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Radiological Dispersal Device Incident Response Planning: Overview

PURPOSE

Provides emergency planners with an overview of core concepts regarding radiological dispersal device (RDD) incident response planning.

SUMMARY

Pre-incident planning and training can facilitate preparedness for, response to, and recovery from an RDD incident. This Best Practice series supports jurisdictions' pre-planning processes by providing information on basic radiation concepts and RDD classification, use, and effectiveness. This document describes the major issues that emergency managers and responders may face after an RDD event. It discusses the essential elements for establishing a minimal RDD emergency response capability.

DESCRIPTION

The Central Intelligence Agency (CIA) defines an RDD as a device "designed to disseminate radioactive material to cause destruction, contamination, and injury from the radiation produced by the material." Experts believe that an RDD would be employed as a weapon of mass disruption, not a weapon of mass destruction. Indeed, an RDD event is expected to cause widespread panic and fear of radiation, not large-scale casualties. Terrorists could employ an RDD to contaminate people and infrastructures, including livestock, water supplies, and food crops.

Various intelligence sources have stated that construction of an RDD is well within the capabilities of many terrorist organizations. Indeed, RDDs are relatively easy to build, and radiological materials can be acquired from many industrial or medical sources.

RDD Definitions
Several organizations have developed RDD definitions including:

- The United States Department of Labor, Occupational Safety & Health Administration's Radiological Dispersal Devices (RDD)/Dirty Bombs
- The United States Nuclear Regulatory Commission's Fact Sheet on Dirty Bombs

Terrorist Interest in RDDs

Intelligence organizations believe that Al Qaeda and other terrorist groups could conduct RDD attacks. Al Qaeda has shown strong and consistent interest in RDDs. In December 2001, CNN journalists discovered a dirty bomb design called "Superbomb" in the home of a senior Al Qaeda official in Kabul, Afghanistan. In March 2002, Pakistani police forces captured Al Qaeda chief of operations and top recruiter Abu Zubaydah during a raid in Faisalabad. Zubaydah informed US interrogators that Al Qaeda was planning a dirty bomb attack against a US city. In May 2002, federal law enforcement officials arrested and charged the suspected Al Qaeda operative Jose Padilla in Chicago with allegedly preparing a dirty bomb attack in the United States. In January 2003, United Kingdom officials reported that their agents had infiltrated an Al Qaeda camp near Herat in Afghanistan. They retrieved several documents indicating that Al Qaeda had successfully built a small dirty bomb. However, the agents did not find the device itself, and it has not since been recovered.

In December 2003, the media reported that homeland security officials believed Al Qaeda was planning to detonate a dirty bomb during a New Year's Eve celebration in a US city. The Department of Energy dispatched a number of experts with detection equipment to monitor several major US cities for RDDs. In August 2004, UK police arrested eight UK citizens of Pakistani origin. The men had collected a large number of smoke detectors and were planning to extract the radioactive americium-241 contained in these devices to build a dirty bomb.

Other terrorist groups have attempted to employ radiological dispersal devices. Chechen separatists planted a 30-pound device containing cesium-137 and explosives in Moscow's Izmailovo Park in November 1995. In December 1998, a Chechen Security Service team found a container emitting high levels of radiation attached to a mine buried near a railway line outside Argun, 10 miles east of Grozny, in Chechnya. In both cases, the devices were deactivated before exploding.

The Dirty Bomb Found in the Izmailovo Park

Source: Public Broadcasting Service, NOVA. *Dirty Bomb*.

Between 2003 and 2005, media sources reported that at least 38 Alazan missiles equipped with radioactive warheads were available for sale in Transdniester. The Alazan is a 3-foot-long rocket with an 8-mile range. Russian military records showed that the Alazan warheads had been modified to carry radioactive material, effectively creating the world's first surface-to-surface dirty bomb. In one of these documents, the Transdniester civil defense commander requested technical help to deal with radiation exposure related to storage of the warheads. He also complained that the uniforms of soldiers working with these warheads were so contaminated that they had to be destroyed. Western intelligence reports that several terrorist groups, including Al Qaeda, have attempted to buy one of these missiles.

The Transdniester Moldova Republic is located along Moldova's eastern border with Ukraine. Western officials believe that the main source of revenue for this region's elite is armament production and illegal weapons, drugs, and human trafficking.

The International Atomic Energy Agency (IAEA) reports that every year hundreds of radioactive sources are abandoned, lost, misplaced, stolen, or removed without authorization throughout the world. The IAEA found that more than 100 countries have inadequate control and monitoring programs to prevent the theft or misplacement of radiation sources. Since the end of the Cold War, hundreds of radioactive sources have disappeared or are not protected adequately in the Newly Independent States of the former Soviet Union. For instance, more than 1,000 unsecured electric generators powered by strontium-90 sources ranging from 40,000 to 150,000 curies are not secured in these states.

RDDs in Perspective

Likelihood of RDD Employment

Several experts view an RDD attack in the United States as a "low-probability high-consequence" event. They believe that the probability of a terrorist organization employing an RDD in a US metropolitan area is small. Many terrorist groups most likely would select conventional means to attack a US city. However, an RDD attack may cause mass panic, long-term loss of property use, extensive disruption of services, and costly remediation of property and facilities that could last for months or years. Such an event also may overwhelm many local emergency response organizations and require the deployment of federal and state resources and expertise.

RDDs as Mass Casualty Devices

Experts believe that many people overestimate the number of radiological casualties that could be caused by an RDD event. Most RDDs that terrorist organizations could build would not result in immediate health hazards to people or first responders outside the blast area. It is expected that an RDD's effects would be primarily psychological, such as panic and social unrest, rather than physical. The immediate casualties would be those of the initial blast; few, if any, people would die due to exposure to radioactive material following an RDD attack. The United States Nuclear Regulatory Commission's *Fact Sheet on Dirty Bombs* states, "In most instances, the conventional explosive itself would have more immediate lethality than the radioactive material. At the levels created by most probable sources, not enough radiation would be present in a dirty bomb to kill people or cause severe illness." Experts believe even RDDs that employ "megasources," such as Russian radioisotope thermal generators or Gamma-Kolos seed irradiators, would be unlikely to cause many human casualties. Indeed, these radioactive sources cannot be broken down easily into highly dispersible particles because they are molded into a single piece of metal or enclosed in very robust capsules.

Megasources

A radioisotope thermoelectric generator (RTG) is an electrical generator that obtains its power from radioactive decay. The Soviet Union built many unmanned lighthouses and navigation beacons powered by RTGs along the coast of the Kola Peninsula and the White Sea. These RTGs contain from 30,000 curies (Ci) to 181,000 Ci of strontium-90. Most Russian RTGs are completely unprotected against theft and lack even minimal safety measures like radioactive hazard signs. Some of these RTGs have been abandoned for more than a decade.

Public Perceptions of Radiation

Emergency planners should be aware that often the public perceptions of radiation danger are inaccurate. A significant number of people are misinformed about radioactivity as well as the short- and long-term effects of radiation exposure. Many people believe that almost any level of exposure to radiation could cause cancer or death. As a result, a large section of the public might consider relatively low levels of radiation exposure after an RDD event a substantial hazard. The public's fear of even relatively small levels of radiation could create mass panic and make emergency response operations particularly difficult. Public misperception of the radiation danger also could cause widespread, long-term economic damage in a jurisdiction.

RDD Classification and Effectiveness

Responders first onsite of an RDD event may find it difficult to identify the incident as one that includes radioactive materials. The type of dissemination method employed can make an RDD incident difficult to recognize as such. Methods that could be used to disseminate the radioactive material include dilution of the material in water supplies, use of remote control devices, explosives, or missiles. A human agent could also deliver the radioactive material.

Various organizations in the United States routinely employ radioactive material sources that could be accessed and used to build an RDD. These sources are, among others, hospital radiation therapy units (cobalt-60, cesium-137), radiopharmaceuticals (thalium-201, xenon-133), and nuclear power plant fuel rods (uranium-235). A number of universities and laboratories also regularly employ cobalt-60, cesium-137, iridium-192, and radium-226. Some of these radionuclides are short lived, available only in small quantities, or heavily guarded.

> The United States Army Center for Health Promotion and Preventive Medicine's *Radiological Sources of Potential Exposure and/or Contamination* lists nuclear weapon products as well as nuclear fuel cycle, biomedical, industrial, and army commodity sources of concern. This manual also includes radiation protection, precaution levels, and case studies.

Classification of Radiological Dispersal Devices

RDDs are usually classified as either active or passive devices:

Active Radiological Device

An active radiological dispersal device physically spreads radioactive material over a large or confined area. An active device disseminates radioactive materials through:

- **Explosive means**, such as dynamite, which disseminates radioactive material over a large area. This is usually referred to as a "dirty bomb."
- **Non-explosive means**, such as aerosolizing radioactive material or dissolving it in a water reservoir. Experts believe that terrorists are less likely to adopt non-explosive means because an enormous amount of radioactive material would be required to produce harmful effects.

Passive Radiological Device

The CIA defines a passive radiological device as "a system in which unshielded radioactive material is dispersed or placed manually at the target." This type of device is also called Radiological Emission Device (RED). An RED could consist of radioactive material hidden in a trashcan or bag and left in a high-profile location. Experts generally believe an RED would cause limited harm to people but would cause extensive panic and economic damage. However, a relatively strong source placed in a location occupied for an extended period of time—such as a sporting event, a movie theater, or the lobby of a hospital—could harm people assembled nearby.

> The Department of Health and Human Services, Centers for Disease Control and Prevention's Radiological Terrorism: Just in Time Training for Hospital Clinicians includes an RED scenario. In this scenario, a patient developed several symptoms after being exposed to a radioactive source hidden under a seat in a subway car. The patient was homeless and sat near the source for several hours.

RDD Effectiveness

Several factors may affect an RDD's capacity to generate extensive destruction and disruption. These factors can be grouped into three variables:

Environmental Conditions

- **Location of the release and dispersion pattern**: The size and shape of the radioactive incident area will depend on the layout, shape, and size of buildings; the construction materials used; the presence or absence of vegetation; and other such characteristics.

- **Weather conditions**: Wind, rain, and other meteorological factors will influence dispersion patterns. The radioactive material's plume will be determined by the wind's speed, direction, and thermal currents. Rain or snow can concentrate the material in rivers, lakes, and seacoasts.

Explosive Employed

- **Quantity**: This will determine the size of the contaminated area.
- **Type**: Different types of explosives with specific chemical characteristics may react with radioactive materials' chemical characteristics.

Radioactive Material Employed

- **Isotope**: The isotope employed in an RDD can determine the magnitude of the physical damage and economic impact. Some isotopes bond strongly to concrete and asphalt, making decontamination particularly challenging and costly. Moreover, exposure to some isotopes is more harmful than exposure to others. For instance, the dose from exposure to a cobalt-60 source is four times that of an equivalent cesium-137 source.
- **Quantity**: Using more radioactive material could increase effects proportionally. Generally, a larger source of material will have a greater impact than a smaller source, other conditions being equal.
- **Size of the particles**: Smaller particles generally disperse more easily and could be more easily inhaled, thus making internal contamination more likely.
- **State of material**: A liquid or powder dispersion can be absorbed or embedded into concrete, paint, or soil. Thus, decontamination after a release of radioactive material in liquid or powder form may require more time, technical expertise, and resources than decontamination following a release of radioactive material in pellet or chunk form.

Major Emergency Response Issues Following an RDD Event

An RDD may present several unique problems for emergency response personnel. Emergency response personnel onsite of an RDD event may face the following during the initial hours or days of response operations:

- **Recognition that an RDD attack occurred**: Responders first onsite of an RDD event may not realize immediately that radioactive material was dispersed. As a result, some emergency responders may become contaminated before they recognize that an RDD attack took place.
- **Size of the incident area**: An RDD incident area could cover several city blocks. Atmospheric conditions, such as wind or rain, will likely alter the size of the area impacted and/or the concentration of radioactive materials. Emergency responders may be required to redefine boundaries and evacuation routes, to move decontamination and triage areas, and to revise emergency response procedures and practices with little or no notice during emergency response operations.
- **Mass monitoring and decontamination**: Many people may need or request monitoring and decontamination after an RDD event. Mass monitoring and decontamination are likely to require extensive time and resources. It is possible that these demands for monitoring and decontamination could overwhelm the emergency response organizations in many jurisdictions. As a result, some people may not be monitored for an extended period of time and may not realize that they

are contaminated. These victims could spread the contamination to other people and locations.

- **Public communication**: Public communication will be particularly challenging after an RDD event. Many people do not understand the short- and long–term effects of radiation or the difference between an RDD attack and a nuclear detonation. Many people may doubt public statements of experts and officials and start believing unfounded rumors after an RDD event. The lack of consensus among experts and media on the consequences of an RDD attack also could intensify public mistrust.
- **Psychological management of the public**: An RDD is a terror weapon that will likely cause mass panic and social unrest. Indeed, experts consider the psychological consequences of RDDs potentially more significant than their lethal effects. Many people may attempt to self-evacuate, start developing psychosomatic symptoms, or adopt disruptive behaviors following an RDD event. Managing the psychological consequences of an RDD event will likely require a considerable amount of resources and expertise and will overpower emergency response organizations in many jurisdictions.

> The Washington State Department of Health's *Protective Action Recommendations for a Radiological Dispersal Event Including Improvised Nuclear Devices, Revision 8* advises emergency planners to develop a list of the contact information of local organizations and agencies that can provide responders with radiation safety expertise and equipment following an RDD event. This list can include the "state radiation control authority, local hospitals, fire departments, law enforcement agencies, schools, universities and radioactive material licensees."

- **Impact on the healthcare system**: Many people will ask for assistance or reassurance from their local healthcare providers after an RDD event. Hospitals and clinics could be overwhelmed by the number of people who will ask for medical attention fearing contamination or exposure.

Minimum Emergency Response Capability

Emergency planners should consider developing a minimum RDD incident response capacity in their jurisdictions tailored to the local resources, expertise, and anticipated threats. Planners should take into account the following key elements when developing a minimum RDD incident response capability:

- **Establishing RDD training programs**: All emergency responders who are likely to respond to an RDD event should receive RDD incident response training at a level corresponding to the duties and functions that they will be expected to perform in an incident. Emergency responders could become exposed to excessive radiation unless they are trained to recognize the radiological component of an RDD and to implement appropriate personal protective measures. Emergency response organizations should integrate RDD-training programs into their training requirements. For more information on training programs available for emergency responders, please refer to the *Lessons Learned Information Sharing* Best Practice document "Radiological Dispersal Device Incident Response Planning: Training and Exercises."
- **Identifying local radiation experts and resources**: Experts believe that many local emergency response organizations that could be called to respond to an RDD event are not familiar with local radiation control authorities or other radiation subject-matter experts (SME) and resources available within their jurisdictions. Pre-identification of available SMEs and radiological incident response resources in a jurisdiction is critical. Many jurisdictions will have to rely on local response

capabilities in the initial hours after an RDD event. Local radiation control authorities and other SMEs could be called at the onset of emergency response operations to help emergency responders manage the immediate consequences of an RDD event. This expertise could be crucial for local emergency response organizations prior to the deployment of state and federal resources. Radiological experts are routinely employed at many local hospitals, universities, and research centers. The local lead agency for radiation control can provide emergency response organizations with information on resources and expertise available in a jurisdiction.

Some military bases also have SMEs who could provide assistance to surrounding jurisdictions after an RDD event. Jurisdictions might consider establishing mutual aid agreements with local military units that have uniformed or civilian personnel who possess radiological expertise.

Experts advise emergency response organizations to involve local SMEs in the RDD incident response planning and training processes. It is essential that emergency responders train with local radiation control authorities and other SMEs prior to an RDD event. This will help emergency responders become familiar with local experts prior to an event.

- **Providing responders with radiation detection instruments**: Emergency responders who will likely respond to an RDD event should be equipped with radiation detection instruments and trained to use them correctly. Radiation detection instruments can alert first responders to the presence of onsite radioactivity at the onset of emergency response operations. These instruments also can help monitor the radiation exposure of emergency responders who are performing time-sensitive, critical activities. Emergency response organizations should consider their specific local requirements and resources when selecting radiation detection instruments. For more information on radiation detection instruments, please also refer to the *Lessons Learned Information Sharing* Best Practice "Radiological Dispersal Device Incident Response Planning: Incident Identification."

Best Practice Series Primary Sources

This series of Best Practices draws on many documents and after-action reports from exercises and incidents. Two documents are particularly helpful when planning for emergency response after an RDD event:

- The Department of Homeland Security's "Nuclear/Radiological Incident Annex" of the *National Response Plan* (NRP). The Annex creates an integrated framework for a coordinated federal response to a nuclear and/or radiological incident in general and an RDD event in particular. It supersedes the *Federal Radiological Emergency Response Plan*. The Annex classifies RDD events as "Incidents of National Significance" and assigns the Department of Homeland Security as the federal agency responsible for overall coordination. The federal response to a specific RDD incident will be based upon a number of factors, including the ability of local jurisdictions and states to respond, the type and amount of radioactive material released, the extent of the impact on the public or the environment, and the size of the affected area.

> In April 2005, the Homeland Security Council released the *National Planning Scenarios: Executive Summaries*. This draft document includes 15 all-hazard planning scenarios for use in nationwide,, federal, state, and local homeland security preparedness activities. Scenario 11 describes dirty bomb attacks against three separate US cities in close proximity to each other.

- The Department of Energy (DOE), National Nuclear Security Administration's *Municipal Radiological/Nuclear Emergency Preparedness Plan*. The plan is a template for municipalities and/or local governments that have not established radiological emergency plans. It provides a model for local emergency response authorities. A Supplementary Guidance Document provides additional implementation details.

The National Institute of Justice's *What Every Public Safety Officer Should Know about Radiation and Radioactive Materials: A Resource Guide* provides a list of RDD resources for law enforcement officers, firefighters, emergency medical responders, and other public safety officers. These resources are designed to help jurisdictions develop and update their policies and guidelines. The guide includes sections on equipment funding, procedural guidelines, personnel training, response resources, and other topics.

About This Series of Best Practices

This Best Practice series provides information that emergency response organizations can utilize to plan for an emergency response following an RDD event. The Best Practices address several essential aspects of RDD emergency response planning procedures:

- Emergency Response Organizations
- Incident Identification
- Training and Exercises
- Protective Actions
- Decontamination
- Incident Site Medical Management
- Psychological Management
- Public Information
- Long-Term Management

Radiation Measurement Units

Experts routinely utilize various units to measure different aspects of ionized radiation. The use of multiple units at an RDD incident site may be confusing for emergency responders who do not understand these units of measurement. The following list includes radiation measurement units, their definitions, and equivalences. These measurement units will be used throughout this Best Practice series.

The units for the amount of radioactivity of a source are related as follows:
1 curie (1 Ci) = 37 billion becquerels (37 GBq) = 2.2 trillion disintegrations per minute (2.2×10^{12} dpm).

The unit for the intensity of a photon radiation field is the roentgen (R).

The units for absorbed dose, or amount of energy deposited in the tissue, are related as follows:
1 radiation absorbed dose (rad) = 0.01 gray (Gy).

The units for equivalent dose, or biologically effective dose, are related as follows:
1 roentgen equivalent man (rem) = 0.01 sievert (Sv).

This Best Practice series considers 1 R = 1 rad = 1 rem. However, responders should consider that this equation will hold true only for beta and gamma radiation. It will not be true if the RDD contains an alpha emitter.

These Best Practice documents provide planners with methods, illustrations, and examples of how to improve their organizations' preparedness to respond to an RDD event. They should be viewed as supplementary resources when establishing a comprehensive RDD emergency response plan. These documents do not constitute an exhaustive list of RDD emergency response planning procedures.

BASIC RADIATION CONCEPTS

The following section presents several radiation definitions and describes different types of ionizing radiation. This section also explains radiation exposure and its health effects.

The Environmental Protection Agency (EPA) defines radiation as "energy that travels in the form of waves or high speed particles." Radiation is a form of energy that cannot be detected by human senses. Radioactive elements naturally present in soil, water, and air constantly emit radiation. The EPA classifies radiation as:

> The Office of Radiation Protection of the Washington State Department of Health has prepared a series of *Radiation Fact Sheets*. The "General Radiation Fact Sheets" are meant to provide information to the public, public information officers, and the news media; the "Advanced Radiation Fact Sheets" are intended for emergency responders, healthcare providers, public health jurisdictions, and other federal and state agencies.

- **Non-Ionizing Radiation**:
  Radiation that does not have enough energy to remove electrons. Examples of non-ionizing radiation are sound waves, visible light, microwaves, and radiofrequencies. Materials that emit non-ionizing radiation cannot be employed to produce an RDD.
- **Ionizing Radiation**: Radiation that has enough energy to remove electrons from previously stable atoms when it passes through or collides with some material. Intense ionizing radiation may cause health effects such as radiation sickness, genetic defects, and cancer. Materials that emit ionizing radiation could be used in an RDD.

Types of Ionizing Radiation

Radioactive materials used for an RDD may emit different types of ionizing radiation. These types include but are not limited to:

- **Alpha particles (α)**: Alpha particles are massive, subatomic particles usually emitted by heavy elements such as radium, uranium, and plutonium. They travel a short distance through the air, and a sheet of paper is sufficient to stop them. Alpha particles are not usually considered an external hazard since they cannot penetrate the outer dead layer of skin. Alpha-emitting isotopes can produce extensive damage if ingested, inhaled, or absorbed through open wounds. Materials emitting alpha particles may be hard to discover because instruments cannot detect alpha radiation through even a thin layer of water, blood, dust, paper, or other material. Alpha radiation is not able to

> **Resources**
>
> These descriptions of alpha, beta, and gamma particles and neutrons are based on the Oak Ridge Institute for Science and Education (ORISE), Radiation Emergency Assistance Center/Training Site (REAC/TS), *Basics on Radiation*. This website also includes information on irradiation and contamination, detection, and radiation emergency management issues.
>
> Several other resources are available to help responders understand types of radiation, health effects, and emergency management procedures:
>
> - The EPA's *Understanding Radiation* covers basic concepts, types of radiation, paths of exposure, health effects, and other relevant topics.
> - The US Department of Labor, Occupational Safety and Health Administration's *Radiation* provides a starting point for technical and regulatory information about non-ionizing and ionizing radiation.

penetrate turnout gear, clothing, or a cover on a probe. Turnout gear and dry clothing can keep alpha emitters off the skin.

- **Beta particles (β)**: Beta particles are fast electrons. They have a smaller mass than alpha particles, are moderately penetrating, and can be stopped by thin aluminum or glass. Beta particles with high energy can penetrate up to 1/2 inch of wood. Beta-emitting contaminants that are left on the skin for a prolonged period of time can produce "beta burns" (severe skin injuries). Beta-emitting particles can also cause organ damage if ingested. Most beta emitters can be detected with a survey instrument. However, some very low energy beta emitters, such as carbon-14, tritium, and sulfur-35, produce poorly penetrating radiation that may be difficult or impossible to detect. Emergency responders should be aware that clothing and turnout gear provide some protection against most beta radiation. Turnout gear and dry clothing can keep beta emitters off the skin.
- **Gamma rays (γ) and X-rays**: Gamma rays and X-rays are highly penetrating, can travel many meters through the air and many centimeters through human tissue, and can produce extensive external and internal damage. This type of radiation is usually stopped only by very heavy shielding, such as lead, uranium, thick concrete, or deep earth barriers. Clothing and turnout gear can provide little shielding from gamma rays and X-rays but will prevent contamination of the skin. Gamma rays can be detected with survey instruments.
- **Neutrons**: Neutrons are uncharged, subatomic particles with a significant mass that are usually produced during certain types of nuclear reactions. Neutrons can cause extreme cellular damage that is not dose-dependant. Neutron emitters likely will not be employed in an RDD.

Radiation Exposure

The EPA defines exposure as "a term relating to the amount of ionizing radiation that strikes a living or inanimate material." REAC/TS's *Guidance for Radiation Accident Management, Types of Radiation Exposure* identifies three types of radiation exposure injuries that could occur as a result of a radiological event:

- **Exposure**:
  - **External exposure** occurs when all or part of the body is exposed to penetrating radiation from an external source distant from or in close proximity to the body. Exposure victims do not become a secondary source of radiation. Thus, emergency responders are not in danger of being irradiated by the victim during rescue operations.
  - **Internal exposure** occurs when a person has been internally contaminated. Radiation from radioactive material inside the body penetrates tissues and organs.
- **Contamination**:
  - **External contamination** occurs when radioactive materials in the form of gases, liquids, or solids are released into the environment and deposited on a person's body or clothing. An externally contaminated person is being continuously exposed to radiation from the radioactive contamination. First responders must be careful not to spread radioactive material further on the victim's body, themselves, or the surrounding area. External contamination can be localized or whole body contamination.
  - **Internal contamination** occurs when radioactive materials in the form of gases, liquids, or solids are released into the environment and inhaled, ingested, or otherwise deposited inside the body. Internal contamination

causes internal exposure. Alpha- and beta-emitting materials are particularly dangerous as internal contaminants.

- **Incorporation** occurs when bones, body cells, tissues, and organs such as the liver, thyroid, or kidney assimilate radioactive materials based upon their chemical properties. Incorporation occurs only when internal contamination has occurred.

Exposure, contamination, and incorporation may occur in combination. Physical injury or illness could further complicate emergency medical management of victims.

Health Effects of Radiation Exposure

The amount and duration of radiation exposure generally affects the severity or type of health effect. However, health effects of radiation exposure can also depend on factors such as the type of radioactive material employed, total dose released, dose rate exposed to, body part irradiated, weather conditions, terrain, population density, etc.

There are two categories of health effects:

- **Deterministic effects**: Deterministic (or non-stochastic) effects have a direct causal link to the dose delivered. These effects appear in cases of exposure to high levels of radiation and become more severe as the exposure increases. Short-term, high-level exposure is referred to as "acute exposure." Acute health effects include burns and radiation sickness. Symptoms of radiation sickness include, but may not be limited to, nausea, weakness, hair loss, radiation burn, or diminished organ function.
- **Stochastic effects**: Stochastic effects are long-term effects impossible to predict based upon the dose delivered. They are associated with long-term, low-level exposure to radiation. Increased exposure levels make health effects more likely to occur but do not influence the type or severity of the effects. Stochastic effects can include an increased probability of developing cancer years after the event as well as hereditary effects.

GLOSSARY OF KEY TERMS

These Best Practices use various radiologically related terms. They rely on definitions derived from the Centers for Disease Control and Prevention's (CDC) *Acute Radiation Symptoms* and *Radiation Glossary*, the DOE's *Radiological Control Manual,* the EPA's *Radiation Terms* and *Understanding Radiation*, and the Health Physics Society's *Radiation Terms and Definitions.* Full citations are found in the "References" section of this document.

Acute Radiation Syndrome (ARS): The CDC's *Acute Radiation Syndrome* defines ARS as "a serious illness caused by receiving a dose greater than 75 rads of penetrating radiation to the body in a short time (usually minutes). The earliest symptoms are nausea, fatigue, vomiting, and diarrhea. Hair loss, bleeding, swelling of the mouth and throat, and general loss of energy may follow. If the exposure has been approximately 1,000 rads or more, death may occur within 2 – 4 weeks."

As Low As Reasonably Achievable (ALARA): The EPA's *Radiation Terms* states that ALARA "indicates that every reasonable effort must be made to maintain exposures as far below the applicable limits as practical."

Contamination: The National Fire Protection Association's *Hazardous Materials Response Handbook* defines contamination as "the direct transfer of hazardous material."

Secondary contamination is obtained when a person unknowingly transfers hazardous material away from a hot zone and indirectly exposes another person.

Decontamination: The DOE's *Radiological Control Manual* defines decontamination as the "process of removing radioactive contamination and materials from personnel, equipment or areas."

Dose: The DOE's *Radiological Control Manual* defines dose as "the amount of energy deposited in body tissue due to radiation exposure."

Effects: Effects of radiation exposure are classified as:

Deterministic effects: The Health Physics Society's *Radiation Terms and Definitions* defines deterministic effects as "health effects, the severity of which varies with the dose and for which a threshold is believed to exist. Deterministic effects generally result from the receipt of a relatively high dose over a short time period. Skin erythema (reddening) and radiation-induced cataract formation are examples of a deterministic effect (formerly called a non stochastic effect)."

Stochastic effects: The Health Physics Society's *Radiation Terms and Definitions* defines stochastic effects as "effects that occur by chance and which may occur without a threshold level of dose, whose probability is proportional to the dose and whose severity is independent of the dose. In the context of radiation protection, the main stochastic effect is cancer."

Exposure: The EPA's *Radiation Glossary* defines exposure as "a term relating to the amount of ionizing radiation that strikes a living or inanimate material. (This is a general definition. In health physics, exposure is specifically defined as a measure of ionization in air caused by x-ray or gamma radiation only.)"

Exposure pathways are the different routes by which people can be exposed to radiation resulting in exposure to different parts of the body. These pathways are:

Inhalation: "Exposure by the inhalation pathway occurs when people breathe radioactive materials into the lungs. The chief concerns are radioactively contaminated dust, smoke, or gaseous radionuclides such as radon."

Ingestion: "Exposure by the ingestion pathway occurs when someone swallows radioactive materials. Alpha- and beta-emitting radionuclides are of most concern for ingested radioactive materials. They release large amounts of energy directly to tissue, causing DNA and other cell damage."

Direct or external exposure: "The concern about exposure to different kinds of radiation varies:

- "Limited concern about alpha particles. They cannot penetrate the outer layer of skin, but if you have any open wounds you may be at risk.
- "Greater concern about beta particles. They can burn the skin in some cases, or damage eyes.

- “Greatest concern is about gamma radiation and x-rays. Different radionuclides emit gamma rays of different strength, but gamma rays can travel long distances and penetrate entirely through the body.

  “Gamma rays can be slowed by dense material (shielding), such as lead, and can be stopped if the material is thick enough. Examples of shielding are containers; protective clothing, such as a lead apron; and soil covering buried radioactive materials.”

Gray (Gy): The Health Physics Society’s *Radiation Terms and Definitions* describes the gray as “the international system (SI) unit of radiation dose expressed in terms of absorbed energy per unit mass of tissue. The gray is the unit of absorbed dose and has been replaced by the rad. 1 gray = 1 Joule/kilogram and also equals 100 rad.”

Monitoring: The DOE’s *Radiological Control Manual* defines monitoring as the “actions intended to detect and quantify radiological conditions.”

Personnel dosimetry: The DOE’s *Radiological Control Manual* defines personnel dosimetry as “devices designed to be worn by a single person for the assessment of dose equivalent such as film badges, thermoluminescent dosimeters (TLDs), and pocket ionization chambers.”

Protective actions: The EPA’s *Radfacts* defines a protective action as “any action taken to reduce or avoid a radiation dose to the public.” The NNSA’s *Municipal Radiological/Nuclear Emergency Preparedness Plan* lists the following three categories of protective actions:

> **Access control**: Measures implemented to control ingress and egress of the public and non-authorized emergency response personnel into and out of the incident area.
>
> **Contamination control**: Measures implemented to prevent the spread of radiological material following an RDD event.
>
> **Exposure control**: Measures implemented to minimize the exposure of emergency response personnel, victims, and the public to radioactive material.

Radiation: The EPA defines radiation as “energy that travels in the form of waves or high speed particles.”

> **Non-ionizing radiation**: Radiation that does not have enough energy to remove electrons.
>
> **Ionizing radiation**: Radiation that has enough energy to remove electrons from previously stable atoms when it passes through or collides with some material.

Radiation Absorbed Dose (rad): The Health Physics Society’s *Radiation Terms and Definitions* defines rad as “the original unit developed for expressing absorbed dose, which is the amount of energy from any type of ionizing radiation (e.g. alpha, beta, gamma, neutrons, etc.) deposited in any medium (e.g. water, tissue, air). A dose of one rad is equivalent to the absorption of 100 ergs (a small but measurable amount of energy) per gram of absorbing tissue. The gray has been replaced by the rad in the SI system of units (100 rad = 1 gray).”

Radioactivity: The DOE's *Radiological Control Manual* defines radioactivity as "a natural and spontaneous process by which the unstable atoms of an element emit or radiate excess energy from their nuclei and, thus, change (or decay) to atoms of a different element or to a lower energy state of the same element."

Whole Body: The DOE's *Radiological Control Manual* defines whole body as, "for the purposes of external exposure, head, trunk (including male gonads), arms above and including the elbow, or legs above and including the knee."

REFERENCES

Selected Standards and Regulations

Department of Energy, 10 CFR 835 – Occupational Radiation Protection

- Relevant subparts include occupational dose limits for general employees, limits for members of the public entering a controlled area, concentrations of radioactive material in air, high and very high radiation areas, emergency exposure situations, and nuclear accident dosimetry.

Nuclear Regulatory Commission, 10 CFR Part 20 – Standards for Protection against Radiation

- Lists occupational dose limits for adults, dose limits for individual members of the public, respiratory protection and controls to restrict internal exposure in restricted areas, and procedures for waste disposal. Appendix A includes assigned protection factors for respirators, and appendix B lists annual limits on intake and derived air concentrations for occupational exposure.

Department of Labor, Occupational Safety and Health Administration Documents

The Occupational Safety and Health Administration's (OSHA) *Safety and Health Topics, Radiological Dispersal Devices (RDD)/Dirty Bombs* consists of a list of directives, standards, and standard interpretations, including:

OSHA Regulations (Standard - 29 CFR) Part 1910.1096 – Ionizing Radiation

- Specifies dose limits per calendar quarter, limits on exposure to airborne radiation, use of personnel monitoring devices (film badges, pocket dosimeters, etc.), warning signs, monitoring and emergency alarms, and incident reporting procedures.

OSHA Regulations (Standard - 29 CFR) Part 1910.120 – Standard on Hazardous Waste Operations and Emergency Response

- Requires a preliminary evaluation to identify risks and threats, a site control program, medical surveillance, appropriate personal protective equipment, monitoring, the proper handling of drums and containers, decontamination procedures, and emergency response plans. Appendix B also provides a description of protective gear.

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