their own decontamination. Quickly remove and double-bag contaminated clothing and personal belongings.

Flush liquid-exposed skin and hair with plain water for 2 to 3 minutes, then wash with mild soap. Rinse thoroughly with water. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Flush exposed or irritated eyes with plain water or saline for at least 15 minutes or until pain resolves. Remove contact lenses if easily removable without additional trauma to the eye. If a corrosive material is suspected or if pain or injury is evident, continue irrigation while transferring the victim to the Support Zone.

In cases of ingestion, **do not induce emesis**. The use of activated charcoal for hydrocarbon absorption is limited, but it may have some effect, especially in cases of mixed overdose. If the victim is alert, asymptomatic, and has a gag reflex, administer a slurry of activated charcoal at 1 gm/kg (usual adult dose 60–90 g, child dose 25–50 g). A soda can and a straw may be of assistance when offering charcoal to a child.

Consider appropriate management of chemically contaminated children at the exposure site. Provide reassurance to the child during decontamination, especially if separation from a parent occurs.

Transfer to the Support Zone

As soon as basic decontamination is complete, move the victim to the Support Zone.

Support Zone

Be certain that victims have been decontaminated properly (see *Decontamination Zone* above). Victims who have undergone decontamination or who have been exposed only to vapor generally pose no serious risks of secondary contamination. In such cases, Support Zone personnel require no specialized protective gear.

ABC Reminders

Quickly access for a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Ensure adequate respiration and pulse. Administer supplemental oxygen as required and establish intravenous access if necessary. Place on a cardiac monitor. Observe for cardiac arrhythmias.

Additional Decontamination

Continue irrigating exposed skin and eyes, as appropriate.

In cases of ingestion, **do not induce emesis**. The use of activated charcoal for hydrocarbon absorption is limited, but it may have some effect, especially in cases of mixed overdose. If activated charcoal has not been given previously and if the patient is alert, asymptomatic, and has a gag reflex, administer a slurry of activated charcoal at 1 gm/kg (usual adult dose 60–90 g, child dose 25–50 g). A soda can and a straw may be of assistance when offering charcoal to a child.

Advanced Treatment

In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, perform cricothyroidotomy if equipped and trained to do so.

Patients who have bronchospasm may be treated with aerosolized bronchodilators. However, the use of sympathomimetic agents such as epinephrine and isoproterenol could precipitate fatal arrhythmias and should be avoided. Selective beta-2 agonists would be preferred, but clinical reports of their use are lacking. Theophylline derivatives have not been studied. Use all catecholamines with caution because of the enhanced risk of cardiac arrhythmias. Also consider the health of the myocardium before choosing which type of bronchodilator should be administered.

Patients who are comatose, hypotensive, or having seizures or cardiac arrhythmias should be treated according to advanced life support (ALS) protocols.

Monitor fluid and electrolyte status carefully. Correct hypokalemia with potassium phosphate (phosphate levels are also generally low). Hypocalcemia may occur following fluid and electrolyte replenishment. Do not administer bicarbonate therapy until potassium and calcium are adequately replaced.

Transport to Medical Facility

Only decontaminated patients or patients not requiring decontamination should be transported to a medical facility. "Body bags" are not recommended.

Report to the base station and the receiving medical facility the condition of the patient, treatment given, and estimated time of arrival at the medical facility.

If toluene has been ingested, prepare the ambulance in case the victim vomits toxic material. Have ready several towels and open plastic bags to quickly clean up and isolate vomitus.

Multi-Casualty Triage

Consult with the base station physician or the regional poison control center for advice regarding triage of multiple victims.

Patients with evidence of substantial inhalation exposure (e.g., confusion, syncope, or coma) and all patients who have ingested toluene should be transported to a medical facility for evaluation. Others may be discharged at the scene after their names, addresses, and telephone numbers are recorded. Those discharged should be advised to seek medical care promptly if symptoms develop (see *Patient Information Sheet* below).

Emergency Department Management

- **Hospital personnel can be secondarily contaminated by direct contact or vapor off-gassing from heavily soaked skin or clothing. Patients do not pose contamination risks after clothing is removed and the skin is washed. Toxic vomitus from patients who have ingested toluene may also off-gas toluene vapor.**

- **Toluene is irritating to the skin, eyes, and respiratory tract. It can cause systemic toxicity by ingestion or inhalation. The most common route of exposure is via inhalation. Symptoms of toluene poisoning include CNS effects (headache, dizziness, ataxia, drowsiness, euphoria, hallucinations, tremor, seizures, and coma), ventricular arrythmias, chemical pneumonitis, respiratory depression, nausea, vomiting, and electrolyte imbalances.**

- **There is no antidote for toluene. Treatment consists of support of respiratory and cardiovascular functions.**

Decontamination Area

Unless previously decontaminated, all patients suspected of contact with liquid toluene and all victims with skin or eye irritation require decontamination as described below. All other patients may be transferred to the Critical Care area.

Be aware that use of protective equipment by the provider may cause fear in children, resulting in decreased compliance with further management efforts.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants absorbed through the skin. Also emergency room personnel should examine children's mouths because of the frequency of hand-to-mouth activity among children.

ABC Reminders

Evaluate and support airway, breathing, and circulation. In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, surgically create an airway.

Patients who have bronchospasm may be treated with aerosolized bronchodilators. However, the use of sympathomimetic agents such as epinephrine and isoproterenol could precipitate fatal arrhythmias and should be avoided. Selective beta-2 agonists would be preferred, but clinical reports of their use are lacking. Theophylline derivatives have not been studied. Use all catecholamines with caution because of the enhanced risk of cardiac arrhythmias. Also consider the health of the myocardium before choosing which type of bronchodilator should be administered.

Patients who are comatose, hypotensive, or have seizures or ventricular arrhythmias should be treated in the conventional manner. Avoid sympathomimetics or catecholamines or use them with caution. Beta-blockers may be more effective than lidocaine in cases of prolonged or resistant arrhythmias.

Monitor fluid and electrolyte status carefully. Correct hypokalemia with potassium phosphate (phosphate levels are also generally low). Hypocalcemia may occur following fluid and electrolyte replenishment. Do not administer bicarbonate therapy until potassium and calcium are adequately replaced.

Basic Decontamination

Patients who are able may assist with their own decontamination. Remove and double-bag contaminated clothing and personal belongings.

Flush liquid-exposed skin and hair with plain water for 2 to 3 minutes, then wash with mild soap. Rinse thoroughly with water. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Flush exposed or irritated eyes with plain water or saline for at least 15 minutes or until pain resolves. Remove contact lenses if present and easily removable without additional trauma to the eye. If a corrosive material is suspected or if pain or injury is evident, continue irrigation while transferring the victim to the Critical Care Area.

In cases of ingestion, **do not induce emesis**. The use of activated charcoal for hydrocarbon absorption is limited, but it may have some effect, especially in cases of mixed overdose. If the victim is alert, asymptomatic, and has a gag reflex, administer a slurry of activated charcoal at 1 gm/kg (usual adult dose 60–90 g, child dose 25–50 g). A soda can and a straw may be of assistance when offering charcoal to a child.

Critical Care Area

Be certain that appropriate decontamination has been carried out (see *Decontamination Area* above).

ABC Reminders

Evaluate and support airway, breathing, and circulation as in *ABC Reminders* above. Establish intravenous access in seriously ill patients if this has not been done previously. Continuously monitor cardiac rhythm. To avoid inducing ventricular fibrillation, use sympathomimetics or catecholamines with caution. Beta-blockers may be more effective than lidocaine in treating patients who have arrhythmia.

Patients who are comatose, hypotensive, or have seizures or ventricular arrhythmia should be treated in the conventional manner. Avoid sympathomimetics or catecholamines or use them with caution. Beta-blockers may be more effective than lidocaine in cases of prolonged or resistant arrhythmia.

Inhalation Exposure

Administer supplemental oxygen by mask to patients who have respiratory complaints. Patients who have bronchospasm may be treated with aerosolized bronchodilators. However, the use of sympathomimetic agents such as epinephrine and isoproterenol could precipitate fatal arrhythmia and should be avoided. Selective beta-2 agonists would be preferred, but clinical reports of their use are lacking. Theophylline derivatives have not been studied. Use all catecholamines with caution because of the enhanced risk of cardiac arrhythmia. Also consider the health of the myocardium before choosing which type of bronchodilator should be administered.

Skin Exposure

If the skin was in prolonged contact with liquid toluene, chemical burns may result; treat as thermal burns.

Because of their larger surface area:body weight ratio, children are more vulnerable to toxicants absorbed through the skin.

Eye Exposure

Ensure that adequate eye irrigation has been completed. Examine the eyes for corneal damage and treat appropriately. Immediately consult an ophthalmologist for patients who have corneal injuries.

Ingestion Exposure

Do not induce emesis.

The use of activated charcoal for hydrocarbon absorption is limited, but it may have some effect, especially in cases of mixed overdose. If activated charcoal has not been given previously and if the patient is alert, asymptomatic, and has a gag reflex, administer a slurry of activated charcoal at 1 gm/kg (usual adult dose 60–90 g, child dose 25–50 g). A soda can and a straw may be of assistance when offering charcoal to a child.

Consider endoscopy to evaluate the extent of gastrointestinal-tract injury. Extreme throat swelling may require endotracheal intubation or cricothyroidotomy. Gastric lavage is useful in certain circumstances to remove toxic material and prepare for endoscopic examination. Consider gastric lavage with a small nasogastric tube if: (1) a large dose has been ingested; (2) the patient's condition is evaluated within 30 minutes; (3) the patient has oral lesions or persistent esophageal discomfort; and (4) the lavage can be administered within one hour of ingestion. Care must be taken when

placing the gastric tube because blind gastric-tube placement may further injure the chemically damaged esophagus or stomach.

Because children do not ingest large amounts of toxic materials, and because of the risk of perforation from NG intubation, lavage is discouraged in children unless performed under endoscopic guidance.

Toxic vomitus or gastric washings should be isolated, e.g., by attaching the lavage tube to isolated wall suction or another closed container.

Antidotes and Other Treatments

There is no antidote for toluene. Hemodialysis and hemoperfusion are ineffective.

Monitor fluid and electrolyte status carefully. Correct hypokalemia with potassium phosphate (phosphate levels are also generally low). Hypocalcemia may occur following fluid and electrolyte replenishment. Do not administer bicarbonate therapy until potassium and calcium are adequately replaced.

Laboratory Tests

Routine laboratory studies for all exposed patients include CBC, glucose, and electrolyte determinations. Additional studies for patients exposed to toluene include ECG monitoring, renal-function tests, and liver-function tests. Chest radiography and pulse oximetry (or ABG measurements) are also recommended for severe inhalation exposure or if pulmonary aspiration is suspected.

Blood levels of toluene may be useful in documenting exposure, but are not useful clinically. Toluene is metabolized to hippuric acid, which is excreted in urine with a biologic half-life of about 3 hours. Results of urinary hippuric acid tests do not correlate well with systemic effects and are not available on an emergency basis; however, they can help confirm the diagnosis or etiology. The ACGIH suggests that levels exceeding 0.5 mg/L of o-cresol or 1.6 g of hippuric acid/g creatinine in urine, or 0.05 mg/L of toluene in blood indicate potential overexposure to toluene, but these are not useful clinically.

Disposition and Follow-up

Consider hospitalizing symptomatic patients who have significant inhalation or ingestion exposure with symptoms of CNS depression or respiratory distress.

Delayed Effects

Observe hospitalized patients for signs of acute tubular necrosis, encephalopathy, and arrhythmia. In addition, patients who have inhaled large amounts of toluene should be observed for signs of pulmonary edema, and those who have ingested toluene should be watched for signs of aspiration pneumonitis.

Patient Release

Patients who remain asymptomatic for 6 to 12 hours after exposure may be discharge with instructions to seek medical care promptly if symptoms develop (see the *Toluene—Patient Information Sheet* below).

Follow-up

Obtain the name of the patient's primary care physician so that the hospital can send a copy of the ED visit to the patient's doctor.

Patients who have corneal injuries should be reexamined within 24 hours. No long-term sequelae due to a single acute exposure to toluene have been reported.

Reporting

If a work-related incident has occurred, you may be legally required to file a report; contact your state or local health department.

Other persons may still be at risk in the setting where this incident occurred. If the incident occurred in the workplace, discussing it with company personnel may prevent future incidents. If a public health risk exists, notify your state or local health department or other responsible public agency. When appropriate, inform patients that they may request an evaluation of their workplace from OSHA or NIOSH. See Appendices III and IV for a list of agencies that may be of assistance.

Toluene
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to toluene.

What is toluene?
Toluene is a clear, colorless liquid with a sweet odor. It is obtained from crude petroleum and is highly flammable. Toluene is used in a variety of industries and is a common solvent for products such as paints, thinners, and glues. It is found in small amounts in gasoline.

What immediate health effects can be caused by exposure to toluene?
Breathing toluene vapors in small amounts may cause a mild headache, dizziness, drowsiness, or nausea. With more serious exposure, toluene may cause sleepiness, stumbling, irregular heartbeat, fainting, or even death. Toluene vapor is mildly irritating to the skin, eyes, and lungs. If liquid toluene contacts the skin, it may cause irritation and a rash. Liquid toluene splashed in the eyes can damage the eyes. Generally, the more serious the exposure, the more severe the symptoms.

Can toluene poisoning be treated?
There is no antidote for toluene, but its effects can be treated, and most exposed persons get well. Persons who have experienced serious symptoms may need to be hospitalized.

Are any future health effects likely to occur?
A single small exposure from which a person recovers quickly is not likely to cause delayed or long-term effects. After a serious exposure to toluene, some symptoms may take a few days to develop.

Repeated sniffing of toluene can cause permanent damage to the brain, muscles, heart, and kidneys.

What tests can be done if a person has been exposed to toluene?
Specific tests for the presence of toluene in blood or urine generally are not useful to the doctor. Hippuric acid, a breakdown product of toluene, can be measured in urine if the toluene dose was high. If a severe exposure has occurred, blood and urine analyses and other tests may show whether the brain, heart, or kidneys have been injured. Testing is not needed in every case.

Where can more information about toluene be found?
More information about toluene can be obtained from your regional poison control center; the state, county, or local health department; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in occupational and environmental health. If the exposure happened at work, you may wish to discuss it with your employer, the Occupational Safety and Health Administration (OSHA), or the National Institute for Occupational Safety and Health (NIOSH). Ask the person who gave you this form for help in locating these telephone numbers.

Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow *only* the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:
fatigue, headache, dizziness, tremor or seizures.
coughing, shortness of breath or wheezing
chest pain or tightness
increased pain or a discharge from injured eyes
increased redness or pain or a pus-like discharge in the area of a skin burn
fever

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.
[ ] Call for an appointment with Dr. _____ in the practice of _____.
When you call for your appointment, please say that you were treated in the Emergency Department at _____ Hospital by _____ and were advised to be seen again in _____ days.
[ ] Return to the Emergency Department/ _____ Clinic on (date) _____at _____ AM/PM for a follow-up examination.
[ ] Do not perform vigorous physical activities for 1 to 2 days.
[ ] You may resume everyday activities including driving and operating machinery.
[ ] Do not return to work for _____ days.
[ ] You may return to work on a limited basis. See instructions below.
[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.
[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.
[ ] Avoid taking the following medications: _____
[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: ___
_____
_____
[ ] Other instructions: _____
_____
_____

- Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.

- You or your physician can get more information on the chemical by contacting: _____ _____ or _____, or by checking out the following Internet Web sites: _____; _____.

Signature of patient _____ Date _____

Signature of physician _____ Date _____

Toluene Diisocyanate ($CH_3C_6H_3[NCO]_2$)
CAS 26471-62-5 (mixture), CAS 584-84-9 (2,4-isomer), CAS 91-08-7 (2,6- isomer); UN 2078

Synonyms include TDI, diisocyanatotoluene, and tolylene diisocyanate.

Persons exposed only to toluene diisocyanate vapor do not pose secondary contamination risks. Persons whose clothing or skin is contaminated with liquid toluene diisocyanate can secondarily contaminate others by direct contact or off-gassing vapor.

At room temperature, toluene diisocyanate is a clear, pale yellow liquid with a sharp, pungent odor. It is combustible only at high temperatures, but burns to produce toxic gases (cyanides and nitrogen oxides). It is volatile, producing toxic concentrations at room temperature. The odor of toluene diisocyanate does not provide adequate warning of hazardous concentrations.

Toluene diisocyanate is absorbed rapidly through the lungs, but dermal absorption is minimal. No information was located pertaining to ingestion of toluene diisocyanate. Exposure by inhalation causes respiratory and systemic effects while dermal exposure causes inflammation and irritation of the skin.

Description

Toluene diisocyanate exists in two isomeric forms (2,4-toluene diisocyanate and 2,6-toluene diisocyanate) which have similar properties and effects. Toluene diisocyanate is produced commercially as an 80:20 (2,4-toluene diisocyanate:2,6-toluene diisocyanate) mixture of the two isomers. At room temperature, the mixture is a clear, pale yellow liquid with a sharp, pungent odor. It should be stored under refrigeration, away from light and moisture in a tightly closed container under an inert atmosphere. Toluene diisocyanate is insoluble in water and miscible with most common organic solvents.

Routes of Exposure

Inhalation

Inhalation is the main route of exposure to toluene diisocyanate. The vapor is readily absorbed from the lungs and is irritating to the respiratory tract and lungs even at low concentrations. Its odor threshold of 2.1 ppm is 100 times greater than the OSHA permissible exposure limit (0.02 ppm). Thus, **odor does not provide an adequate warning of potentially hazardous concentrations.** Toluene diisocyanate vapor is heavier than air and may cause asphyxiation in enclosed, poorly ventilated, or low-lying areas.

Children exposed to the same levels of toluene diisocyanate vapor as adults may receive a larger dose because they have greater lung surface area:body weight ratios and increased minute volumes:weight ratios. In addition, they may be exposed to higher levels than adults in the same location because of their short stature and the higher levels of toluene diisocyanate vapor found nearer to the ground.

Skin/Eye Contact

Direct contact with liquid toluene diisocyanate can cause severe eye and skin irritation. Exposure to relatively high vapor concentrations produces inflammation of mucous membranes. Dermal absorption is slow through intact skin.

Children are more vulnerable to toxicants absorbed through the skin because of their relatively larger surface area:body weight ratio.

Ingestion

No information was located pertaining to ingestion of toluene diisocyanate. Toluene diisocyanate is very irritating; thus, ingestion would probably produce chemical burns of the lips, mouth, throat, esophagus, and stomach. No data were located as to whether ingestion leads to systemic toxicity.

Sources/Uses

Toluene diisocyanate is made by reacting toluene diamine with carbonyl chloride (phosgene).

Toluene diisocyanate is commonly used as a chemical intermediate in the production of polyurethane foams, elastomers, and coatings; paints; varnishes; wire enamels; sealants; adhesives; and binders. It is also used as a cross-linking agent in the manufacture of nylon polymers.

Standards and Guidelines

OSHA PEL (permissible exposure limit) = 0.02 ppm (ceiling)

NIOSH IDLH (immediately dangerous to life or health) = 2.5 ppm

Physical Properties

Description: Clear, straw-colored liquid that becomes cloudy with age

Warning properties: Sharp, pungent odor at 2.1 ppm; inadequate warning of acute or chronic exposures.

Molecular weight: 174.2 daltons

Boiling point (760 mm Hg): 484 °F (251 °C) (mixed isomers)

Freezing point: 52–57 °F (11–14 °C) (mixed isomers)

Vapor pressure: 0.025 mm Hg at 77 °F (25 °C)

Gas density: 6 (air = 1)

Specific gravity: 1.22 (water = 1)

Water solubility: insoluble

Flammability: 250 °F (121 °C) (mixed isomers)

Flammable range: 0.9% to 9.5% (concentration in air)

Incompatibilities

Toluene diisocyanate reacts with strong oxidizers, water, acids, bases, amines, and alcohols.

Health Effects

Toluene diisocyanate is severely irritating to tissues, especially to mucous membranes. Inhalation of toluene diisocyanate produces euphoria, ataxia, mental aberrations, vomiting, abdominal pain, respiratory sensitization, bronchitis, emphysema, and asthma.

The mechanism by which toluene diisocyanate produces toxic symptoms is not known, but the compound is highly reactive and may inactivate tissue biomolecules by covalent binding. No information was found as to whether the health effects of toluene diisocyanate in children are different than in adults. Exposure to toluene diisocyanate produces severe respiratory problems and individuals with pre-existing breathing difficulties may be more susceptible to its effects.

Acute Exposure

The mechanism by which toluene diisocyanate produces toxic symptoms is not known, but the compound is highly reactive and may inactivate tissue biomolecules by covalent binding. Onset of symptoms may be delayed for 4 to 8 hours.

Children do not always respond to chemicals in the same way that adults do. Different protocols for managing their care may be needed.

Respiratory

Toluene diisocyanate produces irritation of the respiratory-tract. Concentration-dependent effects occur, often after a delay of 4 to 8 hours and may persist for 3 to 7 days. High-concentration inhalation can lead to chest tightness, cough, breathlessness, and inflammation of the bronchi with sputum production and wheezing. Accumulation of fluid in the lungs can also occur.

Previously exposed persons may develop inflammation of the lungs when reexposed to extremely low levels of toluene diisocyanate. Flu-like symptoms such as fever, malaise, shortness of breath, and cough can develop 4 to 6 hours after exposure and persist for 12 hours or longer. Chest x-rays may indicate lung changes.

In sensitized individuals, asthmatic attacks can occur after exposure to extremely low toluene diisocyanate air concentrations (0.0001 ppm). Asthmatic reactions can be immediate, delayed (4 to 8 hours), or both.

Exposure to toluene diisocyanate can lead to Reactive Airway Dysfunction Syndrome (RADS), a chemically- or irritant-induced type of asthma.

Children may be more vulnerable because of relatively increased minute ventilation per kg and failure to evacuate an area promptly when exposed.

CNS

Acute exposure to high levels of toluene diisocyanate vapor or toluene diisocyanate-containing smoke has been associated with lightheadedness, headache, insomnia, mental aberrations, impaired gait, loss of consciousness, and coma.

Dermal

Toluene diisocyanate is a skin irritant. Contact with the liquid may cause second- and third-degree skin burns. Skin contact may also result in respiratory sensitization, although this is rare.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants absorbed through the skin.

Ocular

Toluene diisocyanate can cause eye irritation, inflammation of the eye membrane, inflammation of the cornea, clouding of the eye surface, and secondary glaucoma.

Gastrointestinal

No cases involving ingestion were located. Because toluene diisocyanate is a known irritant, it is likely to cause burns of the lips, mouth, throat, esophagus and stomach. No data were located as to whether ingestion leads to systemic toxicity.

Potential Sequelae

After an acute, high-concentration exposure, persons may develop non-specific bronchial hyperresponsiveness and toluene diisocyanate hypersensitization.

Sensitization occurs after exposure to levels greater than 0.02 ppm or after skin exposure. Allergic tendency is not a strong predisposing factor. Toluene diisocyanate can also cause lung-function decline in persons not sensitized to the chemical. Respiratory symptoms related to narrowing of the bronchi can persist for years.

Neurologic effects, such as difficulty concentrating, poor memory, and dull headache, have been reported to persist years after a high-level exposure. It is not known whether these complications resulted from the neurotoxic effects of toluene diisocyanate or from lack of oxygen in the blood.

Chronic Exposure

Workers who chronically inhale low levels of toluene diisocyanate may have minimal or no respiratory symptoms, then suddenly develop asthma. Chronic workplace exposure is associated with an increased prevalence of sensitization; the reported sensitization rate

has varied between 2% and 20% of workers and is dependent on the level of exposure. Sensitized persons are at risk of developing chronic asthma that may be precipitated by exposures to other chemicals.

Chronic exposure may be more serious for children because of their potential longer latency period.

Carcinogenicity

The Department of Health and Human Services has determined that toluene diisocyanate may reasonably be anticipated to be a carcinogen. The International Agency for Research on Cancer has determined that toluene diisocyanate is possibly carcinogenic to humans.

Reproductive and Developmental Effects

No studies were located which address reproductive effects of toluene diisocyanate in either humans or experimental animals. No information was found as to whether toluene diisocyanate crosses the placenta or is excreted in breast milk. Toluene diisocyanate is not included in *Reproductive and Developmental Toxicants*, a 1991 report published by the U.S. General Accounting Office (GAO) that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences.

No known teratogenic effects from acute exposure are known.

Prehospital Management

Victims exposed only to toluene diisocyanate vapor do not pose contamination risks to rescuers. Victims whose clothing or skin is contaminated with liquid toluene diisocyanate can secondarily contaminate response personnel by direct contact or by off-gassing vapor.

Toluene diisocyanate is a direct irritant to mucous membranes, skin, eyes, and the respiratory system. Acute inhalation exposure may lead to euphoria, ataxia, mental aberrations, vomiting, abdominal pain, bronchospasm, chemical bronchitis, hypersensitivity pneumonitis, and noncardiogenic pulmonary edema.

There is no antidote for toluene diisocyanate. Treatment consists of bronchodilators and respiratory and cardiovascular support.

Hot Zone

Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if rescuers have not been trained in its use, assistance should be obtained from a local or regional HAZMAT team or other properly equipped response organization.

Rescuer Protection

Toluene diisocyanate is a severe respiratory tract and skin irritant and sensitizer.

Respiratory Protection: Positive-pressure, self-contained breathing apparatus (SCBA) is recommended in response situations that involve exposure to potentially unsafe levels of toluene diisocyanate.

Skin Protection: Chemical-protective clothing is recommended because toluene diisocyanate can cause skin irritation, burns, and sensitization.

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible.

Victim Removal

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be removed on backboards or gurneys; if these are not available, carefully carry or drag victims to safety.

Consider appropriate management of chemically-contaminated children, such as measures to reduce separation anxiety if a child is separated from a parent or other adult.

Decontamination Zone

Patients exposed only to toluene diisocyanate vapor who have no skin or eye irritation may be transferred immediately to the Support Zone. Other patients will require decontamination as described below.

Rescuer Protection

If exposure levels are determined to be safe, decontamination may be conducted by personnel wearing a lower level of protection than that worn in the Hot Zone (described above).

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. Stabilize the cervical spine with a collar and a backboard if trauma is suspected. Administer supplemental oxygen as required. Assist ventilation with a bag-valve-mask device if necessary.

Basic Decontamination

Victims who are able may assist with their own decontamination. Quickly remove and double-bag contaminated clothing and personal belongings.

Flush exposed skin and hair with water for 2 to 3 minutes, then wash twice with mild soap. Rinse thoroughly with water. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Flush exposed or irritated eyes with plain water or saline for 15 minutes. Remove contact lenses if easily removable without additional trauma to the eye. Continue eye irrigation during other basic care and transport. If a corrosive material is suspected or if pain or injury is evident, continue irrigation while transferring the victim to the Support Zone.

In cases of ingestion, **do not induce emesis**. If the victim is alert, asymptomatic, and has a gag reflex, administer a slurry of activated charcoal at 1 gm/kg (usual adult dose 60–90 g, child dose 25–50 g). A soda can and a straw may be of assistance when offering charcoal to a child.

Victims who are conscious and able to swallow should be given 4 to 8 ounces of milk or water (not to exceed 15 mL/kg in a child). If the victim is symptomatic, delay decontamination until other emergency measures have been instituted.

Consider appropriate management of chemically contaminated children at the exposure site. Provide reassurance to the child during decontamination, especially if separation from a parent occurs.

Transfer to Support Zone

As soon as basic decontamination is complete, move the victim to the Support Zone.

Support Zone

Be certain that victims have been decontaminated properly (see *Decontamination Zone*, above). Victims who have undergone decontamination or have been exposed only to vapor pose no serious risks of secondary contamination to rescuers. In such cases, Support Zone personnel require no specialized protective gear.

ABC Reminders

Quickly access for a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Ensure adequate respiration and pulse. Administer supplemental oxygen as required and establish intravenous access if necessary. Place on a cardiac monitor.

Additional Decontamination

Continue irrigating exposed skin and eyes, as appropriate.

In cases of ingestion, **do not induce emesis**. If the victim is alert, asymptomatic, and has a gag reflex, administer a slurry of activated charcoal at 1 gm/kg (usual adult dose 60–90 g, child dose 25–50 g) if it has not already been administered. A soda can and a straw may be of assistance when offering charcoal to a child.

Victims who are conscious and able to swallow should be given 4 to 8 ounces of milk or water (not to exceed 15 mL/kg in a child) if it has not been given previously. If the victim is symptomatic, delay decontamination until other emergency measures have been instituted.

Advanced Treatment

In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, perform cricothyroidotomy if equipped and trained to do so.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Toluene diisocyanate poisoning is not known to pose additional risk during the use of bronchial or cardiac sensitizing agents. Administer corticosteroids as indicated to patients who have persistent wheezing or hypersensitivity pneumonitis.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Patients who are comatose, hypotensive, or having seizures or cardiac arrhythmias should be treated according to advanced life support (ALS) protocols.

Transport to Medical Facility

Only decontaminated patients or patients not requiring decontamination should be transported to a medical facility. "Body bags" are not recommended.

Report to the base station and the receiving medical facility the condition of the patient, treatment given, and estimated time of arrival at the medical facility.

If toluene diisocyanate has been ingested, prepare the ambulance in case the victim vomits toxic material. Have ready several towels and open plastic bags to quickly clean up and isolate vomitus.

Multi-Casualty Triage

Consult with the base station physician or the regional poison control center for advice regarding triage of multiple victims.

Patients who are seriously symptomatic (as in cases of chest tightness or wheezing), patients who have histories or evidence of significant exposure, and all patients who have ingested toluene diisocyanate should be transported to a medical facility for evaluation. Others may be discharged at the scene after their names, addresses, and telephone numbers are recorded. Those discharged should be advised to seek medical care promptly if symptoms develop (see *Patient Information Sheet* below).

Emergency Department Management

Hospital personnel in an enclosed area can be secondarily contaminated by direct contact or by off-gassing vapor from soaked skin or clothing. Patients do not pose contamination risks after contaminated clothing is removed and the skin is washed.

Toluene diisocyanate is irritating to mucous membranes, skin, eyes, and the respiratory tract. Acute inhalation exposure may lead to euphoria, ataxia, mental aberrations, vomiting, abdominal pain, bronchospasm, chemical bronchitis, hypersensitivity pneumonitis, and noncardiogenic pulmonary edema.

There is no antidote for toluene diisocyanate. Treatment consists of bronchodilators and respiratory and cardiovascular support.

Decontamination Area

Unless previously decontaminated, all patients suspected of contact with toluene diisocyanate liquid and all victims with skin or eye irritation require decontamination as described below. All other patients may be transferred immediately to the Critical Care Area.

Be aware that use of protective equipment by the provider may cause fear in children, resulting in decreased compliance with further management efforts.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants absorbed through the skin. Also emergency room personnel should examine children's mouths because of the frequency of hand-to-mouth activity among children.

ABC Reminders

Evaluate and support airway, breathing, and circulation. In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, surgically create an airway.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Toluene diisocyanate poisoning is not known to pose additional risk during the use of bronchial or cardiac sensitizing agents. Administer corticosteroids as indicated to patients who have persistent wheezing or hypersensitivity pneumonitis.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Patients who are comatose, hypotensive, or have seizures or ventricular arrhythmias should be treated in the conventional manner.

Basic Decontamination

Patients who are able and cooperative may assist with their own decontamination. Remove and double-bag contaminated clothing and all personal belongings.

Flush exposed skin and hair with water for 2 to 3 minutes (preferably under a shower), then wash thoroughly with mild soap. Rinse thoroughly with water.

Use caution when flushing a child's skin to avoid the complication of hypothermia. Use blankets to keep children warm after decontamination.

Flush exposed eyes with plain water or saline for at least 15 minutes. Remove contact lenses if easily removable without additional trauma to the eye. If a corrosive material is present or if pain or injury is evident, continue irrigation while transporting the patient to the Critical Care Area.

In cases of ingestion, **do not induce emesis**. If the victim is alert, asymptomatic, and has a gag reflex, administer a slurry of activated charcoal at 1 gm/kg (usual adult dose 60–90 g, child dose 25–50 g) if it has not already been administered. A soda can and a straw may be of assistance when offering charcoal to a child.

Victims who are conscious and able to swallow should be given 4 to 8 ounces of milk or water (not to exceed 15 mL/kg in a child) if it has not been given previously (see *Critical Care Area* below for more information on ingestion exposure).

Critical Care Area

Be certain that appropriate decontamination has been carried out (see *Decontamination Area* above).

ABC Reminders

Evaluate and support airway, breathing, and circulation as in ABC Reminders above under *Decontamination Zone*. Establish intravenous access in seriously ill patients if this has not been done previously. Continuously monitor cardiac rhythm.

Patients who are comatose, hypotensive, or have seizures or cardiac arrhythmias should be treated in the conventional manner.

Inhalation Exposure

Administer supplemental oxygen by mask to patients who have respiratory symptoms. Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. Cardiac sensitizing agents may be appropriate; however, the use of cardiac sensitizing agents after exposure to certain chemicals may pose enhanced risk of cardiac arrhythmias (especially in the elderly). Toluene diisocyanate poisoning is not known to pose additional risk during the use of bronchial or cardiac sensitizing agents. Administer corticosteroids as indicated to patients who have persistent wheezing or hypersensitivity pneumonitis.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Skin Exposure

If the skin was in contact with liquid toluene diisocyanate, chemical burns may occur; treat as thermal burns.

Because of their larger surface area:body weight ratio, children are more vulnerable to toxicants affecting the skin.

Eye Exposure

Continue irrigation for at least 15 minutes. Test visual acuity. Examine the eyes for corneal damage and treat appropriately. Immediately consult an ophthalmologist for patients who have corneal injuries.

Ingestion Exposure

Do not induce emesis.

If the victim is alert, asymptomatic, and has a gag reflex, administer a slurry of activated charcoal at 1 gm/kg (usual adult dose 60–90 g, child dose 25–50 g) if it has not already been administered. A soda can and a straw may be of assistance when offering charcoal to a child.

Victims who are conscious and able to swallow should be given 4 to 8 ounces of milk or water (not to exceed 15 mL/kg in a child) if it has not been given previously.

Consider endoscopy to evaluate the extent of gastrointestinal-tract injury. Extreme throat swelling may require endotracheal intubation or cricothyriodotomy. Gastric lavage is useful in certain

circumstances to remove caustic material and prepare for endoscopic examination. Consider gastric lavage with a small nasogastric tube if: (1) a large dose has been ingested; (2) the patient's condition is evaluated within 30 minutes; (3) the patient has oral lesions or persistent esophageal discomfort; and (4) the lavage can be administered within one hour of ingestion. Care must be taken when placing the gastric tube because blind gastric-tube placement may further injure the chemically damaged esophagus or stomach.

Because children do not ingest large amounts of corrosive materials, and because of the risk of perforation from NG intubation, lavage is discouraged in children unless performed under endoscopic guidance.

Toxic vomitus or gastric washings should be isolated, e.g., by attaching the lavage tube to isolated wall suction or another closed container.

Antidotes and Other Treatments

There is no antidote for toluene diisocyanate. Treatment is supportive of respiratory function.

Laboratory Tests

Routine laboratory studies for all exposed patients include CBC, glucose, and electrolyte determinations. Patients who have respiratory complaints may require pulse oximetry (or ABG measurements), chest radiography, and peak-flow spirometry.

Disposition and Follow-up

Consider hospitalizing patients who have histories of significant inhalation exposure and are symptomatic (e.g., chest tightness or wheezing) or who have ingested toluene diisocyanate.

Delayed Effects

Toluene diisocyanate-induced bronchospasm can occur 4 to 8 hours after inhalation exposure.

Patient Release

Patients who remain asymptomatic for 8 to 12 hours after exposure may be discharged with instructions to seek medical care promptly if symptoms develop (see the *Toluene Diisocyanate—Patient Information Sheet* below).

Follow-up

Obtain the name of the patient's primary care physician so that the hospital can send a copy of the ED visit to the patient's doctor.

If significant inhalation or skin contact has occurred, monitor pulmonary function. Persons who have wheezing episodes may be permanently sensitized and may need to be removed from future

work with toluene diisocyanate; patients should consult an occupational medicine or pulmonary specialist before returning to work that entails exposure to toluene diisocyanate.

Toluene diisocyanate poisoning can cause permanent alterations of nervous system function, including problems with memory, learning, thinking, sleeping, personality changes, depression, headache, and sensory and perceptual changes. Patients who have shown symptoms such as seizures, convulsions, headache or confusion should be followed for permanent nervous system dysfunction with neurobehavioral toxicity testing.

Patients who have corneal injuries should be reexamined within 24 hours.

Reporting

If a work-related incident has occurred, you may be legally required to file a report; contact your state or local health department.

Other persons may still be at risk in the setting where this incident occurred. If the incident occurred in the workplace, discussing it with company personnel may prevent future incidents. If a public health risk exists, notify your state or local health department or other responsible public agency. When appropriate, inform patients that they may request an evaluation of their workplace from OSHA or NIOSH. See Appendices III and IV for a list of agencies that may be of assistance.

Toluene Diisocyanate
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to toluene diisocyanate.

What is Toluene diisocyanate?
Toluene diisocyanate is a pale-yellow liquid with a strong, sharp odor. It is used mainly to make polyurethane foams and coatings.

What immediate health effects can be caused by exposure to toluene diisocyanate?
Low levels of toluene diisocyanate in the air can irritate the eyes, nose, throat, and lungs and cause cough, chest tightness, and shortness of breath. Higher levels can cause a build-up of fluid in the lungs, which may cause death. If liquid toluene diisocyanate comes in contact with the skin or eyes, it can cause severe burns. Generally, the more serious the exposure, the more severe the symptoms.

Can toluene diisocyanate poisoning be treated?
There is no antidote for toluene diisocyanate, but its effects can be treated and most exposed persons get well. Seriously exposed persons may need to be hospitalized.

Are any future health effects likely to occur?
After exposure to toluene diisocyanate, certain persons can develop allergies in which even small exposures to toluene diisocyanate or other irritants can trigger asthma attacks or shortness of breath. Therefore, it is important to tell your doctor that you have been exposed to toluene diisocyanate. After a serious exposure or repeated exposures, toluene diisocyanate can cause permanent lung damage. Toluene diisocyanate poisoning can cause permanent alterations of nervous system function, including problems with memory, learning, thinking, sleeping, personality changes, depression, headache, and sensory and perceptual changes.

What tests can be done if a person has been exposed to toluene diisocyanate?
Specific tests for the presence of toluene diisocyanate in blood are not available. If a severe exposure has occurred, respiratory function tests and a chest x-ray may show whether damage has been done to the lungs. Patients who have problems with memory, concentration, or personality changes or who experienced seizures or convulsions when exposed to toluene diisocyanate may need neurobehavioral toxicity testing. Testing is not needed in every case.

Where can more information about toluene diisocyanate be found?
More information about toluene diisocyanate can be obtained from your regional poison control center; your state, county, or local health department; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor, or a clinic in your area that specializes in occupational and environmental health. If the exposure happened at work, you may wish to discuss it with your employer, the Occupational Safety and Health Administration (OSHA), or the National Institute for Occupational Safety and Health (NIOSH). Ask the person who gave you this form for help in locating these telephone numbers.

Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow *only* the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:

- coughing, wheezing, difficulty breathing, shortness of breath, or chest pain
- headache or lightheadedness
- increased pain or a discharge from your eyes
  increased redness or pain or a pus-like discharge in the area of a skin burn

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.
[ ] Call for an appointment with Dr. _____ in the practice of _____.
When you call for your appointment, please say that you were treated in the Emergency Department at _____ Hospital by _____ and were advised to be seen again in _____ days.
[ ] Return to the Emergency Department/ _____ Clinic on (date) _____at _____ AM/PM for a follow-up examination.
[ ] Do not perform vigorous physical activities for 1 to 2 days.
[ ] You may resume everyday activities including driving and operating machinery.
[ ] Do not return to work for _____ days.
[ ] You may return to work on a limited basis. See instructions below.
[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.
[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.
[ ] Avoid taking the following medications: _____
[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: ___
_____
_____
[ ] Other instructions: _____
_____
_____

- Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.

- You or your physician can get more information on the chemical by contacting: _____ _____ or _____, or by checking out the following Internet Web sites: _____; _____.

Signature of patient _____ Date _____

Signature of physician _____ Date _____

1,1,1-Trichloroethane (CH_3CCl_3)
CAS 71-55-6; UN 2831

Synonyms include α-T, α-trichloroethane, chloroethene, methylchloroform, methyltrichloromethane, TCEA, and trichloromethylmethane.

Persons exposed only to 1,1,1-trichloroethane vapor pose no risk of secondary contamination. Persons whose skin or clothing is contaminated with liquid 1,1,1-trichloroethane can contaminate response personnel by direct contact or through off-gassing of vapor.

1,1,1-Trichloroethane is a colorless, volatile, nonflammable liquid with a sweet, chloroform-like odor. The vapor is heavier than air and can collect to toxic levels in poorly ventilated spaces. Odor generally provides adequate warning of hazardous concentrations.

1,1,1-Trichloroethane is rapidly absorbed if inhaled or ingested. Dermal absorption is slow and does not contribute significantly to systemic toxicity.
1,1,1-Trichloroethane crosses the placenta and is excreted in breast milk.

Description

1,1,1-Trichloroethane is a colorless, nonflammable liquid. It evaporates quickly and has a sweet, chloroform-like odor. It has only negligible solubility in water, but it is miscible in most organic solvents. It can explode if concentrations of 7.5% to 15.5% in air are ignited by a spark or flame. At temperatures higher than 500 °F (>260 °C), 1,1,1-trichloroethane decomposes to form hydrogen chloride and trace amounts of phosgene, which are severe pulmonary irritants. 1,1,1-Trichloroethane should be stored at ambient temperature in a well-ventilated area away from metals, open flames, and moisture.

Routes of Exposure

Inhalation

Inhalation is the most important route of exposure, and 1,1,1-trichloroethane is readily absorbed from the lungs. The odor threshold for 1,1,1-trichloroethane is 44 ppm, which is about one-eighth of the OSHA PEL. Odor is an adequate warning of hazardous concentrations. The vapor is heavier than air and can collect to toxic levels in poorly ventilated or low-lying spaces. A one hour exposure to 1,000 ppm can cause dizziness and loss of coordination. Central nervous system (CNS) depression generally begins at 5,000 ppm. Levels of 10,000 ppm or higher can cause sedation, hypotension, cardiac dysrhythmia, coma, and death.

Children exposed to the same levels of 1,1,1-trichloroethane vapor as adults may receive a larger dose because they have greater lung surface area:body weight ratios and increased minute volumes:weight ratios. In addition, they may be exposed to higher levels than adults in the same location because of their short stature and the higher levels of 1,1,1-trichloroethane vapor found nearer to the ground.

Skin/Eye Contact

Transient chemical conjunctivitis can result from exposure to high levels of vapor or direct contact with liquid 1,1,1-trichloroethane. The liquid is mildly irritating to the skin. Because absorption across intact skin is slow, systemic toxicity is unlikely unless liquid on the skin is prevented from evaporating by heavy clothing or other impermeable covering.

Children are more vulnerable to toxicants affecting the skin because of their relatively larger surface area:body weight ratio.

Ingestion

Gastrointestinal absorption is rapid and can cause systemic effects similar to those seen with inhalation exposure.

Sources/Uses

1,1,1-Trichloroethane is a synthetic chemical that was first developed as a safer substitute for other chlorinated and flammable solvents. The most common method for industrial production of 1,1,1-trichloroethane is the reaction of hydrochloric acid with vinyl chloride to obtain 1,1-dichloroethane, followed by either thermal or photochemical chlorination. In industry, it has been widely used as a solvent and as a cold cleaning and vapor degreasing agent. It was used in many household products, including aerosol sprays, spot cleaners, glues, and lubricants. While it is no longer used for such products, it is likely that some of these may still be found in homes, garages, workshops, and hazardous waste sites. It has been intentionally abused for its CNS-intoxicating effects. At one time, it was used as an anesthetic agent. Because 1,1,1-trichloroethane damages the ozone layer, production in the United States was phased out in 1996, but supplies as a raw material will be available until the year 2002.

Standards and Guidelines

OSHA PEL (permissible exposure limit) = 350 ppm (averaged over an 8-hour workshift)

NIOSH IDLH (immediately dangerous to life or health) = 700 ppm

AIHA ERPG-2 (emergency response planning guideline) (maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without

experiencing or developing irreversible or other serious health effects or symptoms which could impair an individual's ability to take protective action) = 700 ppm.

Physical Properties

Description: colorless, nonflammable liquid with a sweet, chloroform-like odor

Warning properties: odor detectable at 44 ppm; generally adequate warning to avoid acute, high-level exposure.

Molecular weight: 133.40 daltons

Boiling point (760 mm Hg): 165.38 °F (74.1 °C)

Freezing point: -23 °F (-30.56 °C)

Specific gravity: 1.34 at 68 °F (20 °C) (water = 1)

Vapor pressure: 100 mm Hg at 68 °F (20 °C)

Gas density: 4.63 (air = 1)

Water solubility: Negligible, 0.4% at 68 °F (20 °C)

Flammability: considered nonflammable and usually requires preheating before it will burn. Under extraordinary circumstances of high-energy ignition (e.g., blasting cap) or a high-oxygen atmosphere, the vapors can be ignited and will burn or explode.

Flammable range: 7.5% to 15.5% (concentration in air).

Incompatibilities

1,1,1-Trichloroethane can decompose to form hydrogen chloride gas when it comes in contact with strong caustics, strong oxidizers, or chemically active metals like zinc, sodium or potassium, or aluminum and magnesium powders. 1,1,1-Trichloroethane reacts slowly with water to form hydrochloric acid and forms trace amounts of phosgene when ignited or burned above 260 °C.

Health Effects

1,1,1-Trichloroethane is irritating to the skin and eyes. Inhalation or ingestion of 1,1,1-trichloroethane can produce headache, dizziness, and lack or coordination (at moderate exposure levels, >1,000 ppm) and stupor or coma (at high exposure levels, >10,000 ppm).

CNS and respiratory depression or cardiac dysrhythmia (from high-level exposures) can result in death. Other effects include hypotension, nausea, vomiting, and diarrhea.

1,1,1-Trichloroethane sensitizes the heart to epinephrine, making it more susceptible to epinephrine-induced arrhythmias.

The effects of 1,1,1-trichloroethane on the CNS are thought to be due to direct interaction of 1,1,1-trichloroethane with proteinaceous components of membranes. 1,1,1-Trichloroethane crosses the placenta and is excreted in breast milk.

Acute Exposure

1,1,1-Trichloroethane is thought to depress the CNS via a solvent effect on lipids and protein components of neural membranes. It sensitizes the heart to epinephrine, making it more susceptible to epinephrine-induced arrhythmias. Direct exposure to liquid 1,1,1-trichloroethane degreases the skin, causing redness, blistering, and scaling.

Children do not always respond to chemicals in the same way that adults do. Different protocols for managing their care may be needed.

CNS

1,1,1-Trichloroethane causes concentration-related CNS depression. Symptoms can include euphoria, headache, dizziness, malaise, hallucinations or distorted perceptions, behavioral changes, ataxia, seizures, sedation, coma, cerebral edema, and death. CNS effects resolve quickly when the victim is removed from further exposure.

Cardiovascular

Inhalation of high concentrations can cause hypotension and dysrhythmia. 1,1,1-Trichloroethane sensitizes the heart to epinephrine. Physical exertion, stress, or other stimuli resulting in epinephrine release can trigger dysrhythmia and result in sudden death.

Gastrointestinal

Nausea, vomiting, and diarrhea can occur following ingestion or inhalation of a high dose (3,000–10,000 ppm) of

1,1,1-trichloroethane. Ingestion can produce a burning sensation in the mouth, throat, and esophagus.

Respiratory

Inhalation of 1,1,1-trichloroethane can lead to respiratory arrest due to CNS depression and may also cause pulmonary edema.

Children may be more vulnerable because of relatively increased minute ventilation per kg and failure to evacuate an area promptly when exposed.

Hydrocarbon pneumonitis may be a problem in children.

Hepatic

Although there are no reports of toxicity at low concentrations, hepatic lipidosis, macronodular cirrhosis, and transient hepatitis have been reported following high-level inhalation exposures.

Dermal

Direct skin exposure to liquid 1,1,1-trichloroethane can cause a burning sensation, erythema, and blistering.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants affecting the skin.

Ocular

Exposure to 1,1,1-trichloroethane vapor (>500 ppm for 1 hour) and direct contact with the liquid can cause irritation or transient conjunctivitis.

Potential Sequelae

Some survivors of severe, acute exposures (e.g., involving coma or respiratory arrest) suffer brain or cardiac damage due to hypoxia.

Chronic Exposure

Chronic exposure can cause lethargy, impaired memory, and impaired balance. Chronic skin exposure can cause irritant contact dermatitis.

Chronic exposure may be more serious for children because of their potential longer latency period.

Carcinogenicity

1,1,1-Trichloroethane has been assessed for carcinogenic effects; the International Agency for Research on Cancer (IARC) has assigned 1,1,1-trichloroethane to Group 3 (not classifiable as to carcinogenicity in humans) and the Environmental Protection Agency (EPA) has assigned it to Group D (not classifiable as to carcinogenicity in humans) based on inadequate evidence of cancer for humans and experimental animals.

Reproductive and Developmental Effects

1,1,1-Trichloroethane is not included in *Reproductive and Developmental Toxicants,* a 1991 report published by the U.S. General Accounting Office (GAO) that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences. Adverse reproductive or developmental effects in humans have not been reported and animal studies do not suggest that 1,1,1-trichloroethane is a reproductive or developmental toxicant although it crosses the placenta and is excreted in breast milk.

Prehospital Management

Victims exposed only to 1,1,1-trichloroethane vapor pose no risk of secondary contamination to rescuers. Victims whose skin or clothing is contaminated with liquid 1,1,1-trichloroethane can contaminate rescuers by direct contact or through off-gassing of vapor. Vomitus from patients who have ingested 1,1,1-trichloroethane can also off-gas the vapor.

1,1,1-Trichloroethane is irritating to the skin and eyes. Inhalation or ingestion of 1,1,1-trichloroethane can lead to headache, dizziness, lack of coordination, stupor, coma, CNS and respiratory depression, and cardiac dysrhythmia. Other effects include hypotension, nausea, vomiting, and diarrhea.

There is no antidote for 1,1,1-trichloroethane. Treatment consists of support of respiratory and cardiovascular functions.

Hot Zone

Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if the rescuers have not been trained in its use, call for assistance from a local or regional HAZMAT team or other properly equipped response organization.

Rescuer Protection

1,1,1-Trichloroethane vapor is readily absorbed by inhalation and is a respiratory tract irritant. The liquid is a mild skin irritant with minimal absorption through the skin.

Respiratory protection: Positive-pressure, self-contained breathing apparatus (SCBA) is recommended in response situations that involve exposure to potentially unsafe levels of 1,1,1-trichloroethane vapor.

Skin protection: Chemical-protective clothing is not generally required when only vapor exposure is expected: 1,1,1-Trichloroethane vapor is only mildly irritating and is not absorbed well through the skin. Chemical-protective clothing is recommended when extensive skin contact with the liquid might occur.

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. Provide supplemental oxygen if cardiopulmonary compromise is suspected. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible.

Victim Removal

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk should be removed on backboards or gurneys. If these are not available, carefully carry or drag victims to safety.

Consider appropriate management of chemically contaminated children, such as measures to reduce separation anxiety if a child is separated from a parent or other adult.

Care should be taken that victims (particularly children) do not have problems due to 1,1,1-trichloroethane being heavier than air and settling in pockets close to the ground.

Decontamination Zone

Patients exposed only to 1,1,1-trichloroethane vapor who have no skin or eye irritation may be transferred immediately to the Support Zone. Other patients will require decontamination as described below.

Rescuer Protection

If exposure levels are determined to be safe, decontamination may be conducted by personnel wearing a lower level of protection than that worn in the Hot Zone (described above).

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. Stabilize the cervical spine with a collar and a backboard if trauma is suspected. Administer supplemental oxygen as required. Assist ventilation with a bag-valve-mask device if necessary.

Basic Decontamination

Victims who are able may assist with their own decontamination. Quickly remove and double-bag contaminated clothing and personal belongings.

Flush exposed skin and hair with water for 3 to 5 minutes. Wash with mild soap and water (preferably under a shower). Rinse thoroughly with water. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Flush exposed eyes with plain water or saline for at least 15 minutes. Remove contact lenses if easily removable without additional trauma to the eye. If a corrosive material is suspected or if pain or injury is evident, continue irrigation while transferring the victim to the Support Zone.

In cases of ingestion, **do not induce emesis.** If the victim is alert, asymptomatic, and has a gag reflex, administer a slurry of activated charcoal at 1 gm/kg (usual adult dose 60–90 g, child dose 25–50 g).

A soda can and straw may be of assistance when offering charcoal to a child.

Consider appropriate management of chemically contaminated children at the exposure site. Provide reassurance to the child during decontamination, especially if separation from a parent occurs.

Transfer to Support Zone

As soon as basic decontamination is complete, move the victim to the Support Zone.

Support Zone

Be certain that victims have been decontaminated properly (see *Decontamination Zone* above). Victims who have undergone decontamination or have been exposed only to vapor generally pose no serious risks of secondary contamination. In such cases, Support Zone personnel require no specialized protective gear.

ABC Reminders

Quickly access for a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Ensure adequate respiration and pulse. Administer supplemental oxygen as required and establish intravenous access if necessary. Place on a cardiac monitor.

Additional Decontamination

Continue irrigating exposed skin and eyes, as appropriate.

In cases of ingestion, **do not induce emesis.** If activated charcoal has not been given previously and the victim is alert, asymptomatic, and has a gag reflex, administer a slurry of activated charcoal at 1 gm/kg (usual adult dose 60–90 g, child dose 25–50 g). A soda can and straw may be of assistance when offering charcoal to a child.

Advanced Treatment

In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, perform cricothyroidotomy if equipped and trained to do so.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. However, the use of sympathomimetic agents such as epinephrine and isoproterenol could precipitate fatal dysrhythmias and should be avoided. Selective beta-2 agonists would be preferred, but clinical reports of their use are lacking. Theophylline derivatives have not been studied. Use all catecholamines with caution because of the enhanced risk of cardiac arrhythmias.

Patients who are comatose, hypotensive, or are having seizures or cardiac arrhythmias should be treated according to advanced life support (ALS) protocols.

Transport to Medical Facility

Only decontaminated patients or patients not requiring decontamination should be transported to a medical facility. "Body bags" are not recommended.

Report to the base station and the receiving medical facility the condition of the patient, treatment given, and estimated time of arrival at the medical facility.

If 1,1,1-trichloroethane has been ingested, prepare the ambulance in case the patient vomits toxic material. Have ready several towels and open plastic bags to quickly clean up and isolate vomitus.

Multi-Casualty Triage

Consult with the base physician or the regional poison control center for advice regarding triage of multiple victims

Patients with evidence of significant inhalation exposure such as CNS disruption, breathing difficulties, or cardiac dysrhythmia and patients who ingested 1,1,1-trichloroethane should be transported to a medical facility for evaluation. Others may be discharged from the scene after their names, addresses, and telephone numbers are recorded. Those discharged should be advised to seek medical care promptly if symptoms develop (see *Patient Information Sheet* below).

Emergency Department Management

Patients exposed only to 1,1,1-trichloroethane vapor pose no risk of secondary contamination to rescuers. Patients whose skin or clothing is contaminated with liquid 1,1,1-trichloroethane can contaminate rescuers by direct contact or through off-gassing of vapor. Vomitus from patients who have ingested 1,1,1-trichloroethane can also off-gas the vapor.

1,1,1-Trichloroethane is irritating to the skin and eyes. Inhalation or ingestion of 1,1,1-trichloroethane can lead to headache, dizziness, lack of coordination, stupor, coma, CNS and respiratory depression, and cardiac dysrhythmia. Other effects include hypotension, nausea, vomiting, and diarrhea.

There is no antidote for 1,1,1-trichloroethane. Treatment consists of support of respiratory and cardiovascular functions.

Decontamination Area

Unless previously decontaminated, all patients suspected of contact with liquid 1,1,1-trichloroethane and all victims with skin or eye irritation require decontamination as described below. All other patients may be transferred to the Critical Care area.

Be aware that use of protective equipment by the provider may cause fear in children, resulting in decreased compliance with further management efforts.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants affecting the skin. Also, emergency room personnel should examine children's mouths because of the frequency of hand-to-mouth activity among children.

ABC Reminders

Evaluate and support airway, breathing, and circulation. In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, surgically create an airway. Provide supplemental oxygen if cardiopulmonary compromise is suspected.

Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. However, the use of sympathomimetic agents such as epinephrine and isoproterenol could precipitate fatal dysrhythmias and should be avoided. Selective beta-2 agonists would be preferred, but clinical reports of

their use are lacking. Theophylline derivatives have not been studied. Use all catecholamines with caution because of the enhanced risk of cardiac arrhythmias.

Patients who are comatose, hypotensive, or have seizures or ventricular arrhythmias should be treated in the conventional manner. Avoid sympathomimetics or catecholamines or use them with caution. Beta-blockers may be more effective than lidocaine in cases of prolonged or resistant arrhythmias.

Basic Decontamination

Patients who are able may assist with their own decontamination. Remove and double-bag contaminated clothing and personal belongings.

Flush exposed skin and hair with water for 3 to 5 minutes. Wash with mild soap and water (preferably under a shower). Rinse thoroughly with water. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Flush exposed eyes with plain water or saline for at least 15 minutes. Remove contact lenses if easily removable without additional trauma to the eye. If a corrosive material is suspected or if pain or injury is evident, continue irrigation while transferring the victim to the Critical Care Area.

In cases of ingestion, **do not induce emesis.** If activated charcoal has not been given previously and the victim is alert, asymptomatic, and has a gag reflex, administer a slurry of activated charcoal at 1 gm/kg (usual adult dose 60–90 g, child dose 25–50 g). A soda can and straw may be of assistance when offering charcoal to a child.

Critical Care Area

Be certain that appropriate decontamination has been carried out (see *Decontamination Area* above).

ABC Reminders

Evaluate and support airway, breathing, and circulation as in *ABC Reminders* above. Establish intravenous access in seriously ill patients if this has not been done previously. Continuously monitor cardiac rhythm.

Patients who are comatose, hypotensive, or have seizures or ventricular arrhythmias should be treated in the conventional manner. Avoid sympathomimetics or catecholamines or use them with caution. Beta-blockers may be more effective than lidocaine in cases of prolonged or resistant dysrhythmias.

Inhalation Exposure

Administer supplemental oxygen by mask to patients who have respiratory complaints. Treat patients who have bronchospasm with aerosolized bronchodilators. The use of bronchial sensitizing agents in situations of multiple chemical exposures may pose additional risks. Consider the health of the myocardium before choosing which type of bronchodilator should be administered. However, the use of sympathomimetic agents such as epinephrine and isoproterenol could precipitate fatal dysrhythmias and should be avoided. Selective beta-2 agonists would be preferred, but clinical reports of their use are lacking. Theophylline derivatives have not been studied. Use all catecholamines with caution because of the enhanced risk of cardiac arrhythmias.

Skin Exposure

If the skin was in prolonged contact with liquified 1,1,1-trichloroethane, chemical burns might be present; treat these as thermal burns.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants absorbed through the skin.

Eye Exposure

Ensure that adequate eye irrigation has been completed. Examine the eyes for corneal damage and treat appropriately. Immediately consult an ophthalmologist for patients who have corneal injuries.

Ingestion Exposure

Do not induce emesis.

If the patient is alert, administer a slurry of activated charcoal at 1 gm/kg (usual adult dose 60–90 g, child dose 25–50 g), if not done previously. A soda can and straw may be of assistance when offering charcoal to a child.

Consider endoscopy to evaluate the extent of gastrointestinal tract injury. Extreme throat swelling may require endotracheal intubation or cricothyroidotomy. Gastric lavage is useful in certain circumstances to remove toxic material and prepare for endoscopic examination. Consider gastric lavage with a small nasogastric tube if: (1) a large dose has been ingested; (2) the patient's condition is evaluated within 30 minutes; (3) the patient has oral lesions or persistent esophageal discomfort; and (4) the lavage can be administered within 1 hour of ingestion. Care must be taken when placing the gastric tube because blind gastric-tube placement may further injure the chemically damaged esophagus or stomach.

Because children do not ingest large amounts of toxic materials, and because of the risk of perforation from nasogastric intubation, lavage is discouraged in children unless performed under endoscopic guidance.

Toxic vomitus or gastric washings should be isolated, e.g., by attaching the lavage tube to isolated wall suction or another closed container.

Antidotes and Other Treatments

There is no antidote for 1,1,1-trichloroethane. Treatment is supportive of respiratory and cardiovascular functions.

Laboratory Tests

The diagnosis of acute 1,1,1-trichloroethane toxicity is primarily clinical, based on symptoms of CNS disruption or respiratory distress. However, laboratory testing is useful for monitoring the patient and evaluating complications. Routine laboratory studies for seriously exposed patients include CBC, glucose, electrolytes, and liver enzyme tests. Patients who have respiratory complaints should be evaluated with pulse oximetry or ABG measurements and chest radiography.

1,1,1-Trichloroethane levels in blood or expired air are not clinically useful but can be used to document an exposure. Exposure to 1,1,1-trichloroethane is also suggested by detection of trichloroethanol or trichloroacetic acid in blood or urine; these tests are not specific for 1,1,1-trichloroethane, however.

Disposition and Follow-up

Consider hospitalizing patients who have had significant inhalation exposure (e.g., with loss of consciousness) and patients who have ingested significant amounts of 1,1,1-trichloroethane.

Patient Release

Patients who have not experienced alterations in mental status or had initially mild symptoms and are asymptomatic 6 to 8 hours later may be discharged. Discharged patients should be instructed to seek medical care promptly if symptoms develop (see the *1,1,1-Trichloroethane—Patient Information Sheet* below).

Follow-up

Obtain the name of the patient's primary care physician so that the hospital can send a copy of the ED visit to the patient's doctor.

Follow-up laboratory evaluation of hepatic function should be arranged for severely exposed patients. Neurologic examination for post-hypoxic injury is recommended in cases of severe exposure. Patients who have skin burns or corneal damage should be re-examined within 24 hours.

Reporting

If a work-related incident has occurred, you might be legally required to file a report; contact your state or local health department.

Other persons might still be at risk at the place where this incident occurred. If the incident occurred in the workplace, discussing it with company personnel might prevent future incidents. If a public health risk exists, notify your state or local health department or other responsible public agency. When appropriate, inform patients that they may request an evaluation of their workplace from the Occupational Safety and health Administration (OSHA) or the National Institute for Occupational Safety and Health (NIOSH).

1,1,1-Trichloroethane (CH_3CCl_3)
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to 1,1,1-trichloroethane.

What is 1,1,1-trichloroethane?
1,1,1-Trichloroethane is a colorless, volatile, nonflammable liquid with a sweet, chloroform-like odor. It is used to make other chemicals. It has been used to clean grease from metal parts. It used to be found in many household products, such as spot cleaners and glues. You may still have some of these products in your home, garage or workshop, although use of 1,1,1-trichloroethane has been phased out by the EPA because it damages the ozone layer. Sometimes people intentionally inhale it to get high.

What immediate health effects can be caused by exposure to 1,1,1-trichloroethane?
Breathing or swallowing 1,1,1-trichloroethane can cause lightheadedness, dizziness, blurred vision, a feeling of excitement, nausea, and vomiting. Breathing or swallowing large amounts can cause irregular heart beat, fainting, coma, and even death. If the skin has been in contact with high levels of 1,1,1-trichloroethane for a long time, a skin rash or burns might develop. Generally, the more serious the exposure, the more severe the symptoms.

Can 1,1,1-trichloroethane poisoning be treated?
There is no antidote for 1,1,1-trichloroethane, but its effects can be treated and most exposed persons recover completely. Persons who have swallowed or inhaled large amounts of 1,1,1-trichloroethane might need to be hospitalized.

Are any future health effects likely to occur?
Delayed or long-term effects generally do not occur from single exposures to 1,1,1-trichloroethane. A high-dose exposure, or an exposure over many years, can affect the brain, skin, liver, and heart.

What tests can be done if a person has been exposed to 1,1,1-trichloroethane?
Specific tests for the presence of 1,1,1-trichloroethane breakdown products in blood and urine are available, but they are not generally useful to your doctor. If a severe exposure has occurred, blood and other tests might show whether the heart or liver has been damaged. Testing is not needed in every case.

Where can more information about 1,1,1-trichloroethane be found?
More information about 1,1,1-trichloroethane can be obtained from your regional poison control center; the state, county, or local health department; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in occupational and environmental health. If the exposure happened at work, you may wish to discuss it with your employer, the Occupational Safety and Health Administration (OSHA), or the National Institute for Occupational Safety and Health (NIOSH). Ask the person who gave you this form for help in locating these telephone numbers.

Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow *only* the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:

- Sudden severe weakness, fainting, or dizziness
- irregular heartbeat
- shortness of breath, coughing, or wheezing
- increased pain or discharge from injured eyes

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.
[ ] Call for an appointment with Dr. _____ in the practice of _____. When you call for your appointment, please say that you were treated in the Emergency Department at _____ Hospital by _____ and were advised to be seen again in _____ days.
[ ] Return to the Emergency Department/ _____ Clinic on (date) _____at __ _____ AM/PM for a follow-up examination.
[ ] Do not perform vigorous physical activities for 1 to 2 days.
[ ] You may resume everyday activities including driving and operating machinery.
[ ] Do not return to work for _____ days.
[ ] You may return to work on a limited basis. See instructions below.
[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.
[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.
[ ] Avoid taking the following medications: _____
[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: __ _____
_____
[ ] Other instructions: _____
_____
_____

- Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.

- You or your physician can get more information on the chemical by contacting: _____ _____ or _____, or by checking out the following Internet Web sites: _____; _____.

Signature of patient _____ Date _____

Signature of physician _____ Date _____

Trichloroethylene ($Cl_2C=CHCl$)
CAS 79-01-6; UN 1710

Synonyms include acetylene trichloride, ethylene trichloride, ethinyl trichloride, trichloroethene, TCE, and tri.

- **Persons exposed only to trichloroethylene vapor do not pose significant risks of secondary contamination. Persons whose clothing or skin is contaminated with liquid trichloroethylene can cause secondary contamination by direct contact or through off-gassing vapor.**
- **Trichloroethylene is a colorless liquid at room temperature with a somewhat sweet chloroform-like odor and sweet burning taste. It is flammable at high temperatures. At temperatures >600 °F, it forms hydrogen chloride and phosgene, which are serious pulmonary irritants.**
- **When trichloroethylene contacts alkali or thermally decomposes, it may form dichloroacetylene, an explosive and neurotoxic compound. Odor generally provides inadequate warning of hazardous concentrations.**
- **Trichloroethylene is absorbed readily after inhalation and ingestion, and to a lesser extent, through the skin. Trichloroethylene can cross the placenta and has been detected in breast milk.**

Description

At room temperature, trichloroethylene is a clear, colorless liquid with a sweet, chloroform-like odor. It is volatile, producing potentially toxic concentrations at room temperature. It is nearly insoluble in water, but miscible with most organic solvents. Industrial grade trichloroethylene contains small amounts of stabilizers (0.1% by weight) such as epichlorohydrin, which may increase the irritant effects. At elevated temperatures and in the presence of alkali, trichloroethylene may form more toxic compounds such as phosgene, a serious pulmonary irritant, or dichloroacetylene, a neurotoxin. Since trichloroethylene decomposes photolytically, it should be stored in cans or dark glass bottles to minimize decomposition. Storage areas should be cool, well ventilated, flame-proof, and shielded from direct sunlight, high-temperature surfaces, or sparks.

Routes of Exposure

Inhalation

Trichloroethylene vapor is readily absorbed from the lungs, and inhalation is the main route of exposure. The recognition odor threshold of trichloroethylene is 110 ppm which is slightly higher than the OSHA PEL (100 ppm); thus, **odor generally provides an inadequate indication of hazardous concentrations**. Trichloroethylene is heavier than air and may cause asphyxiation in poorly ventilated or enclosed spaces and in low-lying areas.

Children exposed to the same levels of trichloroethylene vapor as adults may receive a larger dose because they have greater lung surface area:body weight ratios and increased minute volumes:weight ratios. In addition, they may be exposed to higher levels than adults in the same location because of their short stature and the higher levels of trichloroethylene vapor found nearer to the ground.

Skin/Eye Contact

Exposure to liquid trichloroethylene can result in skin irritation and minor corneal injury. Trichloroethylene is absorbed through intact skin, although not in quantities sufficient to cause systemic toxicity.

Children are more vulnerable to toxicants affecting the skin because of their relatively larger surface area:body weight ratio.

Ingestion

Gastrointestinal absorption is rapid and substantial. Ingestion can produce significant CNS depression. Pulmonary aspiration can cause chemical pneumonitis.

Sources/Uses

Trichloroethylene is manufactured either by oxychlorination of ethylene dichloride or by direct chlorination of ethylene dichloride.

Trichloroethylene has wide use as a metal degreasing agent. It is a common ingredient in cleaning agents, paints, adhesives, varnishes, and inks. In the past, it was used as a dry cleaning agent and for food extractions such as removal of caffeine from coffee. It also had limited use as an analgesic and an anesthetic agent, but is no longer used for these purposes because it is now recognized as a potential human carcinogen.

Standards and Guidelines

OSHA PEL (permissible exposure limit) = 100 ppm (averaged over an 8-hour workshift)

OSHA ceiling = 200 ppm

OSHA STEL (short-term exposure limit) = 300 ppm (5-minute exposure in any 2 hours)

NIOSH IDLH (immediately dangerous to life or health) = 1,000 ppm

AIHA ERPG-2 (emergency response planning guideline) (maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health

effects or symptoms which could impair an individual's ability to take protective action) = 500 ppm.

Physical Properties

Description: Clear, colorless liquid with a chloroform-like odor.

Warning properties: Inadequate; chloroform-like odor at 110 ppm.

Molecular weight: 131.4 daltons

Boiling point (760 mm Hg): 189 °F (87 °C)

Freezing point: -99 °F (-73 °C)

Specific gravity: 1.46 at 68 °F (20 °C) (water = 1)

Vapor pressure: 58 mm Hg at 68 °F (20 °C)

Gas density: 4.53 (air = 1)

Water solubility: minimal; 0.1% at 77 °F (25 °C)

Flammability: Flammable liquid that does not burn easily; at temperatures >600 °F (316 °C), it forms hydrogen chloride and phosgene.

Flammable range: 8% to 10.5 % (concentration in air)

Incompatibilities

Trichloroethylene reacts with strong alkalies and chemically active metals such as barium, lithium, sodium, magnesium, titanium, and beryllium.

Health Effects

Trichloroethylene is a mild skin, eye, and respiratory tract irritant. Inhalation or ingestion of trichloroethylene can produce CNS effects including headache, dizziness, lack of coordination, stupor, and coma. Respiratory depression or cardiac dysrhythmia from high-level exposures can result in death. Other effects of acute exposure include hypotension, nausea, vomiting, and diarrhea.

Trichloroethylene sensitizes the heart to epinephrine, making it more susceptible to epinephrine-induced arrhythmias. Trichloroethylene can cross the placenta and has been detected in breast milk.

Acute Exposure

Trichloroethylene is thought to depress the CNS via a solvent effect on lipids and protein components of neural membranes. It sensitizes the heart to epinephrine, making it more susceptible to epinephrine-induced arrhythmias. Direct exposure to liquid trichloroethylene degreases the skin, causing redness, blistering, and scaling. Trichloroethylene can cause respiratory and CNS depression and abnormal heart rhythm. Death may result from respiratory depression. Liver necrosis has been reported for some people exposed to fatal levels of trichloroethylene, but individuals exposed to trichloroethylene as an anesthetic showed only minimal effects on liver function.

Children do not always respond to chemicals in the same way that adults do. Different protocols for managing their care may be needed.

CNS

Trichloroethylene exposure causes concentration-related CNS effects. In the past, concentrations as high as 5,000 to 20,000 ppm were used to produce light-to moderate surgical anesthesia. Typical symptoms of exposure to lower levels of trichloroethylene (>500 ppm) include excitation, lightheadedness, headache, nausea, incoordination, and impaired ability to concentrate. At higher doses (>1,000 ppm), lack of muscle tone, decreased deep-tendon reflexes, drowsiness, dizziness, impaired gait, and stupor may develop. Death may result from respiratory depression.

Peripheral Neurologic

In a few cases, trichloroethylene exposure has been associated with peripheral and cranial nerve damage. A decomposition product of trichloroethylene, dichloroacetylene, is neurotoxic and may be responsible for the cranial nerve effects.

Cardiovascular

At near anesthetic levels of exposure, trichloroethylene may cause acute cardiovascular effects including decreased contraction of the heart's muscle fibers, disordered electrical conduction, and lowered threshold of the heart to the effects of epinephrine, potentially disrupting the heartbeat. Trichloroethylene can also cause blood vessel dilation and low blood pressure.

Respiratory

Trichloroethylene is a mild irritant to the lungs and respiratory tract; however, its thermal breakdown products, phosgene and hydrogen chloride, are severe pulmonary irritants, and phosgene is a suffocating agent. Accumulation of fluid in the lungs has been reported after severe trichloroethylene exposure; the exact role of trichloroethylene breakdown products is unknown.

Children may be more vulnerable because of relatively increased minute ventilation per kg and failure to evacuate an area promptly when exposed.

Hydrocarbon pneumonitis may be a problem in children.

Hepatic

Liver toxicity can occur after prolonged inhalation of high concentrations of trichloroethylene. Ingestion of alcohol may increase this risk. However, liver effects have not been reported in acute-duration human exposure studies, although some older case reports have provided limited evidence of liver damage.

Renal

Kidney effects have not been reported for acute-duration human exposure studies, although some older case reports have provided limited evidence of kidney damage. Minor changes in indicators of renal function have been reported for some workers occupationally exposed to trichloroethylene.

Dermal

Liquid trichloroethylene can irritate the skin. When in prolonged contact with the skin, as under tight-fitting clothing or shoes, trichloroethylene can cause chemical burns. Exfoliative dermatitis and erythema have also been reported after 2 to 5 weeks exposure to trichloroethylene. Trichloroethylene inhalation in combination with alcohol ingestion may cause a red, blotchy appearance of the face and upper portion of the body, commonly referred to as "degreaser's flush."

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants affecting the skin.

Ocular

Trichloroethylene splashed in the eye produces pain and transient eye injury with complete recovery in a few days. Exposure to high concentrations of vapor may also cause these effects.

Potential Sequelae

Some survivors of ingestion or severe inhalation exposure have experienced chronic nerve disorders. Inflammation of the nerves of the eye and blindness have been reported after ingestion.

Chronic Exposure

Chronic exposure has been reported to be associated with damage to the cranial nerves and neurological effects such as memory loss and impaired cognitive function. However, these studies did not have accurate exposure data and individuals were often exposed to mixtures of chemicals. Prolonged or repeated application of trichloroethylene to skin causes degreasing and inflammation of the skin (i.e., contact dermatitis and exfoliative dermatitis).

Chronic exposure may be more serious for children because of their potential longer latency period.

Carcinogenicity

The DHHS is currently reviewing the classification of trichloroethylene; the NTP Board Subcommittee has recommended that it be listed as "reasonably anticipated to be a human carcinogen." The International Agency for Research on Cancer has determined that trichloroethylene is probably carcinogenic to humans (Group 2A).

Reproductive and Developmental Effects

Trichloroethylene is not included in *Reproductive and Developmental Toxicants*, a 1991 report published by the U.S. General Accounting Office (GAO) that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences. Trichloroethylene readily crosses the placenta and is found in fetal blood at levels comparable to those of the mother. Evidence that acute trichloroethylene exposure causes reproductive or developmental toxicity in humans is inconclusive. There have been some reports suggesting an increased incidence of birth defects in children whose mothers were chronically exposed to trichloroethylene in drinking water, but these studies are limited by several factors including poor exposure data and small study populations.

Prehospital Management

Victims exposed only to trichloroethylene vapor do not pose secondary contamination risks to rescuers. Victims whose clothing or skin is contaminated with liquid trichloroethylene can secondarily contaminate response personnel by direct contact or through off-gassing vapor. Trichloroethylene vapor may also off-gas from the vomitus of victims who have ingested trichloroethylene.

Trichloroethylene is a mild to severe skin, eye, and respiratory-tract irritant. Acute exposure can cause CNS and respiratory depression and cardiac dysrhythmias by inhalation or ingestion. Other effects include hypotension, nausea, vomiting, and diarrhea.

There is no antidote for trichloroethylene poisoning. Treatment consists of support of respiratory and cardiovascular functions.

Hot Zone

Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if rescuers have not been trained in its use, assistance should be obtained from a local or regional HAZMAT team or other properly equipped response organization.

Rescuer Protection

Trichloroethylene vapor is absorbed well by inhalation and is a mild respiratory-tract irritant. The liquid is a mild skin irritant with slow skin absorption.

Respiratory Protection: Positive-pressure, self-contained breathing apparatus (SCBA) is recommended in response situations that involve exposure to potentially unsafe levels of trichloroethylene vapor.

Skin Protection: Chemical-protective clothing is not generally required when only vapor exposure is expected because trichloroethylene vapor is neither irritating nor absorbed well through the skin. Chemical protective clothing is recommended when repeated or prolonged contact with the liquid is anticipated because skin irritation and dermal absorption may occur.

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible.

Victim Removal

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be removed on backboards or gurneys; if these are not available, carefully carry or drag victims to safety.

Consider appropriate management of chemically contaminated children, such as measures to reduce separation anxiety if a child is separated from a parent or other adult.

Care should be taken that victims (particularly children) do not have problems due to trichloroethylene being heavier than air and settling in pockets close to the ground.

Decontamination Zone

Patients exposed only to trichloroethylene vapor who have no skin or eye irritation may be transferred immediately to the Support Zone. Other patients will require decontamination as described below.

Rescuer Protection

If exposure levels are determined to be safe, decontamination may be conducted by personnel wearing a lower level of protection than that worn in the Hot Zone (described above).

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. Stabilize the cervical spine with a collar and a backboard if trauma is suspected. Administer supplemental oxygen as required. Assist ventilation with a bag-valve-mask device if necessary.

Basic Decontamination

Victims who are able may assist with their own decontamination. Quickly remove and double-bag contaminated clothing and personal belongings.

Flush exposed skin and hair with water for 3 to 5 minutes. Wash with mild soap and water (preferably under a shower). Rinse thoroughly with water. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Irrigate exposed or irritated eyes with plain water or saline for 15 to 20 minutes. Remove contact lenses if easily removable without additional trauma to the eye. If a corrosive material is suspected or if pain or injury is evident, continue irrigation while transferring the victim to the Support Zone.

In cases of ingestion, **do not induce emesis.** If the victim is alert, asymptomatic, and has a gag reflex, administer a slurry of activated charcoal at 1 gm/kg (usual adult dose 60–90 g, child dose 25–50 g).

A soda can and straw may be of assistance when offering charcoal to a child. The efficacy of activated charcoal has not been demonstrated for trichloroethylene, but it may be of assistance, particularly in cases of mixed ingestion.

Consider appropriate management of chemically contaminated children at the exposure site. Provide reassurance to the child during decontamination, especially if separation from a parent occurs.

Transfer to Support Zone

As soon as basic decontamination is complete, move the victim to the Support Zone.

Support Zone

Be certain that victims have been decontaminated properly (see *Decontamination Zone* above). Victims who have undergone decontamination or have been exposed only to vapor generally pose no serious risks of secondary contamination. In such cases, Support Zone personnel require no specialized protective gear.

ABC Reminders

Quickly access for a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Ensure adequate respiration and pulse. Administer supplemental oxygen as required and establish intravenous access if necessary. Place on a cardiac monitor.

Additional Decontamination

Continue irrigating exposed skin and eyes, as appropriate.

In cases of ingestion, **do not induce emesis.** If the victim is alert, asymptomatic, and has a gag reflex, administer a slurry of activated charcoal at 1 gm/kg (usual adult dose 60–90 g, child dose 25–50 g), if it has not been administered previously. A soda can and straw may be of assistance when offering charcoal to a child. The efficacy of activated charcoal has not been demonstrated for trichloroethylene, but it may be of assistance, particularly in cases of mixed ingestion.

Advanced Treatment

In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, perform cricothyroidotomy if equipped and trained to do so.

Patients who have bronchospasm may be treated with aerosolized bronchodilators. However, the use of sympathomimetic agents such as epinephrine and isoproterenol could precipitate fatal dysrhythmias and should be avoided. Selective beta-2 agonists would be preferred, but clinical reports of their use are lacking. Theophylline derivatives have not been studied. Use all catecholamines with caution because of the enhanced risk of cardiac dysrhythmias. Also

consider the health of the myocardium before choosing which type of bronchodilator should be administered.

Patients who are comatose, hypotensive, or having seizures or cardiac arrhythmias should be treated according to advanced life support (ALS) protocols.

Transport to Medical Facility

Only decontaminated patients or patients not requiring decontamination should be transported to a medical facility. "Body bags" are not recommended.

Report to the base station and the receiving medical facility the condition of the patient, treatment given, and estimated time of arrival at the medical facility.

If trichloroethylene has been ingested, prepare the ambulance in case the victim vomits toxic material. Have ready several towels and open plastic bags to quickly clean up and isolate vomitus.

Multi-Casualty Triage

Consult with the base station physician or the regional poison control center for advice regarding triage of multiple victims.

Patients with evidence of significant inhalation exposure such as CNS disruption, breathing difficulties, or cardiac dysrhythmia and patients who ingested trichloroethylene should be transported to a medical facility for evaluation. Others may be discharged from the scene after their names, addresses, and telephone numbers are recorded. Those discharged should be advised to seek medical care promptly if symptoms develop (see *Patient Information Sheet* below).

Emergency Department Management

Patients exposed only to trichloroethylene vapor do not pose secondary contamination risks to hospital personnel. Patients whose clothing or skin is contaminated with liquid trichloroethylene can secondarily contaminate response personnel by direct contact or through off-gassing vapor. Toxic vomitus from patients who have ingested trichloroethylene may also off-gas the solvent.

Trichloroethylene is a mild skin, eye, and respiratory-tract irritant. Acute exposures can cause CNS and respiratory depression and cardiac dysrhythmias by inhalation or ingestion. Other effects include hypotension, nausea, vomiting, and diarrhea.

There is no antidote for trichloroethylene poisoning. Treatment consists of support of respiratory and cardiovascular functions.

Decontamination Area

Unless previously decontaminated, all patients suspected of contact with liquid trichloroethylene and all victims with skin or eye irritation require decontamination as described below. All other patients may be transferred to the Critical Care area.

Be aware that use of protective equipment by the provider may cause fear in children, resulting in decreased compliance with further management efforts.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants affecting the skin. Also, emergency room personnel should examine children's mouths because of the frequency of hand-to-mouth activity among children.

ABC Reminders

Evaluate and support airway, breathing, and circulation. In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, surgically create an airway.

Patients who have bronchospasm may be treated with aerosolized bronchodilators. However, the use of sympathomimetic agents such as epinephrine and isoproterenol could precipitate fatal dysrhythmias and should be avoided. Selective beta-2 agonists would be preferred, but clinical reports of their use are lacking. Theophylline derivatives have not been studied. Use all catecholamines with caution because of the enhanced risk of cardiac dysrhythmias. Also consider the health of the myocardium before choosing which type of bronchodilator should be administered.

Patients who are comatose, hypotensive, or have seizures or ventricular arrhythmias should be treated in the conventional manner.

Basic Decontamination

Patients who are able may assist with their own decontamination. Remove and double-bag contaminated clothing and personal belongings.

Flush exposed skin and hair with water for 3 to 5 minutes. Wash with mild soap and water (preferably under a shower). Rinse thoroughly with water. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Flush exposed eyes with plain water or saline for 15 to 20 minutes. Remove contact lenses if easily removable without additional trauma to the eye.

In cases of ingestion, **do not induce emesis.** If the victim is alert, asymptomatic, and has a gag reflex, administer a slurry of activated charcoal at 1 gm/kg (usual adult dose 60–90 g, child dose 25–50 g), if it has not been administered previously. A soda can and straw may be of assistance when offering charcoal to a child. The efficacy of activated charcoal has not been demonstrated for trichloroethylene, but it may be of assistance, particularly in cases of mixed ingestion.

Critical Care Area

Be certain that appropriate decontamination has been carried out (see *Decontamination Area* above).

ABC Reminders

Evaluate and support airway, breathing, and circulation as in *ABC Reminders* above. Establish intravenous access in seriously symptomatic patients if this has not been done previously. Continuously monitor cardiac rhythm.

Patients who are comatose, hypotensive, or have seizures or ventricular arrhythmias should be treated in the conventional manner. Avoid sympathomimetics or catecholamines or use them with caution. Beta-blockers may be more effective than lidocaine in cases of prolonged or resistant dysrhythmias.

Inhalation Exposure

Administer supplemental oxygen by mask to patients who have respiratory complaints. Patients who have bronchospasm may be treated with aerosolized bronchodilators. However, the use of sympathomimetic agents such as epinephrine and isoproterenol could precipitate fatal dysrhythmias and should be avoided.

Selective beta-2 agonists would be preferred, but clinical reports of their use are lacking. Theophylline derivatives have not been studied. Use all catecholamines with caution because of the enhanced risk of cardiac dysrhythmias. Also consider the health of the myocardium before choosing which type of bronchodilator should be administered.

Skin Exposure

If the skin was in prolonged contact with liquid trichloroethylene, chemical burns may result; treat as thermal burns.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants affecting the skin.

Eye Exposure

Ensure that adequate eye irrigation has been completed. Examine the eyes for corneal damage and treat appropriately. Immediately consult an ophthalmologist for patients who have corneal injuries.

Ingestion

Do not induce emesis.

If the victim is alert, asymptomatic, and has a gag reflex, administer a slurry of activated charcoal at 1 gm/kg (usual adult dose 60–90 g, child dose 25–50 g), if it has not been administered previously. A soda can and straw may be of assistance when offering charcoal to a child. The efficacy of activated charcoal has not been demonstrated for trichloroethylene, but it may be of assistance, particularly in cases of mixed ingestion.

Consider endoscopy to evaluate the extent of gastrointestinal-tract injury. Extreme throat swelling may require endotracheal intubation or cricothyroidotomy. Gastric lavage is useful in certain circumstances to remove toxic material and prepare for endoscopic examination. Consider gastric lavage with a small nasogastric tube if: (1) a large dose has been ingested; (2) the patient's condition is evaluated within 30 minutes; (3) the patient has oral lesions or persistent esophageal discomfort; and (4) the lavage can be administered within one hour of ingestion. Care must be taken when placing the gastric tube because blind gastric-tube placement may further injure the chemically damaged esophagus or stomach.

Because children do not ingest large amounts of toxic materials, and because of the risk of perforation from nasogastric intubation, lavage is discouraged in children unless performed under endoscopic guidance.

Toxic vomitus or gastric washings should be isolated (e.g., by attaching the lavage tube to isolated wall suction or another closed container).

Antidotes and Other Treatments

There is no antidote for trichloroethylene poisoning. Treatment is supportive of respiratory and cardiovascular functions.

Laboratory Test

The diagnosis of acute trichloroethylene toxicity is primarily clinical, based on symptoms of CNS disruption or respiratory distress. However, laboratory testing is useful for monitoring the patient and evaluating complications. Routine laboratory studies for all exposed patients include CBC, glucose, and electrolyte determinations. Additional studies for patients exposed to trichloroethylene include renal-function and liver-function tests. Patients who have respiratory complaints should be evaluated with pulse oximetry (or ABG measurements) and chest radiography.

Trichloroethylene blood or plasma levels are not clinically useful but may be used as a qualitative index to document an exposure. Exposure to trichloroethylene is also suggested by detection of trichloroacetic acid or trichloroethanol in blood or urine; however, these tests are not specific for trichloroethylene.

Disposition and Follow-up

Consider hospitalizing patients who have had significant inhalation exposure (e.g., with loss of consciousness) and patients who have ingested significant amounts of trichloroethylene.

Delayed Effects

Development of cardiac dysrhythmia may be delayed for 12 to 24 hours after exposure.

Patient Release

Patients who have not experienced alterations in mental status or cardiac dysrhythmia, or who had initially mild symptoms and are asymptomatic 12 to 24 hours later may be discharged. Discharged patients should be instructed to seek medical care promptly if symptoms develop (see *Trichloroethylene—Patient Information Sheet* below).

Follow-up

Obtain the name of the patient's primary care physician so that the hospital can send a copy of the ED visit to the patient's doctor.

Neurologic examination for post-hypoxic injury is recommended in cases of severe exposure.

Reporting

If a work-related incident has occurred, you may be legally required to file a report; contact your state or local health department.

Other persons may still be at risk in the setting where this incident occurred. If the incident occurred in the workplace, discussing it

with company personnel may prevent future incidents. If a public health risk exists, notify your state or local health department or other responsible public agency. When appropriate, inform patients that they may request an evaluation of their workplace from OSHA or NIOSH. See Appendices III and IV for a list of agencies that may be of assistance.

Trichloroethylene
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to trichloroethylene.

What is trichloroethylene?
Trichloroethylene is a colorless liquid with a sweet, chloroform-like smell. It is volatile and flammable, but does not burn easily. Trichloroethylene is used to degrease metal parts and to dry clean fabric. It is also used as a solvent in printing inks, paints, lacquers, varnishes, and adhesives.

What immediate health effects can be caused by exposure to trichloroethylene?
At high levels of exposure, trichloroethylene can cause dizziness, blurred vision, a feeling of excitement, nausea, and vomiting. Breathing very high levels can cause irregular heartbeat, fainting, brain damage, and even death. If the skin has been in contact with trichloroethylene for a long time, skin rash or chemical burns may result. Generally, the more serious the exposure, the more severe the symptoms.

Can trichloroethylene poisoning be treated?
There is no antidote for trichloroethylene poisoning. Patients who have swallowed or inhaled large amounts of trichloroethylene need to be hospitalized. Most patients get completely well.

Are any future health effects likely to occur?
A single small exposure from which a person recovers quickly is not likely to cause delayed or long-term effects. After a serious exposure or many exposures, damage to the nerves can occur. Fatigue, memory loss, headache, confusion, and depression have been reported by workers using trichloroethylene for long periods at their jobs. Trichloroethylene is believed to be a human carcinogen.

What tests can be done if a person has been exposed to trichloroethylene?
Specific tests for the presence of trichloroethylene breakdown products in blood and urine generally are not useful to the doctor. If a severe exposure has occurred, blood and urine analyses and other tests may show whether the nerves, heart, lungs, liver, or kidneys have been damaged. Testing is not needed in every case.

Where can more information about trichloroethylene be found?
More information about trichloroethylene can be obtained from your regional poison control center; your state, county, or local health department; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in occupational and environmental health. If the exposure happened at work, you may wish to discuss it with your employer, the Occupational Safety and Health Administration (OSHA), or the National Institute for Occupational Safety and Health (NIOSH). Ask the person who gave you this form for help in locating these telephone numbers.

Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow *only* the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:

- coughing, wheezing, or shortness of breath
- dizziness or distorted perceptions
- nausea or diarrhea
- increased pain or a discharge from your eyes
- increased redness or pain or a pus-like discharge in the area of a skin burn

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.
[ ] Call for an appointment with Dr. _____ in the practice of _____. When you call for your appointment, please say that you were treated in the Emergency Department at _____ Hospital by _____ and were advised to be seen again in _____ days.
[ ] Return to the Emergency Department/ _____ Clinic on (date) _____at _____ AM/PM for a follow-up examination.
[ ] Do not perform vigorous physical activities for 1 to 2 days.
[ ] You may resume everyday activities including driving and operating machinery.
[ ] Do not return to work for _____ days.
[ ] You may return to work on a limited basis. See instructions below.
[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.
[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.
[ ] Avoid taking the following medications: _____
[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: ___
_____
_____
[ ] Other instructions: _____
_____
_____

- Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.

- You or your physician can get more information on the chemical by contacting: _____ _____ or _____, or by checking out the following Internet Web sites: _____; _____.

Signature of patient _____ Date _____

Signature of physician _____ Date _____

Unidentified Chemical

All attempts should be made to determine the identity of the hazardous material before the *Unidentified Chemical* guideline is used. Responders should obtain assistance in identifying the chemical(s) from container shapes, placards, labels, shipping papers, and analytical tests. General information on these identification techniques is located in *Managing Hazardous Materials Incidents Volumes I* and *II*. The Unidentified Chemical protocol provides basic victim management recommendations but the techniques for a specific chemical could provide information which would allow more effective patient treatment.

Unidentified Chemical
Prehospital Management

Potential for Secondary Contamination. The route and extent of exposure are important in determining the potential for secondary contamination. Victims who were exposed only to gas or vapor and have no gross deposition of the material on their clothing or skin are not likely to carry significant amounts of chemical beyond the Hot Zone and are not likely to pose risks of secondary contamination to response personnel. However, victims whose skin or clothing is soaked with liquid chemical or victims who have condensation of chemical vapor on their clothes or skin may contaminate others by direct contact or by off-gassing vapor. If the victim has ingested a chemical, toxic vomitus may also pose a danger to others through direct contact or off-gassing vapor.

Hot Zone

Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if rescuers have not been trained in its use, call for assistance from a local or regional HAZMAT team or other properly equipped response organization.

Rescuer Protection

When a chemical is unidentified, worst-case possibilities concerning toxicity must be assumed. The potential for severe local effects (e.g., irritation and burning) and severe systemic effects (e.g., organ damage) should be assumed when specific rescuer-protection equipment is selected.

Respiratory Protection: Pressure-demand, self-contained breathing apparatus (SCBA) should be used in all response situations.

Skin Protection: Chemical-protective clothing should be worn when local and systemic effects are unknown.

ABC Reminders

Quickly ensure a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible.

Victim Removal

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be removed on backboards or gurneys; if these are not available, carefully carry or drag victims to safety.

Decontamination Zone

Victims exposed only to gas or vapors who have no skin or eye irritation may be transferred immediately to the Support Zone. All others require decontamination (see *Basic Decontamination* below).

Rescuer Protection

If the chemical or concentration is unidentified, personnel in the Decontamination Zone should wear the same protective equipment used in the Hot Zone (see Rescuer Protection, above).

ABC Reminders

Quickly ensure a patent airway. Stabilize the cervical spine with a collar and a backboard if trauma is suspected. Administer supplemental oxygen as required. Assist ventilation with a bag-valve-mask device if necessary.

Basic Decontamination

Victims who are able and cooperative may assist with their own decontamination. Remove and double-bag contaminated clothing and personal belongings.

Flush exposed or irritated skin and hair with plain water for 3 to 5 minutes. For oily or otherwise adherent chemicals, use mild soap on the skin and hair.

Flush exposed or irritated eyes with plain water or saline for at least 5 minutes. Remove contact lenses if present and easily removable without additional trauma to the eye. If a corrosive material is suspected or if pain or injury is evident, continue irrigation while transferring the victim to the Support Zone.

In cases of ingestion, do not induce emesis. Victims who are conscious and able to swallow should be given 4 to 8 ounces of water. Obtain medical care immediately.

Transfer to Support Zone

As soon as basic decontamination is complete, move the victim to the Support Zone.

Support Zone

Be certain that victims have been decontaminated properly (see Decontamination Zone above). Victims who have undergone decontamination or who have been exposed only to gas or vapor and who have no evidence of skin or eye irritation generally pose no serious risks of secondary contamination. In such cases, Support Zone personnel require no specialized protective gear.

ABC Reminders

Quickly ensure a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Ensure adequate respiration; administer supplemental oxygen as required. Ensure a palpable pulse. Establish intravenous access if necessary. Attach a cardiac monitor.

Additional Decontamination

Continue irrigating exposed skin and eyes, as appropriate.

In cases of ingestion, do not induce emesis. If the patient is conscious and able to swallow, administer 4 to 8 ounces of water if it has not been given previously. Obtain medical care immediately.

Advanced Treatment

Intubate the trachea in cases of respiratory compromise. When the patient's condition precludes endotracheal intubation, perform cricothyroidotomy if equipped and trained to do so.

Treat patients who have bronchospasm with aerosolized bronchodilators. Use these and all catecholamines with caution because of the enhanced risk of cardiac dysrhythmias after exposure to certain chemicals.

Patients who are comatose, hypotensive, or have seizures or cardiac dysrhythmias should be treated according to ALS protocols.

Transport to Medical Facility

Report to the base station and the receiving medical facility the condition of the patient, treatment given, and estimated time of arrival at the medical facility.

If a chemical has been ingested, prepare the ambulance in case the victim vomits toxic material. Have ready several towels and open plastic bags to quickly clean up and isolate vomitus.

Multi-Casualty Wage

All exposed patients should be transported to a medical facility for evaluation.

Asymptomatic patients who have not had direct chemical exposure can he discharged from the scene after their names, addresses, and telephones numbers are recorded. Those discharged should be advised to seek medical care promptly if symptoms develop.

Consult with the base station physician or regional poison control center for advice regarding triage of multiple victims.

Unidentified Chemical
Emergency Department Management

Potential for Secondary Contamination. Victims who were exposed only to gas or vapor and have no gross deposition of the material on their clothing or skin are not likely to carry significant amounts of chemical beyond the Hot Zone and are not likely to pose risks of secondary contamination to hospital personnel. However, victims whose skin or clothing are covered with liquid or solid chemical or victims who have condensation of chemical vapor on their clothes or skin may contaminate hospital personnel and the ED by direct contact or by off-gassing vapor. If the victim has ingested a chemical, toxic vomitus may also pose a danger through direct contact or off-gassing vapor.

Decontamination Area

Previously decontaminated patients and patients exposed only to gas or vapor who have no evidence of skin or eye irritation may be transferred immediately to the Critical Care Area. Other victims will require decontamination as described below.

ABC Reminders

Evaluate and support airway, breathing, and circulation. Intubate the trachea in cases of respiratory compromise. If the patient's condition precludes intubation, surgically create an airway.

Treat patients who have bronchospasm with aerosolized bronchodilators; use these and all catecholamines with caution because of the possible enhanced risk of cardiac dysrhythmias.

Patients who are comatose, hypotensive, or have seizures or ventricular dysrhythmias should be treated in the conventional manner.

Basic Decontamination

Patients who are able and .cooperative may assist with their own decontamination. Remove and double-bag contaminated clothing and personal belongings.

Flush exposed or irritated skin and hair with plain water for 3 to 5 minutes. For oily or otherwise adherent chemicals, use mild soap on the skin and hair. Rinse thoroughly with water.

Flush exposed or irritated eyes with plain water or saline for at least 5 minutes. Remove contact lenses if present and easily removable without additional trauma to the eye. If a corrosive material is suspected or if pain or injury is evident, continue irrigation while transferring the patient to the Critical Care Area.

In cases of ingestion, do not induceemesis. Administer4 to 8 ounces of water to dilute stomach contents if the patient is

conscious and able to swallow. Immediately transfer the patient to the Critical Care Area.

Critical Care Area

Be certain that appropriate decontamination has been carried out. (See Decontamination Area, above.)

ABC Reminders

Evaluate and support airway, breathing, and circulation as in ABC Reminders, page 7. Establish intravenous access in seriously ill patients. Continuously monitor cardiac rhythm.

Patients who are comatose, hypotensive, or have seizures or ventricular dysrhythmias should be treated in the conventional manner.

Inhalation Exposure

Administer supplemental oxygen by mask to patients who have respiratory complaints. Treat patients who have bronchospasm with aerosolized bronchodilators; use these and all catecholamines with caution because of the potential or possible enhanced risk of cardiac dysrhythmias.

Skin Exposure

If chemical burns are present, treat as thermal burns.

Eye Exposure

Ensure that adequate eye irrigation has been completed. Test visual acuity. Examine the eyes for corneal damage using a magnifying device or a slit lamp and fluorescein stain. For small corneal defects, use ophthalmic ointment or drops, analgesic medication, and an eye patch. Immediately consult an ophthalmologist for patients who have severe corneal injuries.

Ingestion Exposure

Do not induce emesis. If the patient is alert and charcoal has not been given previously, administer a slurry of activated charcoal. If a corrosive material is suspected, administer 4 to 8 ounces of water do not give a slurry of activated charcoal. Consider endoscopy to evaluate the extent of gastrointestinal-tract injury. If a large dose has been ingested and the patient's condition is evaluated within 30 minutes after ingestion, consider gastric lavage.

Antidotes and Other Treatments

Treatment consists of supportive measures.

Laboratory Tests

Routine laboratory studies for all exposed patients include CBC, glucose, and electrolyte determinations. Additional studies for patients exposed to an unidentified chemical include ECG monitoring, renal-function tests, and liver-function tests. Chest radiography and pulse oximetry (or

ABG measurements) are recommended for severe inhalation exposure.

Disposition and Followup

Consider hospitalizing patients who have suspected serious exposures and persistent or progressive symptoms.

Delayed Effects

When the chemical has not been identified, the patient should be observed for an extended period or admitted to the hospital.

Patient Release

Asymptomatic patients who have minimal exposure, normal initial examinations, and no signs of toxicity after 6 to 8 hours of observation may be discharged with instructions to seek medical care promptly if symptoms develop.

Followup

Provide the patient with follow-up instructions to return to the emergency department or a private physician to reevaluate initial findings. Patients who have corneal injuries should be reexamined within 24 hours.

Reporting

If a work-related incident has occurred, you may be legally required to file a report; contact your state or local health department.

Other persons may still be at risk in the setting where this incident occurred. If the incident occurred in the workplace, discussing it with company personnel may prevent future incidents. If a public health risk exists, notify your state or local health department or other responsible public agency. When appropriate, inform patients that they may request an evaluation of their workplace from OSHA or NIOSH. See Appendices III and IV for a list of agencies that may be of assistance.

Vinyl Chloride (C_2H_3Cl)
CAS 75-01-4; UN 1086

Synonyms include chloroethene, chloroethylene, 1-chloroethylene, ethylene monochloride, monochloroethylene, monovinyl chloride, MVC, VC, VCM, and vinyl chloride monomer.

- **Persons exposed only to vinyl chloride gas pose no risk of secondary contamination. Persons whose clothing or skin is contaminated with pressurized liquid vinyl chloride can secondarily contaminate rescuers by direct contact or through off-gassing of vapor.**
- **At all ambient temperatures, vinyl chloride is an extremely flammable and potentially explosive gas that is heavier than air. It has a mild, sweet odor, but odor is not an adequate warning of hazardous concentrations.**
- **Inhalation is the major route of vinyl chloride exposure; absorption is rapid and nearly complete. Gastrointestinal absorption is unlikely as vinyl chloride is a gas at room temperature. Dermal absorption is negligible.**

Description

At room temperature, vinyl chloride is a colorless, highly flammable, potentially explosive gas. It has a faint sweet odor. The odor threshold for vinyl chloride is about 3,000 ppm in air, depending on the individual. When confined under high pressure in special containers, vinyl chloride exists in a liquefied state. It is shipped and handled this way. When burned or heated to a high enough temperature, vinyl chloride decomposes to hydrogen chloride, carbon monoxide, carbon dioxide, and traces of phosgene. Vinyl chloride should be stored in a cool, dry, well ventilated location, separate from oxidizing materials and accelerants. Phenol is often added as a stabilizer.

Routes of Exposure

Inhalation

Inhalation is the primary route of exposure, and vinyl chloride is readily absorbed from the lungs. **Its odor threshold is too high to provide an adequate warning of hazardous concentrations**. The odor of vinyl chloride becomes detectable at around 3,000 ppm and the OSHA PEL is 1 ppm (8-hour TWA). Therefore, workers can be overexposed to vinyl chloride without being aware of its presence. A 5-minute exposure to airborne concentrations of 8,000 ppm can cause dizziness. As airborne levels increase to 20,000 ppm, effects can include drowsiness, loss of coordination, visual and auditory abnormalities, disorientation, nausea, headache, and burning or tingling of the extremities. Exposure to higher concentrations of vinyl chloride for longer durations can cause death, presumably due

to central nervous system (CNS) and respiratory depression. The gas is heavier than air and can cause asphyxiation in poorly ventilated or enclosed spaces.

Children exposed to the same levels of vinyl chloride as adults may receive a larger dose because they have greater lung surface area:body weight ratios and increased minute volumes:weight ratios. In addition, they may be exposed to higher levels than adults in the same location because of their short stature and the higher levels of vinyl chloride found nearer to the ground.

Skin/Eye Contact

Direct skin contact with escaping compressed gas or liquid vinyl chloride can cause frostbite injury, but systemic absorption is negligible. Direct ocular exposure to vinyl chloride vapor can cause localized burns or irritation of the conjunctiva and cornea.

Ingestion

Ingestion of vinyl chloride is unlikely because it is a gas at room temperature. Small amounts can dissolve in other liquids, but in such small concentrations that acute toxicity is unlikely.

Sources/Uses

Annual production levels of vinyl chloride continue to increase, with 14.98 billion pounds produced in the United States in 1995. Vinyl chloride is produced by chlorinating ethylene to produce 1,2-dichloroethane, which is then subjected to high pressures and temperatures. This causes pyrolysis (thermal cracking) of the 1,2-dichloroethane to produce the vinyl chloride monomer. Most vinyl chloride is polymerized to form polyvinyl chloride (PVC), a material used to manufacture automotive parts and accessories, furniture, packaging materials, pipes, wall coverings, and wire coatings. Vinyl chloride is also used as an intermediate in the production of other chlorinated compounds and as a component in mixed-monomer plastics. Historically, it was used as a solvent, propellant, and refrigerant, and it was once evaluated as a potential anesthetic.

Standards and Guidelines

OSHA PEL (permissible exposure limit) = 1 ppm (averaged over an 8-hour workshift)

NIOSH IDLH (immediately dangerous to life or health) = not yet determined; vinyl chloride is treated as a human carcinogen.

Physical Properties

Description: colorless gas with a sweet odor at room temperature; colorless liquid when contained under pressure or cooled.

Warning properties: **inadequate** (odor threshold of about 3,000 ppm; varies significantly among individuals)

Boiling point: 7.9 °F (-13.4 °C)

Freezing Point: -244.8 °F (-153.8 °C)

Specific gravity: 0.9106 (liquid) at 68 °F (20 °C) (water = 1.00)

Vapor pressure: 2,530 mm Hg at 68 °F (20 °C)

Vapor density: 2.16 (air = 1.00)

Water solubility: (1,100 to 2,763 mg/L at 77 °F [25 °C])

Flammability: highly flammable and explosive gas; flammability range is 3.6% to 33% (concentration in air)

Flash point: -108.4 °F (-78 °C)

Incompatibilities

Vinyl chloride self-polymerizes explosively if peroxidation occurs (e.g., if heated, exposed to sunlight, or mixed with air and contaminants). Avoid contact with oxygen, strong oxidizing agents, aluminum, copper, iron, and steel.

Health Effects

- **The primary target of vinyl chloride acute exposure is the CNS. Signs and symptoms include dizziness, ataxia, inebriation, fatigue, numbness and tingling of the extremities, visual disturbances, coma, and death.**
- **Vinyl chloride can irritate the eyes, mucous membranes, and respiratory tract. Escaping compressed gas or liquid can cause frostbite or irritation of the skin and eyes.**
- **Chronic exposure can cause permanent liver injury and liver cancer, neurologic or behavioral symptoms, and changes to the skin and bones of the hand.**
- **Vinyl chloride's acute CNS effects are likely to be caused by interaction of the parent compound with neural membranes. Other effects appear to be caused by interaction of reactive intermediates with macromolecules.**

Acute Exposure

Vinyl chloride is thought to depress the CNS via a solvent effect on lipids and protein components of neural membranes that interrupts signal transmission. Reactive metabolic intermediates may also cause specific target organ toxicity by covalently bonding to tissue or initiating destructive chain reactions such as lipid peroxidation. There may be a latent period of hours to days between exposure and symptom onset. Vinyl chloride is rapidly metabolized and the metabolites are eliminated in the urine.

Children do not always respond to chemicals in the same way that adults do. Different protocols for managing their care may be needed.

CNS

The CNS is the primary target of vinyl chloride acute toxicity. The symptoms reported most commonly stem from the anesthetic properties of vinyl chloride; these symptoms include dizziness, ataxia, fatigue, drowsiness, headache, and loss of consciousness. With inhalation exposure, signs and symptoms increase in severity over a range of 8,000 to 20,000 ppm in air. Exposure to higher concentrations for longer durations can cause death, presumably due to CNS and respiratory depression. Sublethal CNS effects resolve quickly when the victim is removed from further exposure.

Respiratory

Vinyl chloride gas inhalation can cause mild respiratory tract irritation, wheezing, and chemical bronchitis. These effects are transient and resolve quickly following removal from exposure. Death may result from respiratory depression.

Exposure to certain chemicals can lead to Reactive Airway Dysfunction Syndrome (RADS), a chemically- or irritant-induced type of asthma.

Children may be more vulnerable because of relatively increased minute ventilation per kg and failure to evacuate an area promptly when exposed.

Hydrocarbon pneumonitis may be a problem in children.

Cardiovascular

Vinyl chloride may lower the myocardial threshold to the dysrhythmogenic effects of catecholamines; it might predispose patients to ventricular ectopy and fibrillation. In experimental animals, exposure to vinyl chloride has led to ECG abnormalities, including ventricular ectopy, heart block, and T-wave inversions.

Dermal

Exposure to escaping compressed gas or liquid can cause frostbite injury with redness, blistering, and scaling.

Ocular

Exposure to escaping compressed gas or liquid can cause frostbite injury with corneal and conjunctival irritation or burns. High concentrations of vapor can cause eye irritation.

Potential Sequelae

Patients exposed to significant amounts of vinyl chloride may not develop symptoms immediately and should be monitored for CNS and respiratory depression and liver and kidney damage for 24 to 48 hours.

Chronic Exposure

Prolonged absorption of vinyl chloride can induce hepatotoxicity and hepatic cancers, including angiosarcoma. Portal hypertension and cirrhosis can occur. Vinyl chloride toxicity is thought to result from the binding of reactive epoxide metabolites to hepatic DNA. Other effects of chronic exposure include sensory-motor polyneuropathy; pyramidal, extrapyramidal, and cerebellar abnormalities; neuropsychiatric symptoms such as sleep disorders, loss of libido, headaches, and irritability; EEG alterations; and immunopathologic phenomena such as purpura and thrombocytopenia. Vinyl chloride disease is a syndrome consisting of Raynaud's phenomenon, acroosteolysis (dissolution of the bones of the terminal phalanges and sacroiliac joints), and scleroderma-like skin changes.

Carcinogenicity

The U.S. Department of Health and Human Services (DHHS) and the International Agency for Research on Cancer (IARC) have classified vinyl chloride as a known human carcinogen. Vinyl chloride has caused angiosarcoma of the liver in heavily exposed

workers. It is also suspected to cause cancer of the brain, lungs, gastrointestinal tract, and lymphatic/hematopoietic system.

Reproductive and Developmental Effects

Vinyl chloride is included in *Reproductive and Developmental Toxicants*, a 1991 report published by the U.S. General Accounting Office (GAO) that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences. However, there is no conclusive evidence of reproductive or developmental effects in humans. A few case reports describe decreased libido or fertility in men with chronic occupational exposure, and some animal studies also support this finding. Some studies in experimental animals have reported developmental toxicity associated with high-dose exposures, but vinyl chloride is not considered a developmental toxicant.

Special consideration regarding the exposure of pregnant women is warranted, since vinyl chloride has been shown to be a genotoxin; thus, medical counseling is recommended for the acutely exposed pregnant women.

Prehospital Management

- **Victims exposed only to vinyl chloride gas pose no risk of secondary contamination to rescuers. Victims whose skin or clothing is contaminated with liquid vinyl chloride can contaminate rescuers by direct contact or through off-gassing of vapor.**
- **The primary target of vinyl chloride acute exposure is the CNS. Signs and symptoms include dizziness, ataxia, inebriation, fatigue, numbness and tingling of the extremities, visual disturbances, coma, and death.**
- **Vinyl chloride also can irritate the eyes, mucous membranes, and respiratory tract. Escaping compressed gas or liquid can cause frostbite or irritation of the skin and eyes.**
- **There is no antidote for vinyl chloride. Treatment consists of support of respiratory and cardiovascular functions.**

Hot Zone

Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if the rescuers have not been trained in its use, call for assistance from a local or regional hazardous materials (HAZMAT) team or other properly equipped response organization.

Rescuer Protection

Vinyl chloride gas is readily absorbed by inhalation and can irritate the respiratory tract. Liquid vinyl chloride on the skin or eyes can cause frostbite injury and irritation. A negligible amount of vinyl chloride is absorbed through the skin.

Respiratory protection: Positive-pressure, self-contained breathing apparatus (SCBA) is recommended in response situations that involve exposure to any level of vinyl chloride gas.

Skin protection: Chemical-protective clothing is recommended when contact with escaping compressed gas or liquid is anticipated because skin irritation and frostbite injury can occur.

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. Provide supplemental oxygen if cardiopulmonary compromise is suspected. If trauma is suspected, manually maintain cervical immobilization and apply a cervical collar and a backboard when feasible. Apply direct pressure to stop any heavy bleeding.

Victim Removal

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk should be removed on backboards or gurneys. If these are not available, carefully carry or drag victims to safety.

Consider appropriate management of chemically contaminated children, such as measures to reduce separation anxiety if a child is separated from a parent or other adult.

Decontamination Zone

Victims exposed only to vinyl chloride gas who have no eye irritation do not need decontamination. They may be transferred immediately to the Support Zone. All others require decontamination as described below.

Rescuer Protection

If exposure levels are determined to be safe, decontamination may be conducted by personnel wearing a lower level of protection than that required in the Hot Zone (see *Rescuer Protection* under *Hot Zone*, above).

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. Provide supplemental oxygen if cardiopulmonary compromise is suspected. If trauma is suspected, manually maintain cervical immobilization and apply a cervical collar and a backboard when feasible. Administer supplemental oxygen as required. Assist ventilation with a bag-valve-mask device if necessary. Apply direct pressure to stop any heavy bleeding.

Basic Decontamination

Victims who are able may assist with their own decontamination. Remove and double bag contaminated clothing and all personal belongings.

Handle frostbitten skin and eyes with caution. Gently wash exposed skin and hair very thoroughly with mild soap and water (preferably under a shower). Rinse thoroughly with water. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Do not irrigate frostbitten eyes. Irrigate exposed or irritated eyes with plain water or saline for at least 15 minutes. Remove contact lenses if easily removable without additional trauma to the eye. If pain or injury is evident, continue irrigation while transferring the victim to the Support Zone.

Consider appropriate management of chemically contaminated children at the exposure site. Also, provide reassurance to the child

during decontamination, especially if separation from a parent occurs. If possible, seek assistance from a child separation expert.

Transfer to Support Zone

As soon as basic decontamination is complete, move the victim to the Support Zone.

Support Zone

Be certain that victims have been decontaminated properly (see *Decontamination Zone* above). Victims who have undergone decontamination or have been exposed only to vinyl chloride gas pose no serious risk of secondary contamination to rescuers. In such cases, Support Zone personnel require no specialized protective gear.

ABC Reminders

Quickly access for a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Ensure adequate respiration and pulse. Administer supplemental oxygen as required and establish intravenous access if necessary. Place on a cardiac monitor.

Additional Decontamination

Continue irrigating exposed skin and eyes, as appropriate.

Advanced Treatment

In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, perform cricothyroidotomy if equipped and trained to do so.

Treat patients who have bronchospasm with aerosolized bronchodilators. **Use these and all catecholamines at the lowest efficacious dose because of the possible enhanced risk of cardiac dysrhythmias**. Also consider the health of the myocardium before choosing which type of bronchodilator should be administered.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Patients who are comatose, hypotensive, or having seizures or cardiac arrhythmia should be treated according to advanced life support (ALS) protocols, keeping in mind the precaution about administration of catecholamines. If frostbite is present, treat by rewarming in a warm water bath at a temperature of 102–108 °F (40–42 °C) for 20 to 30 minutes and continue until a flush has returned to the affected area.

Transport to Medical Facility

Only decontaminated patients or patients not requiring decontamination should be transported to a medical facility. "Body bags" are not recommended.

Report to the base station and the receiving medical facility the condition of the patient, treatment given, and estimated time of arrival at the medical facility.

If the patient has ingested vinyl chloride (extremely unlikely), prepare the ambulance in case the patient vomits toxic material or has diarrhea. Have ready several towels and open plastic bags to quickly clean up and isolate vomitus.

Multi-Casualty Triage

Consult with the base station physician or the regional poison control center for advice regarding triage of multiple victims.

Patients who have persistent symptoms after being removed from the source of exposure should be transported to a medical facility for evaluation.

Patients who are asymptomatic or had mild or transient symptoms (e.g., dizziness, headache) that rapidly resolved may be discharged from the scene after their names, addresses, and telephone numbers are recorded. These patients should be advised to rest and to seek medical care promptly if symptoms develop or recur (see the *Patient Information Sheet* below).

Emergency Department Management

- **Patients exposed only to vinyl chloride gas pose no risk of secondary contamination to rescuers. Patients whose skin or clothing is contaminated with liquid vinyl chloride can contaminate rescuers by direct contact or through off-gassing of vapor.**
- **The primary target of vinyl chloride acute exposure is the CNS. Signs and symptoms include dizziness, ataxia, inebriation, fatigue, numbness and tingling of the extremities, visual disturbances, coma, and death.**
- **Vinyl chloride also can irritate the eyes, mucous membranes, and respiratory tract. Escaping compressed gas or liquid can cause frostbite or irritation of the skin and eyes.**
- **There is no antidote for vinyl chloride. Treatment consists of support of respiratory and cardiovascular functions.**

Decontamination Area

Previously decontaminated patients and those exposed only to vinyl chloride gas who have no eye irritation may be transferred immediately to the Critical Care Area. Others require decontamination as described below.

Be aware that use of protective equipment by the provider may cause fear in children, resulting in decreased compliance with further management efforts.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants absorbed through the skin.

ABC Reminders

Evaluate and support the airways, breathing, and circulation. Provide supplemental oxygen if cardiopulmonary compromise is suspected. In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, surgically create an airway.

Treat patients who have bronchospasm with aerosolized bronchodilators. Use these and all catecholamines at the lowest efficacious dose because vinyl chloride might increase the risk of arrhythmia by lowering the myocardial threshold to the effects of epinephrine. Also consider the health of the myocardium before choosing which type of bronchodilator should be administered.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution

in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Patients who are comatose, hypotensive, or seizing or have cardiac arrhythmia should be treated in the conventional manner, observing the precautions about catecholamines described above. Arrhythmias might respond to beta-adrenergic blockers (e.g., propranolol, esmolol) if lidocaine is ineffective.

Basic Decontamination

Patients who are able may assist with their own decontamination. Remove and double-bag contaminated clothing and all personal belongings.

Handle frostbitten skin and eyes with caution. Gently wash exposed skin and hair very thoroughly with mild soap and water (preferably under a shower). Rinse thoroughly with water. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Flush exposed or irritated eyes with plain water or saline for at least 15 minutes. Remove contact lenses if easily removable without additional trauma to the eye. If pain or injury is evident, continue irrigation while transferring the victim to the Critical Care Area.

Critical Care Area

Be certain that appropriate decontamination has been carried out (see *Decontamination Area*, above).

ABC Reminders

Evaluate and support the airways, breathing, and circulation as in *ABC Reminders* above. Establish intravenous access in seriously ill patients. Continuously monitor cardiac rhythm.

Patients who are comatose, hypotensive, or who have seizures or cardiac arrhythmia, should be treated in the conventional manner, observing the precautions about catecholamines described below.

Inhalation Exposure

Administer supplemental oxygen by mask to patients who have respiratory complaints or CNS symptoms. Treat patients who have bronchospasm with aerosolized bronchodilators. Use these and all catecholamines at the lowest efficacious doses because vinyl chloride might increase the risk of cardiac arrhythmia by lowering the myocardial threshold to the effects of epinephrine. Also consider the health of the myocardium before choosing which type of bronchodilator should be administered.

Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25–0.75 mL of 2.25% racemic epinephrine solution

in 2.5 cc water, repeat every 20 minutes as needed, cautioning for myocardial variability.

Skin Exposure

Escaping compressed gas or liquid vinyl chloride exposure can cause frostbite injury. If frostbite is present, treat by rewarming in a water bath at a temperature of 102–108 °F (40–42 °C) for 20 to 30 minutes and continue until a flush has returned to the affected area. If chemical burns from other toxicants are present, treat as thermal burns.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants absorbed through the skin.

Eye Exposure

Ensure that adequate eye irrigation has been completed. Test visual acuity. Examine the eyes for conjunctival or corneal damage and treat appropriately. Consult with an ophthalmologist for patients who have suspected severe corneal injuries.

Antidotes and Other Treatments

There is no antidote for vinyl chloride. Treatment is supportive.

Laboratory Tests

Routine laboratory studies for all exposed patients include CBC, glucose, and electrolyte determinations; liver and kidney function tests are also recommended. Chest radiography and pulse oximetry (or ABG measurements) are recommended in cases of severe inhalation exposure.

Vinyl chloride is rapidly eliminated from the body in the breath and its major metabolite, thiodiglycolic acid, is excreted in the urine. Breath levels of vinyl chloride and urine levels of thiodiglycolic acid are not clinically helpful in acute exposure. Urine levels of thiodiglycolic acid peak about 20 hours after exposure.

Disposition and Follow-Up

Consider hospitalizing patients who have persistent or progressive symptoms.

Delayed Effects

Hepatic injury can develop a few days after exposure, depending on the magnitude of the exposure. Patients with significant CNS depression or severe exposure should be observed for 24 hours.

Patient Release

Patients who have not experienced significant alterations in mental status or respiratory difficulty may be discharged. Patients who initially had mild symptoms, but who become asymptomatic during a 6- to 8-hour observation period, may be discharged. These patients should be advised to rest and to seek medical care promptly if symptoms develop or recur (see the *Vinyl Chloride—Patient*

Information Sheet below). Patients who had significant CNS symptoms initially should be observed overnight even if their CNS symptoms appear to resolve.

Follow-up

Obtain the name of the patient's primary care physician so that the hospital can send a copy of the ED visit to the patient's doctor.

Follow-up laboratory evaluation of hepatic function should be arranged for severely exposed patients. Neurologic examination for post-hypoxic injury is recommended in cases of severe cardiorespiratory compromise. Patients who have skin or corneal lesions should be reexamined within 24 hours.

Reporting

If a work-related incident has occurred, you might be legally required to file a report; contact your state or local health department for more information.

Other persons might still be at risk at the place where this incident occurred. If the incident occurred in the workplace, discussing it with company personnel might prevent future incidents. If a public health risk exists, notify your state or local health department or other responsible public agency. When appropriate, inform patients that they may request an evaluation of their workplace from the Occupational Safety and Health Administration (OSHA) or the National Institute of Occupational Safety and Health (NIOSH). See Appendices III and IV for a list of agencies that may be of assistance.

Vinyl Chloride (C_2H_3Cl)
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to vinyl chloride.

What is vinyl chloride?
Vinyl chloride is a colorless gas at room temperature that has a mild, sweet odor. It is handled and shipped as a liquid under high pressure in a special container. It is used to produce polyvinyl chloride (PVC), a plastic material used to make many products, including automotive parts, furniture, and building materials.

What immediate health effects can be caused by exposure to vinyl chloride?
Inhaling vinyl chloride causes sleepiness and dizziness, and can cause loss of consciousness. If pressurized liquid vinyl chloride escapes from its container and comes in contact with the skin or eyes, it can cause frostbite or irritation.

Can vinyl chloride poisoning be treated?
There is no antidote for vinyl chloride, but its effects can be treated and most exposed persons recover completely. Persons who have inhaled large amounts of vinyl chloride might need to be hospitalized.

Are any future health effects likely to occur?
A single small exposure from which a person recovers quickly is unlikely to cause delayed or long-term effects. Exposure to vinyl chloride over many years can affect the liver, nervous system, and skin. Long-term exposure can cause a rare form of liver cancer.

What tests can be done if a person has been exposed to vinyl chloride?
Specific tests for the presence of vinyl chloride in the breath or breakdown products in the urine are available, but they must be performed shortly after exposure and are not generally helpful. If a severe exposure has occurred, blood and other tests might show whether the liver or other organs have been damaged. Testing is not needed in every case.

Where can more information about vinyl chloride be found?
If the exposure happened at work, you might be required to contact your employer and the Occupational Safety and Health Administration (OSHA). Employees may request a Health Hazard Evaluation from the national Institute for Occupational Safety and Health (NIOSH).

You can get more information about vinyl chloride from your regional poison control center; your state, county, or local health department; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in occupational and environmental health. Ask the person who gave you this form for help locating these telephone numbers.

Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow *only* the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:

- dizziness, disorientation, drowsiness, or headaches
- difficulty breathing
- burning of skin or eyes
- nausea or loss of appetite

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.
[ ] Call for an appointment with Dr. _____ in the practice of _____. When you call for your appointment, please say that you were treated in the Emergency Department at _____ Hospital by _____ and were advised to be seen again in _____ days.
[ ] Return to the Emergency Department/ _____ Clinic on (date) _____at _____ AM/PM for a follow-up examination.
[ ] Do not perform vigorous physical activities for 1 to 2 days.
[ ] You may resume everyday activities including driving and operating machinery.
[ ] Do not return to work for _____ days.
[ ] You may return to work on a limited basis. See instructions below.
[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.
[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.
[ ] Avoid taking the following medications: _____
[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: ___
_____
_____
[ ] Other instructions: _____
_____
_____

- Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.

- You or your physician can get more information on the chemical by contacting: _____ _____ or _____, or by checking out the following Internet Web sites: _____; _____.

Signature of patient _____ Date _____

Signature of physician _____ Date _____

Xylene $(C_6H_4)(CH_3)_2$
CAS 1330-20-7; UN 1307

Synonyms include dimethylbenzene, methyl toluene, xylol, and mixed xylenes.

Persons exposed only to xylene vapor do not pose substantial risks of secondary contamination. Persons whose clothing or skin is contaminated with liquid xylene can cause secondary contamination by direct contact or through off-gassing vapor.

Xylene is a clear, colorless liquid. It is volatile, readily producing flammable and toxic concentrations at room temperature. Its vapor is heavier than air and may accumulate in low-lying areas. Xylene's odor generally provides adequate warning of hazardous concentrations.

Xylene is rapidly absorbed after inhalation and ingestion. Exposure via ingestion and inhalation produces systemic toxicity. Xylene is slowly absorbed through intact skin, but percutaneous absorption may contribute to total body burden.

Description

Xylene exists as three isomers (ortho-, meta-, and para-xylene), which can be found singly or, more commonly, mixed in varying proportions. Commercial grade xylene, in which m-xylene is usually the major constituent, is a clear, colorless liquid with a sweet, aromatic odor. It is generally referred to as Mixed, Total or Technical-Grade Xylene. There is a fourth structural isomer, ethylbenzene $(C_6H_5)(C_2H_5)$ that may be present as a congener, but is not toxicologically distinct to a significant degree. Xylene is flammable at room temperature; therefore, it constitutes a fire hazard. It is insoluble in water, but mixes readily with many organic solvents. Xylene is less dense than water and will float on the surface of water.

Routes of Exposure

Inhalation

Most exposures to xylene occur by inhalation and xylene is readily absorbed from the lungs. Xylene's odor threshold is about 1 ppm, which is 100 times less than the OSHA PEL and generally provides adequate warning of acutely hazardous concentrations. Irritation of eye and throat occur at about 200 ppm. Xylene vapor is heavier than air and may cause asphyxiation in enclosed, poorly ventilated, or low-lying areas.

Children exposed to the same levels of xylene vapor as adults may receive a larger dose because they have greater lung surface area:body weight ratios and increased minute volumes:weight ratios. In addition, they may be exposed to higher levels than adults

in the same location because of their short stature and the higher levels of xylene vapor found nearer to the ground.

Skin/Eye Contact

Xylene vapor is only mildly irritating to mucous membranes; however, xylene splashed in the eyes can result in corneal injury. Repeated or prolonged skin contact with liquid xylene can defat the skin, causing it to crack and peel. Percutaneous absorption is slow through intact skin; however, xylene absorbed through the skin may contribute to body burden.

Children are more vulnerable to toxicants absorbed through the skin because of their relatively larger surface area:body weight ratio.

Ingestion

Acute systemic toxicity can result from ingestion of xylene.

Sources/Uses

Xylene is among the 30 most abundantly produced chemicals in the United States. It is obtained primarily from crude petroleum. It is widely used as a degreasing agent and as a thinner and solvent in paints, inks, adhesives, and many other products. It is commonly found as a solvent in pesticide products.

Standards and Guidelines

OSHA PEL (permissible exposure limit) = 100 ppm (averaged over an 8-hour workshift)

NIOSH IDLH (immediately dangerous to life or health) = 900 ppm

Physical Properties

Description: Clear, colorless liquid

Warning properties: Adequate; sweet, aromatic odor at 1 ppm

Molecular weight: 106.2 daltons

Boiling point (760 mm Hg)*: 292 °F (144 °C), 269 °F (139 °C), and 281 °F (138 °C)

*Freezing point**: -13 °F (-25 °C), -54 °F (-48 °C), and 56 °F (13 °C)

*Specific gravity**: 0.88, 0.86, and 0.86 (water = 1)

*Vapor pressure**: 5, 6, and 6.5 mm Hg at 68 °F (20 °C)

Gas density: 3.8 (air = 1)

Water solubility: insoluble

*Flammability**: 63 °F (17 °C), 81 °F (27 °C), 81 °F (27 °C)

Flammable range: 1.0% to 7.0% (concentration in air)

*ortho-, meta-, and para-xylene, respectively.

Incompatibilities Xylene reacts with strong oxidizers and strong acids.

Health Effects

- **Xylene is irritating to the skin, eyes, and respiratory tract. It can cause systemic toxicity by ingestion or inhalation. The most common route of exposure is via inhalation.**
- **Symptoms of xylene poisoning include CNS effects (headache, dizziness, ataxia, drowsiness, excitement, tremor, and coma), ventricular arrythmias, acute pulmonary edema, respiratory depression, nausea, vomiting, and reversible hepatic impairment.**
- **The mechanism by which xylene produces toxicity is not known.**

Acute Exposure

The mechanism by which xylene produces toxicity is not known. CNS toxicity may be due to the liposolubility of xylene in the neuronal membrane. It has been suggested that xylene interferes with the normal function of neuronal proteins. It has also been suggested that the toxicity of xylene may be due to some of its metabolic intermediates. CNS toxicity is generally discernible within a short time of exposure, but pulmonary edema may not appear for up to 72 hours after exposure. No information was found as to whether the health effects of xylene in children are different than in adults.

Children do not always respond to chemicals in the same way that adults do. Different protocols for managing their care may be needed.

CNS

Generally, symptoms of CNS toxicity are apparent immediately after inhalation of high xylene concentrations and 30 to 60 minutes after ingestion. Effects of mild CNS depression include headache, lightheadedness, dizziness, confusion, nausea, impaired gait, and blurred vision. More severe effects include tremors, rapid respiration, paralysis, loss of consciousness, coma, and death. Coma may be prolonged, although most victims regain consciousness rapidly after they are removed from exposure.

Respiratory

Acute exposure to xylene vapor may irritate the mucous membranes of the respiratory tract. With massive exposure, accumulation of fluid in the lungs and respiratory arrest may ensue. Pulmonary aspiration of toxic vomitus or ingested liquid xylene may cause inflammation of the lungs.

Exposure to certain chemicals can lead to Reactive Airway Dysfunction Syndrome (RADS), a chemically- or irritant-induced type of asthma.

Children may be more vulnerable because of relatively increased minute ventilation per kg and failure to evacuate an area promptly when exposed.

Hydrocarbon pneumonitis may be a problem in children.

Cardiovascular Inhalation of massive doses of xylene can cause cardiac abnormalities. Xylene lowers the threshold of the heart to the effects of epinephrine, partially disrupting the rhythm. Irregular heart rhythm leading to cardiac arrest has occurred in solvent abusers, often immediately after intense physical activity.

Renal Blood and protein in the urine can occur after massive inhalation. These effects usually are reversible if exposure is terminated.

Metabolic High-level xylene exposure may lead to acid-base imbalance. In solvent abusers, electrolyte and acid-base disturbances can cause renal-tubular acidosis, inadequate amounts of potassium in the blood, and low blood phosphate. Ethanol or aspirin may prolong the half-life of xylene in the body.

Because of their higher metabolic rates, children may be more vulnerable to toxicants interfering with basic metabolism.

Dermal Xylene can cause skin inflammation and defatting, particularly after prolonged or repeated contact with the liquid. Redness of the skin and blisters may occur.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants absorbed through the skin.

Hepatic Reversible liver damage has been reported in some individuals exposed to xylene.

Ocular High concentrations of xylene vapor may cause eye irritation, but ophthalmic injury is rare. When splashed in the eyes, xylene may cause burning pain, conjuctivitis, corneal vacuolation, and keratitis.

Gastrointestinal If swallowed, xylene can irritate the stomach, causing nausea, vomiting, and diarrhea.

Potential Sequelae

During recovery, patients may continue to experience impaired gait, lightheadedness, dilated and poorly responsive pupils, and decreased or absent deep-tendon reflexes. Anxiety, fatigue, and insomnia may last several days. No long-term effects due to acute xylene exposure have been reported.

Chronic Exposure

Repeated exposure to xylene due to solvent abuse can result in progressive and permanent neuropsychiatric manifestations. In its more severe form this has been called "chronic toxic encephalopathy."

There is some evidence from human epidemiological studies that occupational exposure to solvents including xylene may be associated with proliferative glomerulonephritis. However, individuals were exposed to mixtures of solvents and so it is not possible to attribute this effect solely to xylene exposure.

Chronic exposure may be more serious for children because of their potential longer latency period.

Carcinogenicity

The International Agency for Research on Cancer has determined that xylene is not classifiable as to its carcinogenicity to humans. The EPA has determined that xylene is not classifiable as to its human carcinogenicity.

Reproductive and Developmental Effects

Xylene is not included in *Reproductive and Developmental Toxicants*, a 1991 report published by the United States General Accounting Office (GAO) that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences. Xylene has been reported to cross the placenta in humans. Limited human developmental data are available, but animal studies suggest that exposure to high doses of xylene may be fetotoxic.

Prehospital Management

Victims exposed only to xylene vapor do not pose significant risks of secondary contamination to rescuers outside the Hot Zone. Victims whose clothing or skin is contaminated with liquid xylene can secondarily contaminate response personnel by direct contact or through off-gassing vapor. Xylene vapor may also off-gas from the toxic vomitus of victims who have ingested xylene.

Xylene is irritating to the skin, eyes, and respiratory tract. It can cause systemic toxicity by ingestion or inhalation. The most common route of exposure is via inhalation. Symptoms of xylene poisoning include CNS effects (headache, dizziness, ataxia, drowsiness, excitement, tremor, and coma), ventricular arrythmias, acute pulmonary edema, respiratory depression, nausea, vomiting, and reversible hepatic impairment.

There is no antidote for xylene. Treatment consists of support of respiratory and cardiovascular functions.

Hot Zone

Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if rescuers have not been trained in its use, assistance should be obtained from a local or regional HAZMAT team or other properly equipped response organization.

Rescuer Protection

Xylene vapor is a mild respiratory-tract irritant. The liquid is a mild skin irritant with slow skin absorption.

Respiratory Protection: Positive-pressure, self-contained breathing apparatus (SCBA) is recommended in response situations that involve exposure to potentially unsafe levels of xylene vapor.

Skin Protection: Chemical-protective clothing is not generally required when only vapor exposure is expected because xylene vapor is neither irritating nor absorbed well through the skin. Chemical-protective clothing is recommended when repeated or prolonged contact with the liquid is anticipated because skin irritation and dermal absorption may occur.

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible.

Victim Removal

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be removed on backboards or gurneys; if these are not available,

carefully carry or drag victims to safety. Care should be taken that the victims (particularly children) do not have problems due to xylene being heavier than air and settling in pockets close to the ground.

Consider appropriate management of chemically contaminated children, such as measures to reduce separation anxiety if a child is separated from a parent or other adult.

Decontamination Zone

Patients exposed only to xylene vapor who have no skin or eye irritation do not need decontamination. They may be transferred immediately to the Support Zone. Other patients will require decontamination as described below.

Rescuer Protection

If exposure levels are determined to be safe, decontamination may be conducted by personnel wearing a lower level of protection than that worn in the Hot Zone (described above).

ABC Reminders

Quickly access for a patent airway, ensure adequate respiration and pulse. Stabilize the cervical spine with a collar and a backboard if trauma is suspected. Administer supplemental oxygen as required. Assist ventilation with a bag-valve-mask device if necessary.

Basic Decontamination

Victims who are able may assist with their own decontamination. Quickly remove and double-bag contaminated clothing and personal belongings.

Flush exposed skin and hair with plain water for 3 to 5 minutes, then wash with mild soap. Rinse thoroughly with water. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Flush exposed or irritated eyes with plain water or saline for at least 5 minutes or until pain resolves. Remove contact lenses if easily removable without additional trauma to the eye. If a corrosive material is suspected or if pain or injury is evident, continue irrigation while transferring the victim to the Support Zone.

In cases of ingestion, **do not induce emesis**. The use of activated charcoal for hydrocarbon absorption is limited, but it may have some effect, especially in cases of mixed overdose. If the victim is alert, asymptomatic, and has a gag reflex, administer a slurry of activated charcoal at 1 gm/kg (usual adult dose 60–90 g, child dose 25–50 g). A soda can and a straw may be of assistance when offering charcoal to a child.

Consider appropriate management of chemically contaminated children at the exposure site. Provide reassurance to the child during decontamination, especially if separation from a parent occurs.

Transfer to Support Zone

As soon as basic decontamination is complete, move the victim to the Support Zone.

Support Zone

Be certain that victims have been decontaminated properly (see *Decontamination Zone* above). Victims who have undergone decontamination or have been exposed only to vapor pose no serious risks of secondary contamination to rescuers. In such cases, Support Zone personnel require no specialized protective gear.

ABC Reminders

Quickly access for a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Ensure adequate respiration and pulse. Administer supplemental oxygen as required and establish intravenous access if necessary. Place on a cardiac monitor. Observe for cardiac arrhythmias.

Additional Decontamination

Continue irrigating exposed skin and eyes, as appropriate.

In cases of ingestion, **do not induce emesis**. The use of activated charcoal for hydrocarbon absorption is limited, but it may have some effect, especially in cases of mixed overdose. If activated charcoal has not been given previously and if the patient is alert, asymptomatic, and has a gag reflex, administer a slurry of activated charcoal at 1 gm/kg (usual adult dose 60–90 g, child dose 25–50 g). A soda can and a straw may be of assistance when offering charcoal to a child.

Advanced Treatment

In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, perform cricothyroidotomy if equipped and trained to do so.

Patients who have bronchospasm may be treated with aerosolized bronchodilators. However, the use of sympathomimetic agents such as epinephrine and isoproterenol could precipitate fatal arrhythmias and should be avoided. Selective beta-2 agonists would be preferred, but clinical reports of their use are lacking. Theophylline derivatives have not been studied. Use all catecholamines with caution because of the enhanced risk of cardiac arrhythmias. Also consider the health of the myocardium before choosing which type of bronchodilator should be administered.

Patients who are comatose, hypotensive, or having seizures or cardiac arrhythmias should be treated according to advanced life support (ALS) protocols.

Transport to Medical Facility

Only decontaminated patients or patients not requiring decontamination should be transported to a medical facility. "Body bags" are not recommended.

Report to the base station and the receiving medical facility the condition of the patient, treatment given, and estimated time of arrival at the medical facility.

If xylene has been ingested, prepare the ambulance in case the victim vomits toxic material. Have ready several towels and open plastic bags to quickly clean up and isolate vomitus.

Multi-Casualty Triage

Consult with the base station physician or the regional poison control center for advice regarding triage of multiple victims.

Patients with evidence of significant inhalation exposure such as CNS depression and all persons who have ingested xylene should be transported to a medical facility for evaluation. Others may be discharged at the scene after their names, addresses, and telephone numbers are recorded. Those discharged should be advised to seek medical care promptly if symptoms develop (see *Patient Information Sheet* below).

Emergency Department Management

Hospital personnel can be secondarily contaminated by direct contact or by vapor off-gassing from heavily soaked clothing or skin. Patients do not pose contamination risks after clothing is removed and the skin is washed. Toxic vomitus from patients who have ingested xylene may also off-gas xylene vapor.

Xylene is irritating to the skin, eyes, and respiratory tract. It can cause systemic toxicity by ingestion or inhalation. The most common route of exposure is via inhalation. Symptoms of xylene poisoning include CNS effects (headache, dizziness, ataxia, drowsiness, excitement, tremor, and coma), ventricular arrythmias, acute pulmonary edema, respiratory depression, nausea, vomiting, and reversible hepatic impairment.

There is no antidote for xylene. Treatment consists of support of respiratory and cardiovascular functions.

Decontamination Area

Unless previously decontaminated, all patients suspected of contact with liquid xylene and all victims with skin or eye irritation require decontamination as described below. All other patients may be transferred to the Critical Care area.

Be aware that use of protective equipment by the provider may cause fear in children, resulting in decreased compliance with further management efforts.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants absorbed through the skin. Also emergency room personnel should examine children's mouths because of the frequency of hand-to-mouth activity among children.

ABC Reminders

Evaluate and support airway, breathing, and circulation. In cases of respiratory compromise secure airway and respiration via endotracheal intubation. If not possible, surgically create an airway.

Patients who have bronchospasm may be treated with aerosolized bronchodilators. However, the use of sympathomimetic agents such as epinephrine and isoproterenol could precipitate fatal arrhythmias and should be avoided. Selective beta-2 agonists would be preferred, but clinical reports of their use are lacking. Theophylline derivatives have not been studied. Use all catecholamines with caution because of the enhanced risk of cardiac arrhythmias. Also consider the health of the myocardium before choosing which type of bronchodilator should be administered.

Patients who are comatose, hypotensive, or have seizures or ventricular arrhythmias should be treated in the conventional manner.

Basic Decontamination

Patients who are able may assist with their own decontamination. Remove and double-bag contaminated clothing and personal belongings.

Flush liquid-exposed skin and hair with plain water for 3 to 5 minutes, then wash with mild soap. Rinse thoroughly with water. Use caution to avoid hypothermia when decontaminating children or the elderly. Use blankets or warmers when appropriate.

Flush exposed or irritated eyes with plain water or saline for at least 5 minutes or until pain resolves. Remove contact lenses if easily removable without additional trauma to the eye. If a corrosive material is suspected or if pain or injury is evident, continue irrigation while transferring the victim to the Critical Care Area.

In cases of ingestion, **do not induce emesis**. The use of activated charcoal for hydrocarbon absorption is limited, but it may have some effect, especially in cases of mixed overdose. If the victim is alert, asymptomatic, and has a gag reflex, administer a slurry of activated charcoal at 1 gm/kg (usual adult dose 60–90 g, child dose 25–50 g). A soda can and a straw may be of assistance when offering charcoal to a child.

Critical Care Area

Be certain that appropriate decontamination has been carried out (see *Decontamination Area* above).

ABC Reminders

Evaluate and support airway, breathing, and circulation as in *ABC Reminders* above. Establish intravenous access in seriously ill patients if this has not been done previously. Continuously monitor cardiac rhythm.

Patients who are comatose, hypotensive, or have seizures or cardiac arrhythmias should be treated in the conventional manner.

Inhalation Exposure

Administer supplemental oxygen by mask to patients who have respiratory complaints. Patients who have bronchospasm may be treated with aerosolized bronchodilators. However, the use of sympathomimetic agents such as epinephrine and isoproterenol could precipitate fatal arrhythmias and should be avoided. Selective beta-2 agonists would be preferred, but clinical reports of their use are lacking. Theophylline derivatives have not been studied. Use all catecholamines with caution because of the enhanced risk of cardiac

arrhythmias. Also consider the health of the myocardium before choosing which type of bronchodilator should be administered.

Skin Exposure

If liquid xylene was in prolonged contact with the skin, chemical burns may result; treat as thermal burns.

Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants absorbed through the skin.

Eye Exposure

Ensure that adequate eye irrigation has been completed. Examine the eyes for corneal damage and treat appropriately. Immediately consult an ophthalmologist for patients who have severe corneal injuries.

Ingestion Exposure

Do not induce emesis.

The use of activated charcoal for hydrocarbon absorption is limited, but it may have some effect, especially in cases of mixed overdose. If activated charcoal has not been given previously and if the patient is alert, asymptomatic, and has a gag reflex, administer a slurry of activated charcoal at 1 gm/kg (usual adult dose 60–90 g, child dose 25–50 g). A soda can and a straw may be of assistance when offering charcoal to a child.

Consider endoscopy to evaluate the extent of gastrointestinal-tract injury. Extreme throat swelling may require endotracheal intubation or cricothyroidotomy. Gastric lavage is useful in certain circumstances to remove toxic material and prepare for endoscopic examination. Consider gastric lavage with a small nasogastric tube if: (1) a large dose has been ingested; (2) the patient's condition is evaluated within 30 minutes; (3) the patient has oral lesions or persistent esophageal discomfort; and (4) the lavage can be administered within one hour of ingestion. Care must be taken when placing the gastric tube because blind gastric-tube placement may further injure the chemically damaged esophagus or stomach.

Because of the risk of perforation from NG intubation, lavage is discouraged in children unless performed under endoscopic guidance.

Toxic vomitus or gastric washings should be isolated (e.g., by attaching the lavage tube to isolated wall suction or another closed container).

If the patient who has ingested xylene is coughing or is dyspneic, pulmonary aspiration may have occurred. Patients who show no

clinical signs of pulmonary aspiration within 6 hours are not likely to develop aspiration chemical pneumonitis.

Antidotes and Other Treatments

There is no antidote for xylene. Hemodialysis and hemoperfusion are ineffective.

Laboratory Tests

Routine laboratory studies for all exposed patients include CBC, glucose, and electrolyte determinations. Additional studies for patients exposed to xylene include ECG monitoring, renal-function tests, and liver-function tests. Chest radiography and pulse oximetry (or ABG measurements) are recommended for severe inhalation exposure or if pulmonary aspiration is suspected.

Blood levels of xylene may be used to document exposure, although they are not useful clinically. Xylene is metabolized to methylhippuric acid, which is excreted in urine. Xylene is almost completely excreted within 24 hours. Urinary methylhippuric acid levels do not correlate well with systemic effects and are not available on an emergency basis; however, methylhippuric acid levels can help confirm the diagnosis or etiology.

Disposition and Follow-up

Consider hospitalizing symptomatic patients who have significant inhalation or ingestion exposure with symptoms of CNS depression or respiratory distress.

Delayed Effects

Observe hospitalized patients for signs of acute tubular necrosis, encephalopathy, and arrhythmias. In addition, patients exposed by inhalation should be watched for signs of pulmonary edema, and those who have ingested xylene should be watched for signs of aspiration pneumonitis.

Patient Release

Patients who remain asymptomatic 6 to 12 hours after exposure may be discharged with instructions to seek medical care promptly if symptoms develop (see the *Xylene—Patient Information Sheet* below).

Follow-up

Obtain the name of the patient's primary care physician so that the hospital can send a copy of the ED visit to the patient's doctor.

Patients who have corneal injuries should be reexamined within 24 hours. No long-term sequelae due to a single acute exposure to xylene have been reported.

Reporting

If a work-related incident has occurred, you may be legally required to file a report; contact your state or local health department.

Other persons may still be at risk in the setting where this incident occurred. If the incident occurred in the workplace, discussing it with company personnel may prevent future incidents. If a public health risk exists, notify your state or local health department or other responsible public agency. When appropriate, inform patients that they may request an evaluation of their workplace from OSHA or NIOSH. See Appendices III and IV for a list of agencies that may be of assistance.

Xylene
Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to xylene.

What is xylene?
When pure, xylene is a clear, colorless liquid with a sweet odor. It burns readily. Xylene is obtained from crude petroleum and is used widely in many products such as paints, glues, and pesticides. It is found in small amounts in gasoline.

What immediate health effects can be caused by exposure to xylene?
Breathing xylene vapors in small amounts can cause headache, dizziness, drowsiness, and nausea. With more serious exposure, xylene can cause sleepiness, stumbling, irregular heartbeat, fainting, or even death. Xylene vapors are mildly irritating to the skin, eyes, and lungs. If liquid xylene is held against the skin, it may cause burning pain. Liquid xylene splashed in the eyes can damage the eyes. Generally, the more serious the exposure, the more severe the symptoms.

Can xylene poisoning be treated?
There is no antidote for xylene, but its effects can be treated, and most exposed persons get well. Persons who have experienced serious symptoms may need to be hospitalized.

Are any future health effects likely to occur?
A single small exposure from which a person recovers quickly is not likely to cause delayed or long-term effects. After a serious exposure, some symptoms may take a few days to develop. Repeated sniffing of xylene can cause permanent damage to the brain, muscles, heart, and kidneys.

What tests can be done if a person has been exposed to xylene?
Specific tests for the presence of xylene in blood and urine generally are not useful to the doctor. Methylhippuric acid, a metabolite of xylene, may be measured in urine if the xylene dose was high. If a severe exposure has occurred, blood and urine analyses and other tests may show whether the brain, heart, or kidneys have been injured. Testing is not needed in every case.

Where can more information about xylene be found?
More information about xylene can be obtained from your regional poison control center; the state, county, or local health department; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in occupational and environmental health. If the exposure happened at work, you may wish to discuss it with your employer, the Occupational Safety and Health Administration (OSHA), or the National Institute for Occupational Safety and Health (NIOSH). Ask the person who gave you this form for help in locating these telephone numbers.

Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow *only* the instructions checked below.

[ ] Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:
coughing
shortness of breath or wheezing
chest pain or tightness
increased pain or a discharge from exposed eyes
increased redness or pain or a pus-like discharge in the area of a skin burn
fever

[ ] No follow-up appointment is necessary unless you develop any of the symptoms listed above.
[ ] Call for an appointment with Dr. _____ in the practice of _____.
When you call for your appointment, please say that you were treated in the Emergency Department at _____ Hospital by _____ and were advised to be seen again in _____ days.
[ ] Return to the Emergency Department/ _____ Clinic on (date) _____at _____ AM/PM for a follow-up examination.
[ ] Do not perform vigorous physical activities for 1 to 2 days.
[ ] You may resume everyday activities including driving and operating machinery.
[ ] Do not return to work for _____ days.
[ ] You may return to work on a limited basis. See instructions below.
[ ] Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.
[ ] Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.
[ ] Avoid taking the following medications: _____
[ ] You may continue taking the following medication(s) that your doctor(s) prescribed for you: ___
_____
_____
[ ] Other instructions: _____
_____
_____

- Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.

- You or your physician can get more information on the chemical by contacting: _____ _____ or _____, or by checking out the following Internet Web sites: _____; _____.

Signature of patient _____ Date _____

Signature of physician _____ Date _____

Appendix I

AAPCC-Certified Regional Poison Control Centers

AAPCC-Certified Regional Poison Control Centers

Poison Control Centers were established around 1953 to help physicians deal with poisoning of adults and children in the United States. In 1983, the American Association of Poison Control Centers (AAPCC) was established as the professional organization for Poison Control Centers. The Regional Poison Control Centers can act as a valuable resource in providing information about the toxicity and health effects of hazardous exposures involved in poisonings.

ALABAMA
Alabama Poison Center
2503 Phoenix Drive
Tuscaloosa AL35405
Emergency: (800) 462-0800 (AL only)
(205)345-0600

Children's Hospital of Alabama Poison Control Center
1600 7th Avenue South
Birmingham AL 35233
Emergency: (800) 292-6678 (AL only)
(205) 933-4050

ALASKA
Anchorage Poison Control Center
3200 Providence Drive
P.O. Box 196604
Anchorage AK 99519
Emergency: (800) 478-3193
(907) 261-3193

ARIZONA
Arizona Poison and Drug Information Center
Arizona Health Sciences Center
Room 1156
1501 North Campbell Avenue
Tuscon AZ 85724
Emergency: (800) 362-0101 (AZ only)
(602) 626-6016

Samaritan Regional Poison Center
Good Samaritan Regional Medical Center
1111 E. McDowell–Ancillary 1
Phoenix AZ 85006
Emergency:(800) 362-0101 (AZ only)
(602) 253-3334

ARKANSAS
Arkansas Poison and Drug Information Center
College of Pharmacy
University of Arkansas for Medical Sciences
Mail Slot 552
4301 W. Markham
Little Rock AR 77205
Emergency: (800) 376-4766
TDD/TTY (800) 641-3805

CALIFORNIA
California Poison Control System-Fresno/Madera
Valley Children's Hospital
9300 Valley Children's Place
Madera CA 93638
Emergency: (800) 876-4766 (CA only)

California Poison Control System-Sacramento
UC Davis Medical Center
2315 Stockton Boulevard
Sacramento CA 95817
Emergency: (800) 876-4766 (CA only)

California Poison Control System-Dan Diego
UC San Diego, Medical Center
200 West Arbor Drive
San Diego CA 92103
Emergency: (800) 876-4766

California Poison Control System-San Francisco
San Francisco General Hospital
1001 Potrero Avenue, Room 1E86
San Francisco CA 94110
Emergency: (800) 876-4766 (CA only)

COLORADO
Rocky Mountain Poison and Drug Center
9902 E. Ninth Avenue
Denver CO 80220
Emergency: (800) 332-3073 (CO only/outside metro area)
(303) 739-1123 (Denver metro)

CONNECTICUT
Connecticut Poison Control Center
University of Connecticut Health Center
263 Farmington Avenue
Farmington CT 06030
Emergency: (800) 343-2722 (CT only)
(860) 679-3456

DELAWARE
The Poison Control Center
3535 Market Street, Suite 985
Philadelphia PA 19104
Emergency: (800) 772-7112
(215) 386-2100

DISTRICT OF COLUMBIA
National Capitol Poison Control Center
3201 New Mexico Avenue, NW
Suite 310
Washington DC 20016
Emergency: (202) 625-3333
TDD/TTY: (202) 362-8563 (TTY)

FLORIDA
Florida Poison Information Center-Jacksonville
655 West Eighth Street
Jacksonville FL 32209
Emergency: (800) 282-3171 (FL only)
(904) 549-4480

Florida Poison Information Center-Miami
University of Miami
Department of Pediatrics
P.O. Box 016960 (R-131)
Miami FL 33101
Emergency: (800) 282-3171 (FL only)
(305) 585-5253

FLORIDA (continued)
Florida Poison Information Center-Tampa
Tampa General Hospital
P.O. Box 1289
Tampa FL 33601
Emergency: (800) 282-3171 (FL only)
(813) 253-4444

GEORGIA
Georgia Poison Center
Hughes Spalding Children's Hospital
Grady Health System
80 Butler Street, SE, P.O. Box 26066
Atlanta GA 30335
Emergency: (404) 606-9000
TDD/TTY: (404) 606-9287 (TDD)

HAWAII
Hawaii Poison Center
1319 Punahou Street
Honolulu HI 96826
Emergency: (808) 941-4411

IDAHO
Rocky Mountain Poison and Drug Center
8802 E. Ninth Avenue
Denver CO 80220
Emergency: (800) 860-0620 (ID only)

ILLINOIS
Illinois Poison Center
222 S. Riverside Plaza, Suite 1900
Chicago IL 60606
Emergency: (800) 942-5969 (IL only)

INDIANA
Indiana Poison Center
Methodist Hospital
I-65 at 21st Street
Indianapolis IN 46206
Emergency: (800) 382-9097 (IN only)
(317) 929-2323
TDD/TTY: (317) 929-2336 (TTY)

IOWA
Iowa Poison Center
St. Luke's Regional Medical Center
2720 Stone Park Boulevard
Sioux City IA 51104
Emergency: (800) 352-2222
(712) 277-2222

IOWA (continued)
Poison Control Center
Department of Pharmaceutical Care,CC101 GH
The University of Iowa Hospitals and Clinics
200 Hawkins Drive
Iowa City IA 52242
Emergency: (800) 272-6477 (IA only)

KANSAS
Mid-American Poison Control Center
University of Kansas Medical Center
3901 Rainbow Blvd., Room B-400

Kansas City KS 66160
Emergency: (800) 332-6633
(913) 588-6633
TDD/TTY: (913) 588-6639 (TDD)

KENTUCKY
Louisville
Kentucky Regional Poison Center
Medical Towers South, Suite 572
234 East Gray Street
Louisville KY 40202
Emergency: (502) 589-8222

LOUISIANA
Louisiana Drug and Poison Information Center
Unitversity of Louisiana at Monroe
College of Pharmacy
Sugar Hall
Monroe, LA 71209
Emergency: (800) 256-9822 (LA only)

MAINE
Maine Poison Control Center
Maine Medical Center
22 Bramhall Street
Portland ME 04102
Emergency: (800) 442-6305 (ME only)
(207) 871-2950

MARYLAND
Maryland Poison Center
University of MD at Baltimore
School of Pharmacy
20 North Pine Stree, PH230
Baltimore MD 21201
Emergency: (800) 492-2414 (MD only)
(410) 528-7701
TDD/TTY: (410) 706-1858

National Capitol Poison Control Center
3201 New Mexico Avenue, NW
Suite 310
Washington DC 20016
Emergency: (202) 625-3333
TDD/TTY: (202) 362-8563 (TTY)

MASSACHUSETTS
Regional Center for Poison Control and Prevention Services for Massachusetts and Rhode Island
300 Longwood Avenue
Boston MA 02115
Emergency: (800) 682-9211 (MA and RI only)
(617)232-2120

MICHIGAN
Regional Poison Control Center
Chidren's Hospital of Michigan
4160 John R Harper Professional Office Bldg, Suite 616
Detroit MI 48201
Emergency: (800) 764-7661 (MI only)
(313) 745-5711
TTD/TTY: (800) 356-3232 (TTY)

Spectrum Health Regional Poison Center
1840 Wealthy S.E.
Grand Rapids MI 49506
Emergency: (800) 764-7661 (MI only)
TTD/TTY: (800) 356-3232 (TTY)

MINNESOTA
Hennepin Regional Poison Center
Hennepin County Medical Center
701 Park Avenue
Minneapolis MN 55415
Emergency: (800) POISON1 (MN and SD only)
(612) 347-3141
TDD/TTY: (612) 904-4691 (TTY)

PROSAR International Poison Control Center
1295 Bandana Boulevard
Suite 335
St. Paul MN 55108
Emergency: (888) 779-7921

MISSISSIPPI
Mississippi Regional Poison Control Center
University of Mississippi Medical Center
2500 N. State Street
Jackson MS 39216
Emergency: (601) 354-7660

MISSOURI
Regional Poison Center
Cardinal Glennon Children's Hospital
1465 S. Grand Blvd.
St. Louis MO 63104
Emergency: (800) 366-8888
(314) 772-5200

MONTANA

Rocky Mountain Poison and Drug Center
8802 E. Ninth Avenue
Denver CO 80220
Emergency: (800) 525-5042 (MT only)

NEBRASKA
The Poison Center
Children's Hospital
8301 Dodge Street
Omaha NE 68114
Emergency: (800) 955-9119 (NE and WY only)
(402) 354-5555

NEVADA
Oregon Poison Center
Oregon Health Sciences University
3181 SW Sam Jackson Park Road
Portland OR 97201
Emergency: (503) 494-8968

NEVADA (continued)
Rocky Mountain Poison and Drug Center
8802 E. Ninth Avenue
Denver CO 80220
Emergency: (800) 446-6179 (NV only)

NEW HAMPSHIRE
New Hampshire Poison Information Center
Dartmouth-Hitchcock Medical Center
One Medical Center Drive
Lebanon NH 03756
Emergency: (800) 562-8236 (NH only)
(603) 650-8000

NEW JERSEY
New Jersey Poison Information and Education System
201 Lyons Avenue
Newark NJ 07112
Emergency: (800) POISON-1 (NJ only)

NEW MEXICO
New Mexico Poison and Drug Information Center
Health Science Center Library
Room 125
University of New Mexico
Albuquerque NM 87131
Emergency: (800) 432-6866 (NM only)
(505) 272-2222

NEW YORK
Central New York Poison Center
750 East Adams Street
Syracuse NY 13210
Emergency: (800) 252-5655 (NY only)
(315) 476-4766

Finger Lakes Regional Poison and Drug Information Center
University of Rochester Medical Center
601 Elmwood Avenue
P.O. Box 321
Rochester NY 14642
Emergency: (800) 333-0542 (NY only)
(716) 275-3232
TDD/TTY: (716) 273-3854 (TTY)

NEW YORK (continued)
Hudson Valley Regional Poison Center
Phelps Memorial Hospital Center
701 North Broadway
Sleepy Hollow NY 10591
Emergency: (800) 336-6997 (NY only)
(914) 366-3030

Long Island Regional Poison Control Center
Winthrop University Hospital
259 First Street
Mineola NY 11501
Emergency: (516) 542-2323
(516) 663-2650
TTD/TTY: (516) 924-8811 (TDD Suffolk)
(516) 747-3323 (TDD Nassau)

New York City Poison Control Center
NYC Department of Health
455 First Avenue
Room 123, Box 81
New York NY 10016
Emergency: (800) 210-3985
(212) 340-4494; (212) POI-SONS;
(212) VEN-ENOS
TDD/TTY: (212) 689-9014 (TDD)

Western New York Regional Poison Control Center
Children's Hospital of Buffalo
219 Bryant Street
Buffalo NY 14222
Emergency: (800) 888-7655 (NY western regions only)
(716)-878-7654

NORTH CAROLINA
Carolinas Poison Center
Carolinas Medical Center
5000 Airport Center Parkway, Suite B
Charlotte NC 28208
Emergency: (800) 848-6946 (NC only)
(704) 355-4000

NORTH DAKOTA
North Dakota Poison Information Center
Meritcare Medical Center
720 4th Street North
Fargo ND 58122
Emergency: (800) 732-2200 (ND, MN, SD only)
(701) 234-5575

OHIO
Central Ohio Poison Center
700 Children's Drive, Room L032
Columbus OH 43205
Emergency: (800) 682-7625 (OH only)
(800) 762-0727 (Dayton, OH only)
TDD/TTY: (614) 228-2272

Cincinnati Drug and Poison Information Center
Regional Poison Control System
2368 Victory Parkway, Suite 300
Cincinnati OH 45206
Emergency: (800) 872-5111 (OH only)
(513) 558-5111

Greater Cleveland Poison Control Center
11100 Euclid Avenue
Cleveland OH 44106
Emergency: (888) 231-4455
(216) 231-4455

OKLAHOMA
Oklahoma Poison Control Center
Children's Hospital of Oklahoma
940 N.E. 13th Street, Room 3512
Oklahoma City OK 73104
Emergency: (800) 764-7661 (OK only)
(405) 271-5454

OREGON
Oregon Poison Center
Oregon Health Sciences University
3181 SW Sam Jackson Park Road
Portland OR 97201
Emergency: (800) 452-7165 (OR only)
(503)494-8968

PENNSYLVANIA
Central Pennsylvania Poison Center
Penn State Geisinger Health System
The Milton S. Hershey Medical Center
MC HO453 PO Box 850
500 University Drive
Hershey PA 17033
Emergency: (800) 521-6110
TDD/TTY: (717) 531-8335

Pittsburgh Poison Center
Children's Hospital of Pittsburgh
3705 Fifth Avenue
Pittsburgh PA 15213
Emergency: (412) 681-6669

The Poison Control Center
3535 Market Street, Suite 985
Philadelphia PA 19104
Emergency: (800) 772-7112
(215) 386-2100

RHODE ISLAND
Regional Center for Poison Control and Prevention Services for Massachusetts and Rhode Island
300 Longwood Avenue
Boston MA 02115
Emergency: (617) 232-2120

SOUTH CAROLINA
Palmetto Poison Center
College of Pharmacy
University of South Carolina
Columbia SC 29208
Emergency: (800) 922-1117 (SC only)
(803) 777-1117

SOUTH DAKOTA
Hennepin Regional Poison Center
Hennepin County Medical Center
701 Park Avenue
Minneapolis MN 55415
Emergency: (800) POISON1 (MN and SD only)
(612) 347-3141
TDD/TTY: (612) 904-4691 (TTY)

TENNESSEE
Middle Tennessee Poison Center
The Center for Clinical Toxicology
501 Oxford House
1161 21st Avenue South
Nashville TN 37232
Emergency: (800) 288-9999 (TN only)
(615) 936-2034 (Greater Nashville)
TDD/TTY: (615) 936-2047 (TDD)

Southern Poison Center
875 Monroe Avenue
Suite 104
Memphis TN 35163
Emergency: (800) 288-9999 (TN only)
(901) 528-6048

TEXAS
Central Texas Poison Center
Scott and White Memorial Hospital
2401 South 31st Street
Temple TX 76508
Emergency: (800) POISON-1 (TX only)
(254) 724-7401

North Texas Poison Center
Texas Poison Center Network
Parkland Health and Hospital System
5201 Harry Hines Blvd.
P.O. Box 35926
Dallas TX 75235
Emergency: (800) POISON-1 (TX only)

South Texas Poison Center
The University of Texas Health Science Center-San Antonio
Forensic Science Building, Room 146
Department of Surgery
7703 Floyd Curl Drive
San Antonio TX 78284
Emergency: (800) 764-7661 (TX only)

Southeast Texas Poison Center
The University of Texas Medical Branch
3.112 Trauma Building
Galveston TX 77555
Emergency: (800) 764-7661 (TX only)
(409) 765-1420

TEXAS (continued)
Texas Panhandle Poison Center
1501 S. Coulter
Armarillo TX 79106
Emergency: (800) 764-7661 (TX only)

West Texas Regional Poison Center
Thomason Hospital
4815 Alameda Aveue
El Paso TX 79905
Emergency: (800) 764-7661 (TX only)

UTAH
Utah Poison Control Center
410 Chipeta Way, Suite 230
Salt Lake City UT 84108
Emergency: (800) 456-7707 (UT only)
(801) 581-2151

VERMONT
Vermont Poison Center
Fletcher Allen Health Care
111 Colchester Avenue
Burlington VT 05401
Emergency: (877) 658-3456 (toll free)

VIRGINIA
Blue Ridge Poison Center
University of Virginia Health System
PO Box 800774
Charlottesville VA 22908
Emergency: (800) 451-1428 (VA only)

National Capitol Poison Control Center
3201 New Mexico Avenue, NW
Suite 310
Washington DC 20016
Emergency: (202) 625-3333
TDD/TTY: (202) 362-8563 (TTY)

Virginia Poison Center
Medical College of Virginia Hospitals
Virginia Commonwealth University
PO Box 980552
Richmond VA 23298
Emergency: (800) 552-6337

WASHINGTON
Washington Poison Center
155 NE 100th Street, Suite 400
Seattle WA 98125
Emergency: (800) 732-6985 (WA only)
(206) 526-2121
TDD/TTY: (206) 517-2394 (TDD)
(800) 572-0638 (TDD WA only)

WEST VIRGINIA
West Virginia Poison Center
3110 MacCorkle Ave., S.E.
Charleston WV 25304
Emergency: (800) 642-3625 (WV only)

WISCONSIN
Children's Hospital of Wisconsin Poison Center
PO Box 1997
Milwaukee WI 53201
Emergency: (800) 815-8855 (WI only)
(608) 262-3702

WYOMING
The Poison Center
Children's Hospital
8301 Dodge Street
Omaha NE 68114
Emergency: (800) 955-9119 (NE and WY only)
(402) 354-5555

ANIMAL POISON CENTER
ASPCA
National Animal Poison Control Center
1717 South Philo Road
Suite 36
Urbana IL 61802
Emergency: (888) 426-4435
(900) 680-0000

Appendix II

Association of Occupational and Environmental Clinics

Association of Occupational and Environmental Clinics (AOEC)

Professionals in the AOEC act as consultants for treatment of persons exposed to hazardous substances.

ALABAMA
University of Alabama at Birmingham
930 20th Street South
Birmingham, AL 35205
(205) 975-2767; FAX (205) 975-4377
Timothy J. Key, MD, MPH

ARIZONA
Samaritan Occupational and Environmental Toxicology Clinic
Department of Medical Toxicology
925 E. McDowell Rd., Second Floor
Phoenix AZ 85006
(602) 239-6690; FAX (602) 239-4138
Kevin Wallace, MD

CALIFORNIA
Occupational & Environmental Medicine Clinic
University of California at San Francisco/SFGH
Building 30, 5th floor,
1001 Potrero Avenue
SanFrancisco CA 94110
(415) 206-4320; FAX (415) 206-8949
Patricia Quinlan, MPH, CH
Alt. Contact:
Denise Souza, RN, MSN, OHNP, COHN-S

UCSF Occupational Health Services
University of California at San Francisco
2380 Sutter Street, 3rd Floor
San Francisco, CA 94115
(415) 885-7580; FAX (415) 771-4472
Robert Harrison, MD, MPH
Alt. Contact: Leslie Israel, DO, MPH

Occupational & Environmental Health Clinic
Employee Health Services
University of California, Davis Medical Center
Primary Care Building, Suite A
2221 Stockton Blvd.
Sacramento CA 95817
(916) 734-8393; FAX (916) 734-7510
Appointments: (916) 734-8393
Stephen McCurdy, MD, MPH

Occupational & Health Environmental Clinic
University of California at Irvine
Center for Occupational and Environmental Health
19722 MacArthur Blvd.
Irvine CA 92715
(949)-824-8641; FAX (949) 824-2345
Dean Baker, MD, MPH

COLORADO
Division of Environmental & Occupational Health Sciences
National Jewish Medical Research Center Center
1400 Jackson Street
Denver CO 80206
(303) 398-l520; FAX (303) 398-l452
Appointments (303) 398-1733
Peggy Mroz, MSPH
Alt. Contact: Cecile Rose, MD, MPH

Toxicology Associates
2555 S. Downing Street #260
Denver CO 80210
(303) 765-3800; FAX (303) 765-3804
Scott Phillips, MD, FACP

CONNECTICUT
Yale Occupational & Environmental Medicine Program
135 College Street, 3rd Floor
New Haven, CT 06510
(203) 785-7267; FAX (203) 785-7391
Mark R. Cullen, MD
Alt. Contact: Peter M. Rabinowitz, MD, MPH

University of Connecticut
Occupational and Environmental Medicine Program
263 Farmington Avenue
Farmington, CT 06030
(860) 679-2893; FAX (860) 679-4587
Eileen Storey, MD, MPH

CALIFORNIA (continued)

CONNECTICUT (continued)
Northwest Connecticut Occupational Medical Center
333 Kennedy Drive, Suite 202
Torrington CT 06790
(860) 482-4552; FAX (860) 489-4647
Gregory E. McCarthy, MD

DISTRICT OF COLUMBIA
Division of Occupational and Environmental Medicine
School of Medicine, George Washington University
2300 K Street, NW
Washington, DC 20037
(202) 994-1734; FAX (202) 994-0011
Tee L. Guidotti, MD, MPH
Alt. Contact: Katherine Hunting, PhD, MPH

Section of Occupational & Environmental Medicine
Washington Hospital Center
110 Irving St., NW
Washington, DC 20010-2975
(202) 877-5466; FAX (202) 877-4136
Laura Welch, MD

GEORGIA
Environmental and Occupational Medicine Consultative Clinic
The Emory Clinic
1525 Clifton Road, NE, Rm 404
Atlanta, GA 30322
(404) 778-5978; FAX (404) 727-8744
Howard Frumkin, MD, Dr. PH

ILLINOIS
Occupational Medicine Clinic
Cook County Hospital
1900 W. Polk, Rm 500
Chicago IL 60612
(312) 633-5310; FAX (312) 633-6442
Rachel Rubin, MD, MPH
Alt. Contact :Ann Naughton, RN, MPH, COHN

University of Illinois Occupational Medicine Program
914 S. Wood, M/C 684
Chicago IL 60612
(312) 996-7420; FAX (312) 413-8485
Linda Forst, MD, MPH

IOWA
University of Iowa, Occupational Medicine Clinic
Department of Internal Medicine, College of Medicine
200 Hawkins Drive, C33-GH
Iowa City, IA 52242
(319) 356-4419; FAX (319) 356-7147
Gary Hunninghake, MD

KENTUCKY
University of Kentucky Occupational Medicine Program
2400 Greatstone Point
Lexington, KY 40504
(606) 257-5150; FAX (606) 257-8982
Terrence Collins, MD, MPH

LOUISIANA
Ochsner Center for Occupational Health
1514 Jefferson Highway
New Orleans, LA 70121
(504) 842-3955; FAX (504) 842-3977
Gregg A. Bendrick, MD, MPH
Alt. Contact: Lori Brown

Tulane Centers for Occupational Health
1415 Tulane Avenue, Box HC31
New Orleans LA 70112
(540) 736-5333; FAX (504) 736-4835
Douglas A. Swift, MD, MPH

MARYLAND
Johns Hopkins University
Center for Occupational and Environmental Health
5501 Hopkins Bayview Circle
Baltimore, MD 21224
(410) 550-2322; FAX (410) 550-3355
Edward J. Bernacki, MD, MPH

Occupational Health Project
University of Maryland School of Medicine
405 Redwood Street
Baltimore, MD 21201
(410) 706-7464; FAX (410) 706-4078
Janie Gordon, ScM

MASSACHUSETTS
Caritas Good Samaritan Occupational Health Services
Merchants Building
75 Stockwell Dr.
Avon MA 02322
(508) 427-3900; FAX (508) 427-3905
Robert Naparstek, MD

Center for Occupational and Environmental Medicine
Massachusetts Respiratory Hospital
2001 Washington Street
South Braintree, MA 02184
(781) 848-2600; FAX (718) 849-3290
Dianne Plantamura, MSW, Coordinator
Alt. Contact: David Christiani, MD, MPH, MS

Occupational Health Program
Department of Family and Community Medicine
University of Massachusetts
55 Lake Avenue North
Worcester, MA 10655
(508) 856-2818; FAX (508) 856-l 680
Tom Hicks, MD, MPH

Occupational and Environmental Health Center
Cambridge Hospital
1493 Cambridge Street
Cambridge, MA 02139
(617) 665-1580; FAX (617) 665-1671
Rose Goldman, MD, MPH

Occupational & Environmental Health Center
Children's Hospital
300 Longwood Ave
Boston MA 02115
(617) 355-8177; FAX (617) 738-0032
Michael Shannon, MD, MPH
Alt. Contact: Alan Woolf, MD, MPH

MICHIGAN
Michigan State University
Department of Medicine
117 Est Fee
East Lansing, MI 48824
(517) 353-1846; FAX (517) 432-3606
Appointments: (517) 353-4941
Kenneth Rosenman, MD

MICHIGAN (continued)
Division of Occupational and Environmental Health
Wayne State/Department of Family Medicine
4201 Street Antoine, Suite 4J
Detroit, Ml 48201
(313) 577-l 420; FAX (313) 577-3070
Appointments/Clinic: (313) 745-4093
Maryjean Schenk, MD, MPH

Occupational Health Program
School of Public Health, University of Michigan
1420 Washington Heights
Ann Arbor, Ml 48109
(734) 764-2594; FAX (734) 763-8095
David Garabrant, MD, MPH
Alt. Contact: Alfred Franzblau, MD

Center for Occupational and Environmental Medicine
22255 Greenfield Rd., Suite 440
Southfield, MI 48075
(248) 559-6663; FAX (248) 559-8254
Laura Harbut, EMT, MBA

Occupational Health Service
St. Lawrence Hospital Work and Health Institute
1210 W. Saginaw
Lansing, MI 48915
(517) 377-0309; FAX (517) 377-0310
R. Michael Kelly, MD, MPH

MINNESOTA
HealthPartners-Regions Hospital
Occupational & Environmental Medicine
640 Jackson St.
St. Paul, MN 55101-2595
(651) 221-3771; FAX (651) 221-8848
Paula Geiger
Alt. Contact: William H. Lohman, MD

Columbia Park Medical Group
Occupational Medicine Department
6401 University Ave., NE #200
Minneapolis MN 55432
(612) 572-5710; FAX (612) 571-3008
Donald Johnson, MD
Alt. Contact: Dorothy Quick

NEW JERSEY
Environmental and Occupational Health Clinical Center
Environmental and Occupational Health Sciences Institute
UMDNJ-Robert Wood Johnson Medical School
170 Frelinghuysen Rd.
Piscataway, NJ 08854
(732) 445-0123; FAX (732) 445-0127
Howard Kipen, MD, MPH
Alt. Contact: Gail Buckler, RN, MPH, COHN-S

NEW MEXICO
Presbyterian Occupational Medicine Clinic
5901 Harper, NE
PO Box 26666
Albuquerque NM 87125
(505) 823-8450; FAX (505) 823-8484
William I. Christensen, MD, MPH

Occupational and Environmental Medicine Clinic
2400 Tucker NE, Rm 177
Albuquerque NM 87131
(505) 272-2900; FAX (505) 272-4494
Karen B. Mulloy, DO, MSCH

NEW YORK
Eastern NY Occupational & Environmental Health Center
155 Washington Avenue
Albany NY 12210
(518) 436-5511; FAX (518) 436-9110
Anne Tencza, BS, RN, COHN-S
Alt. Contact: Eckardt Johanning, MD

Mount Sinai -Irving J. Selikoff Center for Occupational and Environmental Medicine
P.O. Box 1058
Gustave Levy Place
New York, NY 10029
(212) 241-0176; FAX (212) 996-0407
Appointments: (212) 987-6043
Stephen Mooser, MPH
Alt. Contact: Stephen Levin, MD

NEW YORK (continued)
Center for Occupational & Environmental Medicine
School of Medicine
Health Sciences Center, Level 3-086
University at Stony Brook
Stony Brook, NY 11794
(516) 444-2196; FAX (516) 444-7525
Wajdy Hailoo, MD, Msc, DIH

Central NY Health Clinical Center
6712 Brooklawn Parkway
Suite 204
Syracuse, NY 13211
(315) 432-8899; FAX (315) 431-9528
Michael B. Lax, MD, MPH

New York University/Bellevue Hospital Occupational and Environmental Medicine Clinic
Bellevue Hospital, Room CD 349
462 1st Avenue
New York, NY 10016
(212) 562-4572; FAX (212) 562-4574
George Friedman-Jimenez, MD

Finger Lakes Occupational Health Services
980 Westfall Road, Suite 210
Rochester NY 14618
(716) 256-0843; FAX (716) 256-2271
Deanna Woodhams, MA

NORTH CAROLINA
Division of Occupational and Environmental Medicine
Duke University Medical Center
Box 3834
Durham, NC 27710
(919) 286-3232; FAX (919) 286-1021
Dennis J. Darcey, MD, MSPH
Alt. Contact: Gary Greenberg, MD, MPH

OHIO
Community Health Partners Occupational Health Center
The Lorain Clinic for Occupational Medicine &

Rehabilitation
1800 Livingston Ave
Lorain OH 44052
(440) 233-1068; FAX (440) 246-4560
Kathleen Fagan, MD, MPH
Alt. Contact: Ann Wise, MD

Center for Occupational Health
Holmes Hospital-Tate Wing
University of Cincinnati College of Medicine
Eden and Bethesda Avenue
Cincinnati, OH 45267
(513) 584-1234; FAX (513) 584-1010
James Donovan, MD, MS
Alt. Contact: Susan Pinney, MD

OKLAHOMA
University Occupational Health Services
Division of Occupational and Environmental Medicine
Oklahoma Memorial Hospital
900 NE 10th Street, #2400
Oklahoma City, OK 73104
(405) 271-6177; FAX (405) 271-4125
David Paul, MD, MPH

OREGON
Occupational Health Program
Oregon Health Sciences University (OHSU)
3181 SW Sam Jackson Park Rd.
Mail Code OP-20C
Portland OR 97201
(503) 494-1027; FAX (503) 494-4457
Nina Wolf, RN, BSN, COHN-S

PENNSYLVANIA
Occupational and Environmental Medicine Program
University of Pittsburgh
3708 Fifth Avenue, Suite 401,
Medical Arts Bldg.
Pittsburgh, PA 15261
(412) 647-5360; FAX (412) 647-1140
Joseph J. Schwerha, MD, MPH

PENNSYLVANIA (continued)
University of Pennsylvania School of Medicine
Occupational Medicine-Silverstein Pavilion
3400 Spruce Street
Philadelphia, PA 19104
(215) 349-5708; FAX (215) 662-3953
Appointments: (215) 662-2354
Edward A. Emmett, MD

Center for Occupational and Environmental Health
Abington Memorial Hospital
2510 Maryland Road, Suite 101
Willow Grove, PA 19090
(215) 481-5909; FAX (215) 481-5920
Lora S. Regan, MD, MPH

TENNESSEE
Occupational and Environmental Medicine Clinic
Meharry Medical College
1005 D.B. Todd Boulevard
Nashville TN 37208
(615) 327-6736; FAX (615) 327-6717
Otis Cosby, MD, MPH
Alt. Contact: Herman Ellis, MD, MPH

TEXAS
Texas Institute of Occupational Safety & Health
11937 U.S. Highway 271
Tyler, TX 75708
(903) 877-5900; FAX (903) 877-7982
Jeffrey Levin, MD, MPH

University of Texas Health Services
7000 Fannin, Suite 1620
Houston TX 77030
(713) 500-3267; FAX (713) 500-3263
Thomas Mackey, RNC, PhD

UTAH
Rocky Mountain Center for Occupational and Environmental Health
75 South 2000 East
University of Utah
Salt Lake City, UT 84112
(801) 581-3841; FAX (801) 581-7224
Appointments: (801) 581-5056
Anthony Suruda, MD, MPH
Alt. Contact: Royce Moser, MD, MPH

VIRGINIA
Carillon Occupational Medicine
Falin Center
903 S. Jefferson Street
Roanoke, VA 24016
(540) 985-9820; FAX (540) 985-8118
Elaine Gill
Alt. Contact: Hetzal Hartley, MD, MPH

WASHINGTON
Occupational and Environmental Medicine Program
University of Washington Harborview Medical Center
325 9th Avenue, #359739
Seattle, WA 98104
(206) 731-3005; FAX (206) 731-8247
Drew Brodkin, MD, MPH
Alt. Contact: Scott Barnhart, MD, MPH

WEST VIRGINIA
Division of Occupational & Environmental Health
Department of Family and Community Medicine
Marshall University School of Medicine
1600 Medical Center
Huntington, WV 25755
(304) 691-1178; FAX (304) 691-1153
Chris McGuffin, MSCH, MSOSH
Alt. Contact: James Becker, MD

WEST VIRGINIA (continued)
Institute of Occupational & Environmental Health
West Virginia University School of Medicine
3801 Robert F. Byrd health Science Center South
Morgantown WV 26506
(304) 293-3693; FAX (304) 293-2629
Alan Ducatman, MD, Msc

CANADIAN CLINICS

ALBERTA
Occupational Medicine Consultation Clinic
University of Alberta
13-103 Clinical Science Bldg.
Edmonton Alberta, CD T6G 2G3
(780) 492-6291; FAX (780) 492-0364
Jim Cheng, MD

MANITOBA
MFL Occupational Health Centre, Inc.
102-275 Broadway
Winnipeg, Manitoba, CD R3C 4M6
(204) 949-0811; FAX (204) 956-0848
Shiela Braidek

ONTARIO
Occupational Health Clinics for Ontario Workers
15 Gervais Drive, Suite 308
Toronto ON, Canada M3C 1Y8
(416) 449-0009; FAX (416) 449-7772
Andrew King, Executive Director

Occupational Health Clinics for Ontario Workers
848 Main Street East
Hamilton ON, Canada L8M 1L9
(905) 549-2552; FAX (905) 549-7993
Chuck Emberson, Executive Director

Occupational Health Clinics for Ontario Workers
1780 Regent Street South
Times Square Mall
Sudbury ON, Canada P3C 3Z8
(705) 523-2330; FAX (705) 522-8957
Donna Campbell, Executive Director

ONTARIO (continued)
Occupational Health Clinics for Ontario Workers
547 Victoria Ave.
Windsor ON, Canada N9A 4N1
(519) 973-4800; FAX (519) 973-1906
Jim Brophy, Executive Director

Occupational Health Clinics for Ontario Workers
171 Kendall St.
Point Edward ON, Canada N7V 4G6
(519) 337-4627;
Jim Brophy, Executive Director

PEDIATRIC ENVIRONMENTAL HEALTH SPECIALITY UNITS

CALIFORNIA
The University California-San Francisco/ University of California-Irvine Pediatric Environmental Health Speciality Unit
Contact: (415) 206-4320*
Contact for both sites-San Francisco and Irvine

GEORGIA
The Southeast Pediatric Environmental Health Speciality Unit
Emory University
Atlanta GA
(877) 33PEHSU (877-337-3478)

ILLINOIS
Pediatric Environmental Health Center
Cook County Hospital
Chicago IL
(312) 633-5310

MASSACHUSETTS
Pediatric Environmental Health Center at
Children's Hospital
Occupational and Environmental Health Center
at Cambridge Hospital
Boston MA
(888) CHILD14 (888-244-5314)

NEW YORK
Mt. Sinai Pediatric Environmental Health Unit
Mt. Sinai-Irving J Selikoff Center for
Occupational and Environmental Medicine
New York NY
(212) 241-6173

WASHINGTON
Children's Environmental Health Center
University of Washington Occupational and
Environmental Medicine Program
Seattle WA
(877) KID-CHEM (877-543-2463)

ALBERTA
Pediatric Environmental Health Clinic
Misericordia Child Health Centr
Edmonton AB
(780) 930-5794

Appendix III

State Health Departments

State Health Departments

Alabama Department of Public Health
The RSA Tower, Suite 1552
201 Monroe Street
Montgomery, AL 36130
(334) 206-5200

Alaska Department of Health and Social Services
Alaska Office Building
PO Box 110610
Juneau, AK 99811-0610
(907) 465-3090

American Samoa Department of Health
Government of American Samoa
LBJ Tropical Medical Center
Pago Pago AS 96799
011-684-6334606

Arizona Department of Health Services
1740 W. Adams Street, Room 407
Phoenix, AZ 85007
(602) 542-1025

Arkansas Department of Health
4815 W. Markham Street
Little Rock, AR 72205-3867
(501) 661-2417

California Department of Health Services
714 P Street
Sacramento, CA 95814
(916) 657-1431

Colorado Department of Public Health and Environment
4300 Cherry Creek Drive South
Denver, CO 80246
(303) 692-2011

Connecticut Department of Public Health
410 Capitol Avenue
Hartford, CT 06134
(860) 509-7101

Delaware Division of Public Health
Jesse Cooper Bldg.
PO Box 637
Dover, DE 19903
(302) 739-4700

District of Columbia Department of Health
825 North Capitol St., NW, Suite 4400
Washington, DC 20002
(202) 442-5999

Florida Department of Health
2585 Merchants Row Blvd., Suite 140
Tallahassee, FL 32399
(850) 245-4321

Georgia Department of Human Resources
2 Peachtree Street NW, Suite 15-470
Atlanta, GA 30303
(404) 657-2700

Guam Department of Public Health and Social Services
PO Box 2816
Agana, GU 96910
011-671-7357102

Hawaii Department of Health
1250 Punchbowl Street
PO Box 3378
Honolulu, HI 96813
(808) 586-4410

Idaho Department of Health and Welfare
450 W. State Street, Box 83720
Boise, ID 83720
(208) 334-5945

Illinois Department of Public Health
535 W. Jefferson Street
Springfield, IL 62761
(217) 782-4977

Indiana Department
2 North Meridan
Indianapolis, IN 46204
(317) 233-7400

Iowa Department of Public Health
Lucas State Office Bldg.
312 E. 12th Street
Des Moines, IA 50319
(515) 281-5605

Kansas Department of Health and Environment
900 SW Jackson, 6th Floor
Topeka, KS 66612
(785) 296-1086

Kentucky Department for Health Services
275 E. Main Street
Frankfort, KY 40621
(502) 564-3970

Louisiana Department of Health and Hospitals
PO Box 3214
Baton Rouge, LA 70821
(225) 342-8093

Maine Bureau of Health
Department of Human Services
State House Station #11
Augusta, ME 04333
(207) 287-8016

Maryland Department of Health and Mental Hygiene
201 W. Preston Street, Suite 500
Baltimore, MD 21201
(410) 767-6505

Massachusetts Department of Public Health
250 Washington Street, 2nd Floor
Boston, MA 02108
(617) 624-5200

Michigan Department of Community Health
3423 N. Martin Luther King, Jr. Blvd
PO Box 30195
Lansing, Ml 48909
(517) 335-8024

Micronesia Government of the Federal States of Micronesia
P.O. Box PS 70, Palikir Stn
Pohnpei FM 96941
011-691-3202619

Minnesota Department of Health
85 East 7th Place, Suite 400
St. Paul, MN 55101
(651) 251-5813

Mississippi State Department of Health
PO Box 1700
2423 N. State Street
Jackson, MS 39215
(601) 960-7634

Missouri Department of Health
920 Wildwood Drive
Jefferson City, MO 65102
(573) 751-6002

Montana Department of Health and Human Services
111 North Sanders, 3rd Floor
Helena, MT 59604
(406) 444-5622

North Mariana Islands
Department of Public Health
P.O. Box 409, CK
Saipan MP 96950
(670) 234-8950

Nebraska Department of Regulation and Licensure
PO Box 95007
Lincoln, NE 68509
(402) 471-8566

Nevada State Health Division
Nevada Department of Human Resources
505 E. King Street, Room 201
Carson City, NV 89701
(775) 684-4200

New Hampshire Department of Health and Human Services
6 Hazen Drive
Concord, NH 03301
(603) 271-8560

New Jersey Department of Health and Senior Services
PO Box 360, Room 805
Trenton, NJ 08625
(609) 292-7837

New Mexico Health
1190 St. Francis Drive
Santa Fe, NM 87502
(505) 827-2613

New York Department of Health
Corning Tower Building, 14th Floor
Empire State Plaza
Albany, NY 12237
(518) 474-2011

North Carolina Department of Environment,

Health and Natural Resources
Division of Health Services
101 Blair Drive
Adams Building
Raleigh, NC 27626
(919) 733-4392

North Dakota Department of Health
600 E. Boulevard Avenue
Bismark, ND 58505-0200
(701) 328-2372

Ohio Department of Health
246 N. High Street
PO Box 118
Columbus, OH 43266-0588
(614) 466-2253

Oklahoma State Department of Health
1000 NE 10th Street
Oklahoma City, OK 73117
(405) 271-4200

Oregon Department of Human Services
800 NE Oregon Street, #21
Portland, OR 97232
(503) 731-4000

Pennsylvania Department of Health
PO Box 90, Room 802.
Harrisburg, PA 17108
(717) 787-6436

Puerto Rico Department of Health
PO Box 70184
San Juan, PR 00936
(787) 274-7600

Rhode Island Department of Health
3 Capitol Hill
Providence, RI 02908
(401) 222-2231

South Carolina Department of Health and Environmental Control
2600 Bull Street
Columbia, SC 29201
(803) 898-3300

South Dakota State Department of Health
600 East Capitol
c/o 500 East Capitol
Pierre, SD 57501
(605) 773-3361

Tennessee Department of Health
3rd Floor, Cordell Hull Bldg.
425 5th Avenue N
Nashville, TN 37247-0101
(615) 741-3111

Texas Department of Health
1100 W. 49th Street
Austin, TX 78756
(512) 458-7376

Utah Department of Health
288 North 1460 West
PO Box 142802
Salt Lake City, UT 84114
(801) 538-6111

Vermont Department of Health
PO Box 70
Burlington, VT 05402
(802) 863-7280

Virgin Islands Social and Health Services
48 Sugar Estate
St. Thomas, VI 00802
(340) 774-0117

Virginia Department of Health
1500 East Main Street
PO Box 2448
Richmond, VA 23219
(804) 786-3561

Washington State Department of Health
1112SE Quince Street, Mail Stop 7890
Olympia, WA 98504-7890
(360) 236-4015

West Virginia Department of Health and Human Services
1900 Kanawha Blvd., Bldg. 3, Room 518
Charleston, WV 25305
(304) 558-2971

Wisconsin Division of Health
PO Box 309
Madison, WI 53701-0309
(608) 266-1511

Wyoming Department of Health
117 Hathaway Bldg.
Cheyenne, WY 82002
(307) 777-7656

Appendix IV

Consultation Resources

Consultation Resources

American College of Occupational and Environmental Medicine
114 N. Arlington Heights Road
Arlington Heights, IL 60004
(847) 818-1800

American Board of Medical Toxicology
Heather Miller, Executive Director
777 E. Park Drive
PO Box 8820
Harrisburg PA 17105-8820
(717) 558-7846

Association of Occupational and Environmental Clinics
Katherine Kirkland, Executive Director
1010 Vermont Avenue
Suite 513
Washington, DC 20005
(202) 347-4976

The Association of Occupational and Environmental Clinics (AOEC) is a network of clinics affiliated with medical schools throughout the U.S. Member clinics provide professional training, community education about toxic substances, exposure and risk assessment, clinical evaluations, and consultation. A lending library of training materials is maintained for use by members. Membership is open to any person who shares the goals of the Association. Clinicians can contact the AOEC office for referrals.

Teratogen Exposure Registry and Surveillance (TERAS)
Frederick Bieber, Ph.D.
Department of Pathology
Brigham and Women's Hospital
75 Francis Street
Boston, MA 02115
(617) 732-6507

TERAS is a network of geneticists and pathologists studying human embryos and fetuses exposed to teratogens. TERAS maintains information networks for consultation and evaluations.

University programs in occupational health, industrial hygiene, or toxicology
Schools of public health or schools of medicine at universities function as resources to local communities. In addition, some hospitals have occupational or environmental health clinics that accept referrals.

MotherRisk Program

Gideon Koren, M.D., Director
Hospital for Sick Children
555 University Avenue
Toronto, Ontario M5G lX8
(416) 813-6780

The MotherRisk Program will counsel callers about t he safety of an exposure to drugs, chemicals, or radiation during pregnancy or breast feeding. The team of physicians and information specialists give advice on whether medications, X-rays, or chemicals in the work environment will harm the developing fetus or breast-fed baby. Genetic counseling is available from the Hospital for Sick Children's Genetic Department.

State/Federal/National Resources

Chemical Emergencies

National Response Center
(800) 424-8802
http://nrc.uscg.mil/index.htm

Hazardous Waste

Emergency Planning and Community Right-To-Know Hotline (EPA)
Developing chemical contingency plans, gathering site-specific information, list of more than 400 acutely toxic chemicals
(800) 535-0202
http://www.epa.gov/epaoswer/hotline/index.htm

Superfund Order and Information Line
Provides information about Superfund Records of Decision-hazardous waste sites to be cleaned up, actions being taken
(800) 775-5037
http://www.epa.gov/superfund/sites/phonefax/index.htm

Integrated Risk Information System (IRIS)
Hazardous chemicals information, including health effects
(513) 569-7254
http://www.epa.gov/iris/

IRIS User Support
(513) 569-7254

Lung Disease

Lungline/National Jewish Hospital
Information on lung disease from chemical exposure
(800) 222-5864
http://www.NationalJewish.org

Lead

National Center for Environmental Health and Injury Control (CDC)
Lead poisoning prevention
(404) 488-4880
http://www.cdc.gov

Child and Maternal Health Clearinghouse
Publications on lead poisoning
(888) 434-4MCH
http://www.nmchc.org/

Occupational Health

NIOSH
Information and publications on health effects of occupational exposures
(800) 356-4674
http://www.cdc.gov.niosh/homepage.html

Medical Section/Diagnosis and Treatment
(513) 841-4388

Industrial Hygiene
(513) 841-4374

OSHA (Occupational Safety and Health Administration)
Regulations for toxic and hazardous substances in the workplace
For emergencies: (800) 321-6742
For other inquires: (202) 693-1999
http://www.osha.gov

Pesticides

National Pesticide Hotline
(800) 858-7378
http://www.growinglifestyle.com/article/73p5/a1656.html

National Pesticide Telecommunications Network
(800) 858-7378
http://ace.orst.edu/info/nptn/

National Pesticide Information Retrieval System (NPIRS)
Help number for searching NPIRS database to get fact sheets on pesticides, insecticides, fungicides, state and federally registered chemicals. Funded by EPA/USDA, managed by Purdue University
(765) 494-6616
http://ceris.purdue.edu/npirs/npirs.html

Radon

Radon Hotline
(800) SOS-RADON
http://www.epa.gov/iaq/radon/index.html

EPA Radon Information Center
(800) 438-4318
http://www.epa.gov/iaq/iaqinfo.html

Toxic Substances

Toxicology Information Response Center (Oak Ridge)
General toxics information, searches on chemicals
(865) 576-1746
http://www.ornl.gov/TechResources/tirc/hmepg.html

Agency for Toxic Substances and Disease Registry (ATSDR)
Emergency Response Section. Rapid assistance provided about health issues from chemical exposures.
(404) 639-0615 (24 hours)
(404) 639-6360 (24 hours)
(404) 639-6363 (fax)
http://www.atsdr.cdc.gov/

Toxic Substances Control Act (TSCA) Hotline/Public Information Office (EPA)
Answers questions and gives general technical assistance on TSCA. Guidance on TSCA regulations
(202) 554-1404
Http://es.epa.gov/oeca/ccsmd/tsca.html

Toxic Chemical Release Inventory System (EPA)
Information about which chemicals are used, stored, released by companies
(800) 535-0202
http://toxnet.nlm.nih.gov

CHEMTREC (Chemical Manufacturers Association)
Nonemergency health and safety information on chemicals
(800) 282-8200
http://memberexchange.cmahq.com/chemtrec.nsf

Water

EPA Safe Drinking Water Hotline
(800) 426-4791
www.epa.gov.safewater

Chemical Glossary

Chemical Formula	*Structural Formula*	*Chemical Name*
AsH_3	AsH_3	Arsine
As_2O_3	As_2O_3	Arsenic trioxide
$CHCl_2NO$	$ClC[NOH]Cl$	Phosgene oxime
CHN	HCN	Hydrogen cyanide
CH_2Cl_2	CH_2Cl_2	Methylene chloride
CH_2O	HCHO	Formaldehyde
CH_3Br	CH_3Br	Methyl bromide
C_2Cl_4	Cl_2CCCl_2	Tetrachloroethylene
C_2HCl_3	$ClCHCCl_2$	Trichloroethylene
C_2H_3Cl	CH_2CHCl	Vinyl chloride
$C_2H_3Cl_3$	CH_3CCl_3	1,1,1-Trichloroethane
C_2H_4O	$[CH_2]_2O$	Ethylene oxide
$C_2H_6O_2$	$HO[CH_2]_2OH$	Ethylene glycol
C_3H_3N	CH_2CHCN	Acrylonitrile
C_4H_6	$CH_2[CH]_2CH_2$	1,3-Butadiene
C_6H_6	C_6H_6	Benzene
C_6H_6O	C_6H_5-OH	Phenol
C_6H_7N	$C_6H_5NH_2$	Aniline
C_7H_8	C_6H_5-CH_3	Toluene
C_8H_{10}	CH_3-C_6H_4-CH_3	Xylene
$C_9H_6N_2O_2$	$CH_3C_6H_3[NCO]_2$	Toluene diisocyanate
$C_{10}H_6Cl_8$	$C_{10}H_6Cl_8$	Chlordane
$C_{10}H_{14}NO_5PS$	$[C_2H_5O]_2P[S]OC_6H_4NO_2$	Parathion
$COCl_2$	$COCl_2$	Phosgene
Cl_2	Cl_2	Chlorine
HCl	HCl	Hydrogen chloride
HF	HF	Hydrogen fluoride
Hg	Hg	Mercury
H_2O_2	H_2O_2	Hydrogen peroxide
H_2S	H_2S	Hydrogen sulfide
NH_3	NH_3	Ammonia
NO_x	NO_x	Nitrogen oxides
PH_3	PH_3	Phosphine
NaOH	NaOH	Sodium hydroxide
SO_2	O_2S	Sulfur dioxide

Chemical Index

Listed below are names of chemical protocols and their synonyms. Subjects of chemical protocols are in boldface italics (e.g., ***Arsine***)

Acetylene trichloride *See* Trichloroethylene
Acrylonitrile
Alkron *See* Parathion
Alleron *See* Parathion
Aminobenzene *See* Aniline
Aminophen *See* Aniline
Ammonia
Ammonia gas *See* Ammonia
Ammonia solution *See* Ammonia
Ammonium hydroxide *See* Ammonia
Amprolenne *See* Methylene oxide
AN *See* Acrylonitrile
Anammonide *See* Hydrogen cyanide
Anhydrous ammonia *See* Ammonia
Aniline
Aqueous ammonia *See* Ammonia
Arsenic hydride *See* Arsine
Arsenic trihydride *See* Arsine
Arsenic trioxide
Arseniuretted hydrogen *See* Arsine
Arsenous acid *See* Arsenic trioxide
Arsenous oxide *See* Arsenic trioxide
Arsenous hydride *See* Arsine
Arsine
Arylamine *See* Aniline
Benzene
Benzenamine *See* Aniline
Benzenol *See* Phenol
Benzol *See* Benzene
Bis(beta-chloroethyl) sulfide *See* Blister agent (H, HD, HT)
Bis(2-chloroethyl) sulfide *See* Blister agent (H, HD, HT)
Bis(2-chloroethyl)ethylamine *See* Blister agent (HN1, HN2, HN3)
Bis(2-chloroethyl)methylamine *See* Blister agent (HN1, HN2, HN3)
Blister Agent (H, HD, HT)
Blister Agent (HN1, HN2, HN3)
Blister Agent (HL, L)
Bromoethane *See* Methyl bromide
1,3-Butadiene
Bivinyl *See* 1,3-Butadiene
C-100 *See* Chlordane
Carbolic acid *See* Phenol
Carbon oxychloride *See* Phosgene
Carbonic acid dichloride *See* Phosgene
Carbonic dichloride *See* Phosgene
Carbonyl chloride *See* Phosgene
Caustic soda *See* Sodium hydroxide
Caryolysin *See* Blister agent (HN1, HN2, HN3)
CD-68 *See* Chlordane
Chlordan *See* Chlordane
Chlordane
Chlorine
Chlor-Kil *See* Chlordane
Chlormethine *See* Blister agent (HN1, HN2, HN3)
1-Chloro-2(beta-chloroethylthio)ethane *See* Blister agent (H, HD, HT)
2-Chloro-N-(2-chloroethyl)-N-ethylethanamine *See* Blister agent (HN1, HN2, HN3)
Chloroethene *See* 1,1,1-Trichloroethane
Chloroethylene *See* vinyl chloride
Chloroformyl chloride *See* Phosgene
Chlorohydric acid *See* Hydrogen chloride
2-Chloro-N,N-bis(2-chloroethyl)ethanamine *See* Blister agent (HN1, HN2, HN3)
Coal tar naptha *See* Benzene
CX *See* Phosgene oxime
Cyanocthylene *See* Acrylonitrile
Cyclohexatriene *See* Benzene
Danthion *See* Parathion
2,2'-Dichloroethyl sulfide *See* Blister agent (H, HD, HT)
Di-2-chloroethyl sulfide *See* Blister agent (H, HD, HT)
Dichloromethane *See* Methylene chloride
2,2'-Dichloro-N-methyldiethylamine *See* Blister agent (HN1, HN2, HN3)
Dichloren *See* Blister agent (HN1, HN2, HN3)
Dichloroformoxime *See* Phosgene oxime.
2,2'-Dichlorotriethylamine *See* Blister agent (HN1, HN2, HN3)
Dihydrogen dioxide *See* Hydrogen peroxide
Dihydrogen sulfide *See* Hydrogen sulfide
Diisocyanatotoluene *See* Toluene diisocyanate
Dimethylbenzene *See* Xylene
Dimethylene oxide *See* Ethylene oxide
Dinitrogen tetroxide *See* Nitrogen oxides
DNTP *See* Parathion

DPP *See* Parathion
E-605 *See* Parathion
Epoxyethane *See* Ethylene oxide
1,2-Ethanediol *See* Ethylene glycol
Ethyl-S *See* Blister agent (HN1, HN2, HN3)
Ethylbis(2-chloroethyl)amine *See* Blister agent (HN1, HN2, HN3)
Ethyl parathion *See* Parathion
Ethylene glycol
Ethylene oxide
Ethylene tetrachloride *See* Tetrachloroethylene
Ethylene trichloride *See* Trichloroethylene
Ethinyl trichloride *See* Trichloroethylene
Etilon *See* Parathion
ETO *See* Ethylene oxide
Fluoric acid *See* Hydrogen fluoride
Fluorine monohydride *See* Hydrogen fluoride
Formaldehyde
Formalin *See* Formaldehyde
Formic aldehyde *See* Formaldehyde
Formonitrile *See* Hydrogen cyanide
Gasoline
Gas *See* Gasoline
HL *See* Blister agent (HL, L)
HN1 *See* Blister agent (HN1, HN2, HN3)
HN2 *See* Blister agent (HN1, HN2, HN3)
HN3 *See* Blister agent (HN1, HN2, HN3)
Hydrochloric acid *See* Hydrogen chloride
Hydrocyanic acid *See* Hydrogen cyanide
Hydrofluoric acid *See* Hydrogen fluoride
Hydrofluride *See* Hydrogen fluoride
Hydrogen arsenide *See* Arsine
Hydrogen chloride
Hydrogen cyanide
Hydrogen dioxide *See* Hydrogen peroxide
Hydrogen fluoride
Hydrogen peroxide
Hydrogen phosphide *See* Phosphine
Hydrogen sulfide
Hydroperoxide *See* Hydrogen peroxide
Hydroxybenzene *See* Phenol
Iprit *See* Blister agent (H, HD, HT)
Iscobrome *See* Methyl bromide
Kampstoff "Lost" *See* Blister agent (H, HD, HT)
L *See* Blister agent (HL, L)
Lewisite *See* Blister agent (HL, L)
Liquid ammonia *See* Ammonia
Lye *See* Sodium hydroxide
MBA *See* Blister agent (HN1, HN2, HN3)
Mechlorethamine *See* Blister agent (HN1, HN2, HN3)
Mercury
Methanal *See* Formaldehyde
Methane dichloride *See* Methylene chloride
Methyl aldehyde *See* Formaldehyde
Methyl benzene *See* Toluene
Methyl benzol *See* Toluene
Methyl bromide
Methylchloroform *See* 1,1,1-Trichloroethane
Methyl toluene *See* Xylene
Methylene bichloride *See* Methylene chloride
Methylene chloride
Methylene dichloride *See* Methylene chloride
Methylene oxide *See* Formaldehyde
Mixed xylenes *See* Xylene
Molecular chlorine *See* Chlorine
Monobromomethane *See* Methyl bromide
Monohydride *See* Hydrogen fluoride
Monohydroxybenzene *See* Phenol
Mononitrogen monoxide *See* Nitrogen oxides
Monophenol *See* Phenol
Motor fuel *See* Gasoline
Muriatric acid *See* Hydrogen chloride
Mustard gas *See* Blister agent (H, HD, HT)
Mustard-Lewisite *See* Blister agent (HL, L)
Mustine *See* Blister agent (HN1, HN2, HN3)
Nerve agent (GA, GB, GD, VX)
Nitric oxide *See* Nitrogen oxides
Nitrogen dioxide *See* Nitrogen oxides
Nitrogen monoxide *See* Nitrogen oxides
Nitrogen peroxide *See* Nitrogen oxides
Nitrogen tetroxide *See* Nitrogen oxides

NTO *See* Nitrogen oxides
Nitrogen fumes *See* Nitrogen oxides
Nitrous fumes *See* Nitrogen oxides
Nitrogen oxides
Octachlor *See* Chlordane
Oxirane *See* Ethylene oxide
Oxacyclopropane *See* Ethylene oxide
Oxomethane *See* Formaldehyde
Paraform *See* Formaldehyde
Parathion
Perc *See* Tetrachloroethylene
Perchloroethylene *See* Tetrachloroethylene
Peroxide *See* Hydrogen peroxide
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Phenol
Phenyl alcohol *See* Phenol
Phenyl hydroxide *See* Phenol
Phenylic acid *See* Phenol
Phenylic alcohol *See* Phenol
Peroxide *See* Hydrogen peroxide
Phenyl hydride *See* Benzene
Phenylamine *See* Aniline
Phenylmethane *See* Toluene
Phosgene
Phosgene oxime
Phosphine
Phosphorus hydride *See* Phosphine
Phosphorus trihydride *See* Phosphine
Phosphoretted hydrogen *See* Phosphine
Propenenitrile *See* Acrylonitrile
Prussic acid *See* Hydrogen cyanide
Pyrrolyene *See* 1,3-Butadiene
Quick silver *See* Mercury
Sarin *See* Nerve agent (GA, GB, GD, VX)
Senfgas *See* Blister agent (H, HD, HT)
Sewer gas *See* Hydrogen sulfide
Soda lye *See* Sodium hydroxide
Sodium hydrate *See* Sodium hydroxide
Sodium hydroxide
Soman *See* Nerve agent (GA, GB, GD, VX)
Spirits of salt *See* Hydrogen chloride
S-yperite *See* Blister agent (H, HD, HT)
Stathion *See* Parathion
Stink damp *See* Hydrogen sulfide
Sulfur dioxide
Sulfur hydride *See* Hydrogen sulfide
Sulfur mustard agent H *See* Blister agent (H, HD, HT)
Sulfur mustard agent HD *See* Blister agent (H, HD, HT)
Sulfur mustard agent HT *See* Blister agent (H, HD, HT)
Sulfur mustards *See* Blister agent (H, HD, HT)
Sulphos *See* Parathion
Sulfuretted hydrogen *See* Hydrogen sulfide
Sulfur mustard/lewisite *See* Blister agent (HL, L)
Sulfurous anhydride *See* Sulfur dioxide
Sulfurous oxide *See* Sulfur dioxide
TCE *See* Trichloroethylene
TDI *See* Toluene diisocyanate
Tabun *See* Nerve agent (GA, GB, GD, VX)
Termicide C-100 *See* Chlordane
Tetrachloroethylene
Thiophos *See* Parathion
Toluene
Toluene diisocyanate
Toluol *See* Toluene
Tolylene diisocyanate *See* Toluene diisocyanate
Topichlor *See* Chlotdane
Toxichlor *See* Chlordane
Tri *See* Trichloroethylene
1,1,1-Trichloroethane
Trichloroethene *See* Trichloroethylene
Trichloroethylene
2,2',2"-Trichlorotriethylamine *See* Blister agent (HN1, HN2, HN3)
Tris(2-chloroethyl)amine *See* Blister agent (HN1, HN2, HN3)
VCN *See* Actylonittile
Velsicol 1068 *See* Chlordane
Vinyl ethylene *See* 1,3-Butadiene
Vinyl chloride
Vinyl cyanide *See* Acrylonitrile
VX *See* Nerve agent (GA, GB, GD, VX)
White arsenic *See* Arsenic trioxide
Xylene
Xylol *See* Xylene
Yellow cross liquid *See* Blister agent (H, HD, HT)
Yperite *See* Blister agent (H, HD, HT)

Absorption. The incorporation of liquids or gases into the body. Absorption is also the process by which liquid hazardous materials are soaked up by sand, sawdust, or other material to limit the spread of contamination.

Acute effect. A pathologic process caused by a single substantial exposure.

Acute exposure. A single encounter to toxic concentrations of a hazardous material or multiple encounters over a short period of time (usually 24 hours).

Adaptation. The tendency of certain receptors to become less responsive or cease to respond to repeated or continued stimuli.

Adsorption. The property of a substance to attract and hold to its surface a gas, liquid, or other substance.

Air purification devices. Respirators or filtration devices that remove particulate matter, gases, or vapors from the atmosphere. These devices range from full-facepiece, dual-cartridge respirators with eye protection to half-mask, facepiece-mounted cartridges with no eye protection.

Air-supplied respirators. A device that provides the user with compressed air for breathing.

Airways. Any parts of the respiratory tract through which air passes during breathing.

Albuminuria. The presence of protein (primarily albumin) in the urine; usually indicative of transient dysfunction or disease.

Alkali. A basic substance (pH greater than 7) that has the capacity to neutralize an acid and form a salt.

Alveolar ducts. The smallest of the lungs' airways that connect terminal bronchioles and alveolar sacs. Sometimes called bronchioles.

Alveoli (singular alveolus). Microscopic air sacs in which gas exchange between the blood and the lungs occurs.

Anemia. Any condition in which the number of red blood cells, the amount of hemoglobin, and the volume of packed red blood cells per 100 milliliters of blood are less than normal.

Anhydrous. Containing no water.

Anisocytosis. Considerable variation in the size of blood cells.

Anorexia. Lack of appetite; aversion to food.

Anoxia. Lack of oxygen in inspired air, blood, or tissues.

Anterior chamber of the eye. The fluid-filled front portion of the eye between the cornea and the lens.

Antidote. An agent that neutralizes a poison or counteracts its effects.

Anuria. Absence of urine production.

Aplastic anemia. A condition characterized by a decrease in the amount of hemoglobin in the blood due to incomplete or defective development of red blood cells; usually accompanied by defective regeneration of white blood cells and platelets.

Apnea. Cessation of breathing.

Asphyxia. A condition in which the exchange of oxygen and carbon dioxide in the lungs is absent or impaired.
Aspiration pneumonia. Inflammation of the lungs due to inhalation of foreign material, usually food or vomitus, into the bronchi.

Asthma. A chronic condition in which constriction (spasm) of the bronchial tubes occurs in response to irritation, allergy, or other stimuli.

Ataxia. Incoordination of voluntary movement, especially affecting gait and speech.

Atelectasis. Lung collapse.

Atomic weight. The average weight (or mass) of all the isotopes of an element, as determined from the proportions in which they are present in a given element, compared with the mass of the 12 isotope of carbon (taken as precisely 12.000), which is the official international standard; measured in daltons.

Atopy. A tendency or predisposition to allergic reactions.

Autoignition temperature. The lowest temperature at which a gas or vapor-air mixture will ignite from its own heat source or a contacted heated surface without a spark or flame.

Axon. The part of a nerve cell that conducts nervous impulses away from the nerve cell body to the remainder of the cell (i.e., dendrites); large number of fibrils enveloped by a segmented myelin sheath.

Axonal. Pertaining to an axon.

Bilirubin. A red pigment that results from normal and abnormal destruction of red blood cells.

Blepharospasm. Involuntary spasmodic blinking or closing of the eyelids due to severe irritation.

Boiling point. The temperature at which the vapor pressure of a liquid equals the atmospheric pressure and the liquid becomes vapor.

Bradycardia. Slow heart rate, usually under 60 beats per minute.

Bronchi (singular **bronchus**). Large divisions of the trachea that convey air to and from the lungs.

Bronchiole. A small-diameter airway branching from a bronchus.

Bronchitis. Inflammation of the mucous membrane of the bronchial tubes, usually associated with a persistent cough and sputum production.

Bronchorrhea. Increased bronchial secretions.

Bronchospasm. Contraction of the smooth muscle of the bronchi, causing narrowing of the bronchi. This narrowing increases the resistance of air flow into the lungs and may cause a shortness of breath, typically associated with wheezing.

Bullae. Large fluid-filled blisters.

Carcinogenic. Causing cancer.

Cardiac dysrhythmia. Abnormality in the rate, regularity, or sequence of the heart beat. Formerly referred to as cardiac arrhythmia.

Cataract. Loss of transparency (clouding) of the lens of the eye.

Catecholamines. Substances of a specific chemical nature (pyrocatechols with an alkylamine side chain). Catecholamines of biochemical interest am those produced by the nervous system (e.g., epinephrine [adrenaline] or dopamine) to increase heart rate and blood pressure, or medicines with the same general chemical structure and effect.

Caustic. Substance that strongly irritates, bums, corrodes, or destroys living tissue.

Cerebellar abnormalities. Any irregularity in the cerebellum of the brain.

Cerebellum. The large brain mass located at the posterior base of the brain, responsible for balance and coordination of movement.

Cerebral infarctions. Death of tissue in the cerebrum due to lack of blood flow to the area.
Cerebrum. The largest portion of the brain; includes the cerebral hemispheres (cerebral cortex and basal ganglia).

Chemexfoliation. Chemical skin peeling; use of chemicals to remove scars or pigmentation defects.

Chemical formula. The collection of atomic symbols and numbers that indicates the chemical composition of a pure substance.

Chemical-protective clothing. Clothing specifically designed to protect the skin and eyes from direct chemical contact. Descriptions of chemical-protective apparel include nonencapsulating and encapsulating (referred to as liquid-splash protective clothing and vapor-protective clothing, respectively).

Chronic effect. A pathologic process caused by repeated exposures over a period of long duration.

Chronic exposure. Repeated encounters with a hazardous substance over a period of long duration.

Cognitive function. The ability to think.

Coma. State of profound unconsciousness from which the patient cannot be aroused.

Combustible liquid. Any liquid that has a flash point at or above 100 °F (37.7 °C) and below 200 °F (93.3 °C).

Compressed gas. Gas whose volume has been reduced by pressure.

Congenital anomalies. Birth defects.

Conjunctiva (*plural* **conjuctivae**). The delicate mucous membrane that covers the exposed surface of the eyeball and lines the eyelids.

Conjunctivitis. Inflammation of the conjunctiva; can result in redness, irritation, and tearing of the eye.

Contact dermatitis (allergic). A delayed-onset skin reaction caused by skin contact with a chemical to which the individual has been previously sensitized.

Contact dermatitis (irritant). Inflammatory skin reaction caused by a skin irritant.

Control zones. Areas at a hazardous materials incident whose boundaries are based on safety and the degree of hazard; generally includes the Hot Zone, Decontamination Zone, and Support Zone.

Cornea. Transparent membrane that covers the colored part of the eye.

Cornea1 opacification. Clouding of the cornea.

Corrosive. Ability to destroy the texture or substance of a tissue.

Critical Care Area. That area in a hospital designated for the treatment of severely ill patients.

Cyanosis. Bluish discoloration of the skin and mucous membranes due to deficient oxygenation of the blood; usually evident when reduced hemoglobin (i.e., hemoglobin unable to carry oxygen) exceeds 5%.

Decontamination. The process of removing hazardous materials from exposed persons and equipment at a hazardous materials incident.

Decontamination Zone. The area surrounding a chemical hazard incident (between the Hot Zone and the Support Zone) in which contaminants are removed from exposed victims.

Defat. To remove natural oils from the skin.

Degradation. The process of decomposition. When applied to protective clothing, a molecular breakdown of material because of chemical contact; degradation is evidenced by visible signs such as charring, shrinking, or dissolving. Testing clothing material for weight changes, thickness changes, and loss of tensile strength will also reveal degradation.

Delirium. A condition of extreme mental (and sometimes motor) excitement marked by defective perception, impaired memory, and a rapid succession of confused and unconnected ideas, often with illusions and hallucinations.

Dementia. A general deterioration of mental abilities.

Demyelination. Removal (destruction) of the myelin sheath that surrounds and protects nerves.

Denervation atrophy. Shrinkage or wasting of muscles due to loss of nerve supply.

Dermal. Relating to the skin.

Dermatitis. Skin inflammation.

Dermis. The layer of the skin just below the epidermis or outer layer. The dermis has a rich supply of blood vessels, nerves, and skin structures.

Desiccation. Removal of moisture; drying.

Desiccant effect. Drying of the skin caused by removal of soluble oils.

Dilution. The use of water to lower the concentration or amount of a contaminant.

Diaphoresis. Excessive perspiration.

Diplopia. Double vision.

Dyscrasia. Blood disorder.

Dysphagia. Difficulty in swallowing.

Dyspnea. Shortness of breath; difficult or labored breathing.

Dysuria. Painful or difficult urination.

Edema. Accumulation of fluid in body cells or tissues; usually identified as swelling.

Embolization. Obstruction of a blood vessel by a transported clot or other mass.

Embryo. In humans, the developing conceptus up to 8 weeks after fertilization of the egg. See also fetus.

Embryotoxicity. Ability to harm the embryo.

Emergency. A sudden and unexpected event requiring immediate remedial action.

Emesis. Vomiting.

Encephalopathy. Any disease of the brain.

Environmental hazard. A condition capable of posing an unreasonable risk to air, water, or soil quality, or plant or animal life.

Epidermis. The outermost layer of the skin.

Erythroderma. Intense, widespread reddening of the skin.

Erythema. Redness of the skin.

Esophageal strictures. Narrowing of the esophagus that causes difficulty in swallowing; often due to scar formation following extensive bums.

Esophagus. The portion of the digestive canal extending from the throat to the stomach. Also referred to as the gullet.

Euphoria. An intense and exaggerated feeling of well-being.

Exfoliative dermatitis. A skin condition that involves scaling or shedding of the superficial cells of the epidermis.

Exothermic reaction. Chemical reactions that produce heat.

Explosives. Compounds that are unstable and break down with the sudden release of large amounts of energy.

Explosivity. The characteristic of undergoing very rapid decomposition (or combustion) to release large amounts of energy,

Fasciculation. Muscle twitching.

Fetotoxic. Having the ability to harm the fetus.

Fetus. In humans, the conceptus from 8 weeks after fertilization until birth. See also embryo.

Flame-resistant. Slow or unable to bum.

Flammable. The ability of a substance to ignite and bum.

Flammable (explosive) range. The range of gas or vapor concentration (percentage by volume in air) that will bum or explode if an ignition source is present. Limiting concentrations are commonly called the lower explosive limit and upper explosive limit. Below the lower explosive limit, the mixture is too lean to bum; above the upper explosive limit, the mixture is too rich to bum.

Flash point. The minimum temperature at which a liquid produces enough vapor to ignite.

Flashback. The movement of a flame to a fuel source; typically occurs via the vapor of a highly volatile liquid or by a flammable gas escaping from a cylinder.

Fluorosis. Accumulation of excessive fluoride in the body; characterized by increased bone density and mineral deposits in tendons, ligaments, and muscles.

Followup. Constant or intermittent contact with a patient after diagnosis or therapy.

Freezing point. Temperature at which crystals start to form as a liquid is slowly cooled; alternatively, the temperature at which a solid substance begins to melt as it is slowly heated.

Fume. Fine particles (typically of a metal oxide) dispersed in air that may be formed in various ways (e.g., condensation of vapors, chemical reaction).

Gangrene. Death of tissue due to lack of blood supply.

Gas. A physical state of matter that has low density and viscosity, can expand and contract greatly in response to changes in temperature and pressure, readily and uniformly distributes itself throughout any container.

Glaucoma. A disease of the eye characterized by abnormal and damaging high pressure inside the eye; usually due to a blockage of the channel that normally allows the outflow of fluid from the eye.

Glomerulus (plural glomeruli). A tuft formed of capillary loops that filter blood in the kidney.

Hazard. A circumstance or condition that can cause harm.

Hazardous materials. Substances that, if not properly controlled, pose a risk to people, property, or the environment.

Hazardous materials incident. The uncontrolled release or potential release of a hazardous material from its container into the environment.

Hematuria. Condition in which the urine contains an abnormal amount of blood or red blood cells.

Hemodialysis. Removal of soluble substances from the blood by their diffusion through a semipermeable membrane.

Hemoglobinuria. Condition in which the urine contains an abnormal amount of hemoglobin.

Hemolysis. Destruction or dissolution of red blood cells in such a manner that hemoglobin is liberated into the medium in which the cells are suspended.

Hemolytic anemia. Any anemia resulting from destruction of red blood cells.

Hemoptysis. The spitting of blood derived from hemorrhage in the lungs or bronchial tubes.

Hepatic. Pertaining to the liver.

Hepatomegaly. Enlargement of the liver.

Hot Zone. The area immediately surrounding a chemical hazard incident, such as a spill, in which contamination or other danger exists.

Hyperbilirubinemia. A condition in which an abnormally large amount of bilirubin is found in the blood. Jaundice becomes apparent when the level of bilirubin is double the normal level.

Hyperesthesia. Increased sensitivity to touch, pain, or other sensory stimuli.

Hyperpigmentation. An excess of pigment in a tissue or part of the body.

Hyperreflexia. A condition in which the deep tendon reflexes are exaggerated.

Hypersensitization. Increased sensitivity of the immune system; induced by initial exposure with subsequent exposures eliciting a greater than expected immunologic response.

Hypertension. High blood pressure.

Hypocalcemia. A condition in which an abnormally low concentration of calcium ions is present in the blood.

Hypokalemia. A condition in which an abnormally low concentration of potassium ions is present in the blood.

Hypomagnesemia. A condition in which the plasma concentration of magnesium ions is abnormally low; may cause convulsions and concurrent hypocalcemia.

Hypophosphatemia. Condition in which an abnormally low concentration of phosphate is found in the blood.

Hypotension. Low arterial blood pressure.

Hypotonia. A condition in which there is a loss of muscle tone.

Hypoxemia. A condition in which inadequate oxygen is present in arterial blood, short of anoxia.

Hypoxia. Condition in which below-normal levels of oxygen are present in the air, blood, or body tissues, short of anoxia.

Ignition (autoignition) temperature. The minimum temperature required to ignite gas or vapor without a spark or flame being present.

Immediately dangerous to life and health (IDLH). That atmospheric concentration of a chemical that poses an immediate danger to the life or health of a person who is exposed but from which that person could escape without any escape-impairing symptoms or irreversible health effects. A companion measurement to the permissible exposure limit (PEL), IDLH concentrations represent levels at which respiratory protection is required. IDLH is expressed in parts per million (ppm) or mg/m^3.

Inadequate warning property. Characteristic (e.g., odor, irritation) of a substance that is not sufficient to cause a person to notice exposure.

Incident commander. The person responsible for establishing and managing the overall operational plan at a hazardous material incident. The incident commander is responsible for developing an effective organizational structure, allocating resources, making appropriate assignments, managing information, and continually attempting to mitigate the incident.

Insecticide. An agent that has the ability to kill insects.

Intention tremor. Trembling of the extremities during movement.

Interstitial pneumonitis. Inflammation of the alveolar walls and the spaces between them.

Iritis. Inflammation of the colored part of the eye (iris).

Ischemia. Obstruction of blood flow (usually by arterial narrowing) that causes lack of oxygen and other bloodborne nutrients.

Ischemic necrosis. Death of cells as a result of decreased blood flow to affected tissues.

Jaundice. Yellowing of the skin and whites of the eyes due to an accumulation of bile pigments (e.g., bilirubin) in the circulating blood.

Keratitis. Inflammation of the cornea.

Lacrimation. Secretion of tears, especially in excess.

Laryngeal edema. Swelling of the voice box due to fluid accumulation.

Laryngitis. Inflammation of the mucous membrane of the larynx.

Laryngospasm. Spasmodic closure of the vocal apparatus.

Lethargy. A state of extreme tiredness or fatigue.

Leukemia. Progressive proliferation of abnormal leukocytes found in blood and blood-forming tissues and organs; due to cancer of the bone marrow cells that form leukocytes.

Leukocyte. White cell normally present in circulating blood.
Material safety data sheet (MSDS). Documents prepared by the chemical industry to transmit information about the physical properties and health effects of chemicals, and about emergency response plans.

Methemoglobin. A transformation product of hemoglobin in which normal $Fe+^{2}$ is oxidized to $Fe+^{3}$.

Methemoglobin contains oxygen that is firmly bound to the Fe+3 ion, which prevents the release of oxygen to the tissues.

Methemoglobinemia. Condition in which methemoglobin is present in the circulating blood.

Methemoglobinuria. Condition in which methemoglobin is present in the urine.

Miosis. Contraction of the pupil to a pinpoint.

Miscible. Able to mix (but not chemically combine) in any ratio without separating into two phases (e.g., water and alcohol).

Mist. Liquid droplets dispersed in air.

Mitigation. Actions taken to prevent or reduce the severity of harm.

Monocytic leukemia. A form of bone marrow cancer characterized by an increase in the number of large, mononuclear white blood cells in tissues, organs, and the circulating blood.

Molecular weight. The sum of the atomic weights (q.v.) of the atoms in a molecule; measured in daltons.

Myalgia. Severe muscle pain.

Mydriasis. Dilation of the pupil.

Myelocytic leukemia. A form of bone marrow cancer characterized by the presence of large numbers of granular white blood cells in tissues, organs, and the circulating blood.

Myocardial ischemia. Insufficient oxygen supply to meet the metabolic demands of heart muscles.

Myocarditis. Inflammation of the muscles of the heart.

Myoclonus. Involuntary spasm or twitching of a muscle or group of muscles.

Myoglobin. The oxygen-transporting, pigmented protein of muscle; resembles blood hemoglobin in function.

Myoglobinuria. Presence of myoglobin in urine.

Nasopharynx. Relating to the nasal cavity and that part of the throat that lies above the level of the soft palate.

Necrosis. Death of one or more cells or a portion of a tissue or organ.

Nephrotoxic. Capable of damaging the kidney.

Neuropathy. A disorder of the nervous system; in contemporary usage, a disease involving the cranial or spinal nerves.

Noncardiogenic pulmonary edema. An accumulation of an excessive amount of fluid in the lungs as a result of leakage from pulmonary capillaries; not due to heart failure.

Nystagmus. Involuntary rapid movements of the eyeballs, either rhythmical or jerky.

Ocular. Pertaining to the eye.

Odor threshold. The lowest concentration of a vapor or gas that can be detected by smell.

Off-gassing. Giving off a vapor or gas.

Olfactory fatigue. Temporary loss of the sense of smell due to repeated or continued stimulation.

Oliguria. Condition in which abnormally small amounts of urine are produced.

Opisthotonos. Tetanic spasm in which the spine and extremities are bent up and forward so that a reclining body rests on the head and the heels.

Optic atrophy. Shrinkage or wasting of the optic nerve that may lead to partial vision loss or blindness.

Optic neuritis. Inflammation of the optic nerve.

Osteosclerosis. Abnormal hardening or increase in density of the bone.

Paresthesias. An abnormal sensation such as burning, prickling, or tingling.

Percutaneous absorption. Passage of a substance through unbroken skin.

Peripheral neuropathy. A disorder of the peripheral nerves.

Permeation. The passage of chemicals, on a molecular level, through intact material such as protective

clothing.

Permissible exposure limit (PEL). The maximum time-weighted average concentration mandated by the Occupational Safety and Health Administration (OSHA) to which workers may be repeatedly exposed for 8 hours per day, 40 hours per week without adverse health effects.

Photophobia. Abnormal sensitiveness to light, especially of the eyes.

Physical state. The state (solid, liquid, or gas) of a chemical under specific conditions of temperature and pressure.

Pneumonitis. Inflammation of the lungs.

Poikilocytosis. The presence of irregularly shaped red blood cells in the peripheral blood.

Posthypoxic encephalopathy. Condition in which the brain has been damaged as a result of insufficient oxygen.

Proteinuria. A condition in which an abnormal amount of protein is present in the urine. See also albuminuria.

Pruritic. Pertaining to itching.

Psychosis. A mental disorder characterized by derangement of personality and loss of touch with reality.

Pulmonary edema. Accumulation of extravascular fluid in the lungs that impairs gas exchange; usually due to either increased intravascular pressure or increased permeability of the pulmonary capillaries.

Pupil. The circular opening in the center of the iris through which light rays enter the eye.

Reactivity. The ability of a substance to chemically interact with other substances.

Rescuer protection equipment. Gear necessary to prevent injury to workers responding to chemical incidents.

Respiratory depression. Slowing or cessation of breathing due to suppression of the function of the respiratory center in the brain.

Response organization. An organization prepared to provide assistance in an emergency (e.g., fire department).

Response personnel. Staff attached to a response organization (e.g., HAZMAT team).

Retrobulbar neuritis. Inflammation of the portion of the optic nerve behind the eyeball.

Rhinitis. Inflammation of the mucous membranes of the nasal passages.

Rhinorrhea. A discharge from the nasal mucous membrane.

Routes of exposure. The manner in which a chemical contaminant enters the body (e.g., inhalation, ingestion).

Sclera. The tough, white supporting tunic of the eyeball.

Secondary contamination. Transfer of a harmful substance from one body (primary body) to another (secondary body), thus potentially permitting adverse effects to the secondary body.

Self-contained breathing apparatus (SCBA). Protective equipment consisting of an enclosed facepiece and an independent, individual supply (tank) of air; used for breathing in atmospheres containing toxic substances or underwater.

Sensory neuropathy. Damage to the nerves that carry information about sensation (e.g., touch, pain, temperature) to the brain.

Sequela (plural sequelae). A condition that follows as a consequence of injury or disease.

Sloughing. The process by which necrotic cells separate from the tissues to which they have been attached.

Solubility. The ability of one material to dissolve in or blend uniformly with another.

Soluble. Capable of being dissolved.

Solution. A homogeneous mixture of two or more substances, usually liquid.

Solvent. A substance that dissolves another substance.

Specific gravity. The ratio of the mass of a unit volume of a substance to the mass of the same volume of a standard substance (usually water) at a standard temperature.

Status epilepticus. Severe seizures in which recovery does not occur between major episodes.

Stridor. A harsh, high-pitched respiratory sound often heard in acute respiratory obstruction.

Support Zone. That area beyond the Decontamination Zone that surrounds a chemical hazard incident in which medical care can be freely administered to stabilize a victim.

Surfactant. An agent that reduces surface tension (e.g., wetting agents, detergents, dispersing agents).

Tachycardia. Rapid heartbeat (typically greater than 100 beats per minute).

Tachypnea. Rapid breathing.

Teratogenic. Having the ability to cause congenital anomalies.

Tetany. A condition marked by involuntary muscle contractions or spasms.

Thrombocytopenia. A condition in which there is an abnormally small number of platelets in the blood.

Thrombosis. Blood vessel clotting.

Time-weighted average (TWA) air concentration. That concentration of a substance in air that is measured by collecting it on a substrate at a known rate for a given period of time.

Tinnitus. Ringing in the ears.

Toxic potential. The inherent ability of a substance to cause harm.

Toxic. Having the ability to harm the body, especially by chemical means.

Tracheitis. Inflammation of the membrane lining the trachea.

Trismus. Lockjaw.

Tubular necrosis. Death of the cells lining the kidney tubules.

Uremia. Condition in which an abnormally high level of urea or other nitrogenous waste is found in the blood; due to kidney dysfunction.

Urticaria. Hives.

Vapor density. The weight of a given volume of vapor or gas compared to the weight of an equal volume of dry air, both measured at the same temperature and pressure.

Vapor pressure. A measure of the tendency of a liquid to become a gas at a given temperature.

Vapor. The gaseous form of a substance that is normally a solid or liquid at room temperature and pressure.

Vascular. Pertaining to blood vessels.

Vasodilation. Increased diameter of the blood vessels.

Ventricular fibrillation. Rapid, tremulous movement of the ventricle that replaces normal contractions of the heart muscle; results in little or no blood being pumped from the heart

Vertigo. Sensation of spinning or revolving.

Vesicant. An agent that produces blisters.

Vesiculation. The presence or formation of blisters.

Water-reactive material. A substance that readily reacts with water or decomposes in the presence of water, typically with substantial energy release.

Wheezing. Breathing noisily and with difficulty; usually a sign of spasm or narrowing of the airways.