Interim Clearance Strategy for Environments Contaminated with Hazardous Chemicals

The *Interim Clearance Strategy for Environments Contaminated with Hazardous Chemicals* document was developed by the Environmental Remediation Operations Working Group (EROWG) as a separate, stand-alone deliverable to the Wide Area Resiliency and Recovery Program (WARRP). It has been published by WARRP under this heading and is listed in the WARRP Product Reference Guide. This document was developed with input from the combined membership from the EROWG, which included federal, state and local partners and was designed specifically for the WARRP chemical scenario release in Denver, Colorado. It is representative of what the Denver community might do under this scenario and should not be considered policy or guidance. It may be useful as a starting point for other local governments to develop their own clearance strategies, but the EROWG highly recommends that anyone developing a clearance strategy consult with their federal, state, local, private sector, and volunteer organizations to develop an appropriate strategy. Any clearance strategy should also be based on the chemical agent that is released and the site specific conditions of the region where the release takes place.

This document is contained in this National Guidance for use as an example and may not be applicable or appropriate for releases of different agents, or at different locations, or under different circumstances.

Wide Area Recovery & Resiliency Program (WARRP)

Interim Clearance Strategy for Environments Contaminated with *Hazardous Chemicals*

July 2012

Purpose:

This *Interim Clearance Strategy for Environments Contaminated with Hazardous Chemicals* document provides a framework for Federal, State, Territorial, Tribal, and local government officials to use in expediting decisions for characterizing and cleaning up after a wide area hazardous chemical release. The effort will require the development of acceptable clearance criteria for the eventual re-occupancy of the impacted areas. To this end, a Federal interagency group of experts surveyed the current state-of-the-science on risk assessment, sampling analysis strategies, laboratory capacity, decontamination technologies, regulatory environment, and operational logistics as it relates to the development of a chemical clearance strategy. Practical clearance criteria will reduce residual risks to levels acceptable to the Incident/Unified Command (IC/UC). These criteria are incident- and site-specific, therefore the approach that this framework will take is to define a strategic methodology by which these incident- and site-specific clearance criteria are developed. This interim framework is suggested as a living document that will be updated as needed to reflect the state of the science and policy. Hazardous chemicals include chemical warfare agents (CWAs) and toxic industrial chemicals (TICs), with some TICs considered as potential CWAs.

General Clearance Approach:

The overall approach to achieving clearance (a determination that cleanup is not required or that cleanup has met the requirements necessary for re-occupancy) is risk-based. Risk assessment tools have been developed by a variety of government agencies to evaluate threats to exposed populations. Risk assessment informs the risk management process, which integrates public health, political, social, economic, engineering, and other considerations into the response decisions. Risk assessment can be initiated at different phases of the response and can be tailored to quantify and evaluate risk to different groups for different purposes (e.g., clearance versus temporary re-entry). Although detailed, site-specific quantitative estimates of risk can be derived using data gathered during the response, qualitative risk assessments can also be developed through comparisons of measured environmental chemical concentrations to benchmarks of toxicity and exposure (i.e., pre-calculated, health-based exposure guidelines). **Although the clearance approach outlined by this document is site- and situation-specific, the overall goal is to define a process where clearance criteria are protective of human health and the environment and permits unprotected re-entry and re-occupancy.** Figure 1 proposes components of a process that may be used for the development of clearance criteria. Adherence to these processes can guide decision makers to develop appropriate clearance goals that are protective of human health and the environment that are cost and time effective. The process for determining clearance criteria following an incident should balance relevant factors, including:

- Health-based human health exposure guidelines;
- Areas affected (e.g., size, location relative to population);
- Types of contamination (e.g., CWA, TIC);
- Other hazards present; (e.g., fires, floods, other chemical/physicals hazards)
- Public welfare;

- Ecological risks;
- Actions already taken and decisions made during crisis management to protect public health and the environment;
- Projected land use;
- Preservation or destruction of places of historical, national, or regional significance;
- Technical feasibility, including:
  - analytical capability and capacity to support clearance goals,
  - ability to apply decontamination options to events of varying scale,
  - ability of field screening instruments to detect contaminants at operationally useful levels;
  - surfaces, media and material resistant to currently available decontamination technologies
- PPE requirements and safety requirements for cleanup workers;
- Processes to identify and construct temporary staging areas so that waste management activities are removed from the critical path of remediation;
- Wastes generated, treatment/disposal options and costs, and strategies and methods to characterize the waste;
- By-products, degradates and undesirable consequences of decontamination options;
- Costs and available resources to implement and maintain remedial options;
- Potential adverse impacts of remedial options to, e.g., human health, environment, economy;
- Long-term effectiveness;
- Timeliness;
- Public acceptability, including local cultural sensitivities; and
- Economic effects (e.g., tourism, business, and industry, denial of access).

Integral to the development of a clearance strategy is the effective management of wastes generated during decontamination, disposal and remediation activities. Temporary and permanent waste management options must comply with all Federal, state and local regulations and ordinances[1]. Laboratory capacity and capabilities will also be critical. Laboratories will need to provide timely analytical results at or below the site specific health-based concentrations levels in order to verify that decontamination and remediation actions have met the clearance criteria. As noted above, the assessment and management of risk is the central focus of any response to the release of hazardous chemicals. However it must also be noted that an integral part of the overall management of human health risk is risk communication. The planning and implementation of a risk communication strategy that bridges the events from crisis to consequence management is paramount to ensuring public understanding and trust which will contribute to the overall success of the response. A single authoritative source of frequent, clear and concise risk communication messages to the public will be necessary during all phases of the incident response.

[1] If the response action is pursuant to CERCLA and on-site, federal and state requirements, but not local, need to be taken into account through the ARARs process.

Flexible Clearance Approach

Clearance decision-making should not be static and prescriptive; rather it should involve a flexible process that includes situation-specific considerations and the most current understanding of science and engineering. A flexible process is needed in which numerous factors are considered to achieve an end result that balances health risks, local needs and desires, costs, technical feasibility, and other factors.

The goals of a clearance decision-making process are:

1. Transparency **–** The basis for cleanup and other decisions should be available to stakeholder representatives, and ultimately to the public at large
2. Inclusiveness **–** Representative stakeholders should be involved in decision-making activities
3. Effectiveness **–** Technical subject matter experts should analyze remediation options, assess various technologies in order to assist in decisions that are optimal for the incident, and consider clearance decisions and clearance goals
4. Shared Accountability **–** The final decision to proceed will ultimately be made at the local level. In a unified command, with Federal, State, Tribal, and local officials involved in the decision making process, accountability will be shared.

A flexible clearance approach can include consideration of a variety of dose and/or health benchmarks (e.g., advisory levels, clearance goals, etc.), from Federal, State, or other sources (e.g., national and international advisory organizations). These benchmarks may also be useful in analyzing cleanup options. Acute inhalation exposure guideline values could be used when developing health benchmarks for temporary re-entry, while chronic inhalation exposure guideline values could be used when developing health benchmarks for final clearances (Table 1). Figure 2 depicts a side by side comparison of the various inhalation exposure guideline values for Sulfur Mustard at different time frames. Benchmarks derived for shorter or longer exposure durations may be appropriate depending on application, site-specific circumstances or to balance other relevant factors such as technical feasibility. A flexible clearance process provides an opportunity for decision-makers to involve stakeholders and build public confidence in the decision-making process.

Health-based Exposure Guidelines

Many agencies have developed a variety of environmental, health-based exposure guidelines. These guidelines estimate the potential health risks due to exposures by way of inhalation, ingestion or dermal contact from various contaminated matrices for specified periods of exposure. Exposure periods range from acute exposure, typically less than 24 hours, to intermediate exposures lasting up to 7 years, to lifetime or chronic exposures. For example, the EPA has developed health-based Provisional Advisory Levels[2] (PALs), which are threshold inhalation and oral exposure levels for 24-hour, 30-day, 90-day and 2-year exposure durations, for hazardous chemicals. PALs are intended to be used, at the discretion of risk managers in emergency situations, as a means to assist in making informed risk management decisions for

[2] Adeshina, F. et al., Health-based Provisional Advisory Levels (PALs) for Homeland Security, *Inhalation Toxicology*, 2009(S3) 12-16

determining resumed use of infrastructure and temporary re-entry into affected areas. Table 1 summarizes various acute, intermediate and chronic inhalation exposure guidelines, including the inhalation PALs. Table 2 summarizes environmental screening and exposure guidelines for drinking water, soils and surfaces (dermal contact). **Despite numerous standards and regulatory guidelines, there are no predetermined cleanup approaches or levels that are universally applicable to every chemical release incident.**[3] Therefore, coordination among Federal, State, Territorial, Tribal and local governments is critical to ensure the cleanup process is acceptable, effective and yet flexible enough to ensure all the considerations of site-specific characteristics of the particular event are met. These challenges can be addressed by planning ahead, understanding organizational roles and responsibilities, and developing a defined, well-organized and agreed-upon approach to hazardous chemical cleanup decision-making.

Characteristics of Contaminants and Contaminated Areas.

Cleaning up hazardous chemical incidents effectively requires a clear understanding of the contaminant toxicity, concentration, extent of contamination, key physical and chemical characteristics, sources of exposure, routes of exposure, the persistence of the chemical hazards, reactivity (synergistic or antagonistic) with substrate matrices of other substances, as well as the prevailing environmental conditions and characteristics of the media impacted by the specific hazardous chemical incident. Many hazardous chemicals may yield toxic and persistent break down products, or degradates, as a result of interactions/contact with environmental media or the chemical products used for decontamination. The toxicity of and potential exposure to these degradates must be accounted for in any overall site clearance decision such that the risk to the environment and public safety is not compromised. A series of two-page Quick Reference Guides (QRG) that describes selected CWA/TIC characteristics, physical and chemical parameters, possible release scenarios, health effects, personnel health and safety, field detection, sampling and analysis, decontamination and waste disposal are available from the National Response Team website (http://www.nrt.org/).

Key physical and chemical parameters include:

- Vapor pressure, vapor density, and volatility;
- Freezing/melting point and boiling point;
- Solubility in water and other solvents;
- Octanol-water partition coefficient (Log K_{ow});
- Henry's Law Constant;
- Flash Point;
- Reactivity with ultraviolet (UV) light, water, oxidizers, and other decontamination agents;
- Propensity for chemical adsorbtivity and/or physical adsorption; and
- Persistence and environmental fate.

[3] If the response to the release is pursuant to CERCLA, then the National Contingency Plan applies.

Key environmental conditions include:

- Ambient temperature;
- Relative humidity;
- Sunlight levels;
- Wind/ air flow; and
- Topographical relationship to release point and intervening terrain and structures.

Key media characteristics include:

- Porosity (porous/non-porous);
- Organic/inorganic content;
- Time exposed to contaminant(s);
- Reactivity-interactions w/ agents; and
- Sensitive items/historical/cultural significance items.

The judicious use of the knowledge on the prevailing environmental conditions, agent characteristics and impacted surfaces and media can assist planners in directing samplers to the most advantageous areas for characterization and clearance sampling, selecting the most efficacious decontamination methods as well as assisting the risk assessors in determining the most appropriate site-specific clearance goals.

Pre-clearance Re-entry Values

The different phases of the overall remediation process will require temporary re-entry by responders or others. Although not classified as clearance, a similar process can be applied to derive risk-based exposure guidelines to inform decision-makers at various phases of the remediation for differing periods of time. An example of this would be a temporary re-entry exposure guideline established for responders during characterization or decontamination activities to allow site workers to accomplish specific tasks at exposure levels above that designed for clearance, while working in appropriate PPE with site monitoring. Numerous environmental screening or exposure values exist for CWAs that can be used to determine pre-clearance re-entry values (Tables 1 and 2). Selection of temporary re-entry monitoring levels or final clearance goals may include quantitative and qualitative assessments applied at each stage of site restoration decision-making from evaluating cleanup options through implementing the chosen cleanup alternative.

Challenges of Clearance for Wide Area Contamination

Wide area contamination from the deliberate release of hazardous chemicals, including CWAs and TICs, will present unique challenges. The varieties of terrains, environments, public spaces and materials impacted will necessitate a tiered approach toward remediation, as well as a flexible clearance process. Limited analytical capacity, decontamination assets and environmental exposure guideline values on all the possible impacted media may necessitate novel approaches to sampling, analysis, decontamination and clearance. **These procedures must be agreed upon at the highest levels in the Incident Command structure and be clearly and concisely communicated to the public for a successful remediation and recovery to occur.**

A variety of health based values can be used to evaluate exposures for emergency response phase. Exposure guidelines for short and longer-term exposure durations can be used to evaluate occupational and general public health exposures in the remediation and recovery phases, for air, soil and water matrices. These environmental exposure guideline values have been developed by various agencies. The IC/UC Clearance Committee may use these data the basis for developing site- and situation-specific clearance goals. Target population, exposure duration, intended application and level of peer-review are some of the factors that should be considered in choosing appropriate exposure guideline values. No single value will be suited for every chemical or situation, but they provide a starting point for site-specific considerations. Ultimately, it is important to clearly understand what these values represent and what they do not represent so that they are used appropriately. And, if an available value does not adequately reflect the site- and situation-specific nature of the scenario, an experienced toxicologist should be consulted to derive a *de novo* site-specific exposure guideline.[4]

Challenges of Clearance for Indoor-Outdoor Surfaces

Wide area contamination events resulting from accidental or intentional releases of CWA and/or TICs are expected to yield substantial contaminated surface areas that would pose a dermal contact hazard to the general public. Surfaces from both urban and rural areas present a vast array of materials with differing affinities for the hazardous chemical to which they are exposed. Both indoor and outdoor surfaces may present both acute and chronic exposure risks, especially in common public areas such as transportation hubs, sporting/entertainment venues, schools, hospitals, as well as private residences and municipal/governmental buildings. This will challenge the risk assessor/toxicologist in their determinations of exposure and risk to the public. There are currently no peer-reviewed, published values for short- or long-term dermal exposures. Quantitative risk-based methods apply oral toxicity values to assess risks from dermal exposure. Depending on the studies from which a chemical's toxicity value was derived, one may need to adjust the oral toxicity value from an administered dose to an absorbed dose. The methodology is provided in EPA's Risk Assessment Guidance for Superfund (RAGS).[5] More recently, the EPA has recognized the need to expand its efforts to include building surfaces. Subsequent to the attack on the World Trade Center, the EPA became involved in efforts to develop risk-based surface cleanup goals (EPA, 2003)[6] using methodology similar to that provided by RAGS Part B. The World Trade Center model incorporated into the newest edition of the RAGS, Part E, Supplemental Guidance for Dermal Risk Assessment. Other methods for the derivation of surface cleanup goals are currently under consideration. The California EPA (CAL EPA) has recently incorporated EPA's Stochastic Human Exposure and Dose Simulation (SHEDS) Model used for determining the exposure risks from clandestine methamphetamine drug laboratory, to

[4] U.S. EPA, 1991, Risk Assessment Guidance for Superfund: Volume I: Human Health Evaluation Manual (Part B, Development of Risk-based Preliminary Remediation Goals). EPA/540/R-92/003.

[5] See Chapter 4 of the EPA's *Risk Assessment Guidance for Superfund (RAGS)*, Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment, Interim (2004), available at http://www.epa.gov/oswer/riskassessment/ragse/

[6] US EPA 2003, World Trade Center Indoor Environmental Assessment: Selecting Contaminants of Potential Concern and Setting Health-based Benchmarks. Prepared by the Contaminants of Potential Concern (POPC) Committee of the World Trade Center Indoor Air Task Force Working Group

estimate the dermal exposures from surface contact with hazardous chemicals, including CWAs.[7] The CAL EPA modified SHED model has yet to be adequately validated but may provide a platform, along with EPA RAGS methodologies, to develop site- and incident-specific clearance goals for contaminated surfaces.

[7] See http://www.oehha.ca.gov/public_info/public/pdf/ExpoAna122807.pdf

Table 1 – Inhalation Exposure Guidelines for Selected CWAs

Guideline	Duration (hr)	**Sarin** (mg/m^3)	**Sulfur Mustard** (mg/m^3)	**Lewisite** (mg/m^3)	**VX** (mg/m^3)
IDLH[1]	0.5	0.1	0.7	NA	0.003
STEL[1]	0.25	0.0001	0.003	NA	0.00001
AEGL-1[2]	0.17	0.0069	0.4	NA	0.00057
AEGL-1	0.5	0.004	0.13	NA	0.00033
AEGL-1	1	0.0028	0.067	NA	0.00017
AEGL-1	4	0.0014	0.017	NA	0.00010
AEGL-1	8	0.001	0.0083	NA	0.000071
AEGL-2	0.17	0.087	0.6	NA	0.0072
AEGL-2	0.5	0.05	0.2	0.23	0.0042
AEGL-2	1	0.035	0.1	0.12	0.0029
AEGL-2	4	0.017	0.025	0.035	0.0015
AEGL-2	8	0.013	0.013	0.018	0.0010
AEGL-3	0.17	0.38	3.9	3.9	0.029
AEGL-3	0.5	0.19	2.7	1.4	0.015
AEGL-3	1	0.13	2.1	0.74	0.010
AEGL-3	4	0.07	0.53	0.21	0.0052
AEGL-3	8	0.051	0.27	0.11	0.0038
PAL-1[3]	24	0.0002	0.0008	NA	0.000017
PAL-1	720	0.000018	0.0001	NA	0.0000018
PAL-1	2160	0.000018	0.0001	NA	NA
PAL-2	24	0.001	0.013	0.01	0.00063
PAL-2	720	0.00073	0.0029	NA	0.000073
PAL-2	2160	0.0002	0.00097	NA	NA
PAL-3	24	0.015	0.35	0.037	0.0022
PAL-3	720	NA	NA	NA	NA
PAL-3	2160	NA	NA	NA	NA
MRL acute [4]	24	NA	0.0007	NA	NA
MRL acute	336	NA	0.0007	NA	NA
MRL intermed.	360	NA	0.00002	NA	NA
MRL intermed.	8760	NA	0.00002	NA	NA
WPL	8760	0.00003	0.0004	NA	0.000001
WPL[1]	219000	0.00003	0.0004	NA	0.000001
GPL	8760	0.000001	0.00002	NA	0.0000007
GPL[1]	613200	0.000001	0.00002	NA	0.0000007

NA = not available
[1] Chemical Exposure Guidelines - available at http://cdc.gov/NIOSH/ershdb/index_name.htm
[2] Acute Exposure Guideline Levels (AEGLs) – available at http://www.epa.gov/opptintr/aegl/
[3] Provisional Advisory Levels (PAL) – available at http://www.epa.gov/nhsrc/index.html
[4] ATSDR Minimal Risk Levels (MRL) – available at http://www.atsdr.cdc.gov/mrls

Table 2 - Environmental Screening and Exposure Guidelines for Selected CWAs

Drinking Water - (µg/L)	Duration	Sarin	Mustard	Lewisite	VX
RBC [1]	Lifetime	0.7	0.25	3.5	0.021
MEG 5L/day [2]	7 years	28	140	28	15
MEG 15L/day	7 years	9.3	47	27	8
PAL-1 2L/day [3]	1 day	37	NA	NA	2.7
PAL-1 2L/day	30 days	8.1	NA	NA	0.21
PAL-1 2L/day	90 days	2	NA	NA	0.21
Soil - (mg/kg)	Duration	Sarin	Mustard	Lewisite	VX
PRG – Residential [4]	Lifetime	1.3	0.01	0.3	0.042
PRG – Industrial	24 years	32	0.3	3.7	1.1
Surface - ($\mu g/cm^2$)	Duration	Sarin	Mustard	Lewisite	VX
PRG Residential [5]	Lifetime	4.3×10^{-3}	8.1×10^{-5}	6.0×10^{-2}	1.3×10^{-4}
PRG Occupational	24 years	1.2×10^{-2}	2.2×10^{-4}	2.0×10^{-2}	3.6×10^{-4}

[1] Risk Based Criteria (RBCs) - values calculated for chronic exposure calculated akin to EPA's Maximum Contaminant Levels (MCLs), see: http://water.epa.gov/drink/contaminants/index.cfm

[2] Military Exposure Guidelines (MEG), The Medical NBC Battle Book, Technical Guide 244, USACHPPM, 2008

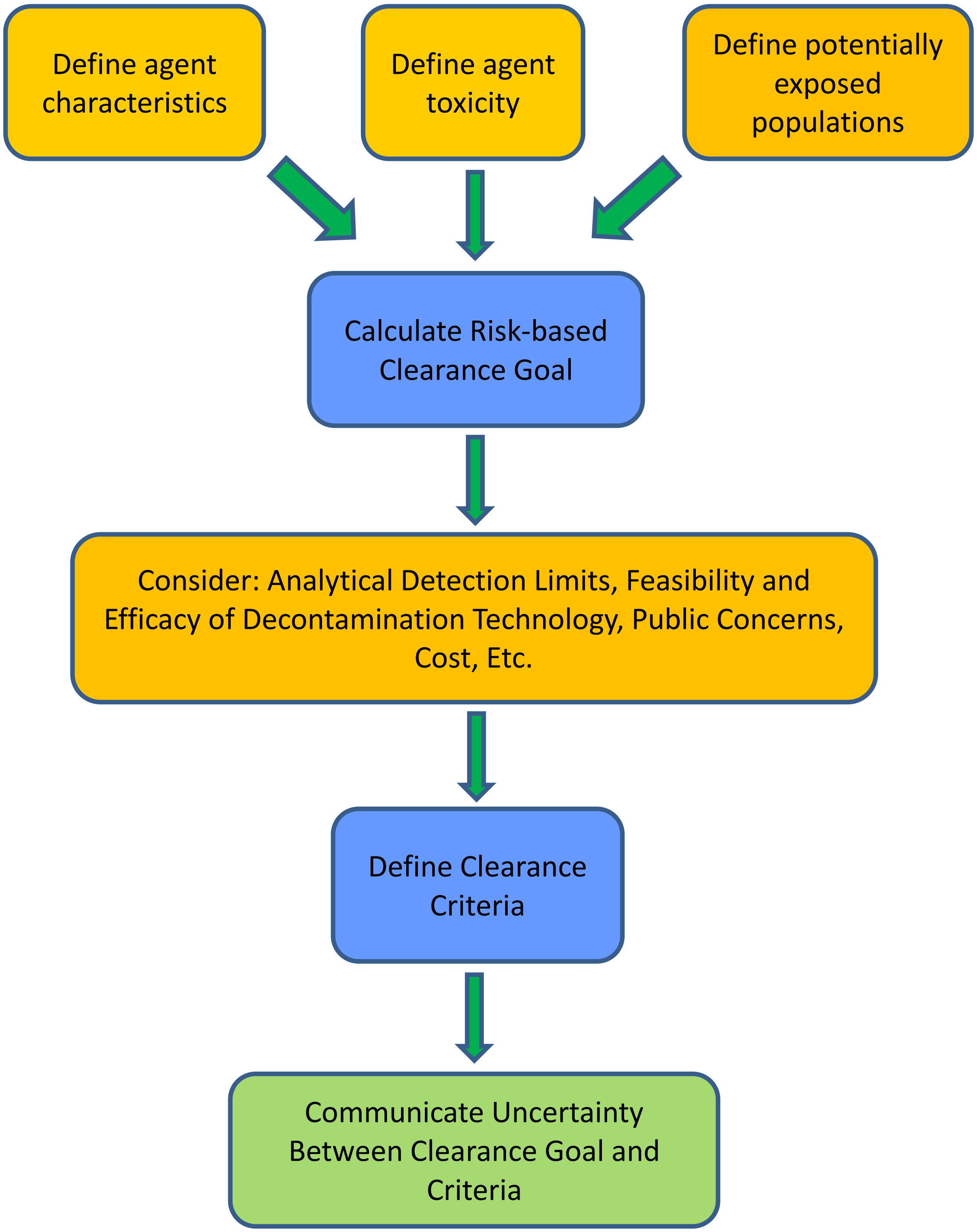
[3] Provisional Advisory Levels, no adverse effects (PAL-1) - available at http://www.epa.gov/nhsrc/index.html

[4] Preliminary Remediation Goals (PRG) risk based goals for soils - available at http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/index.htm

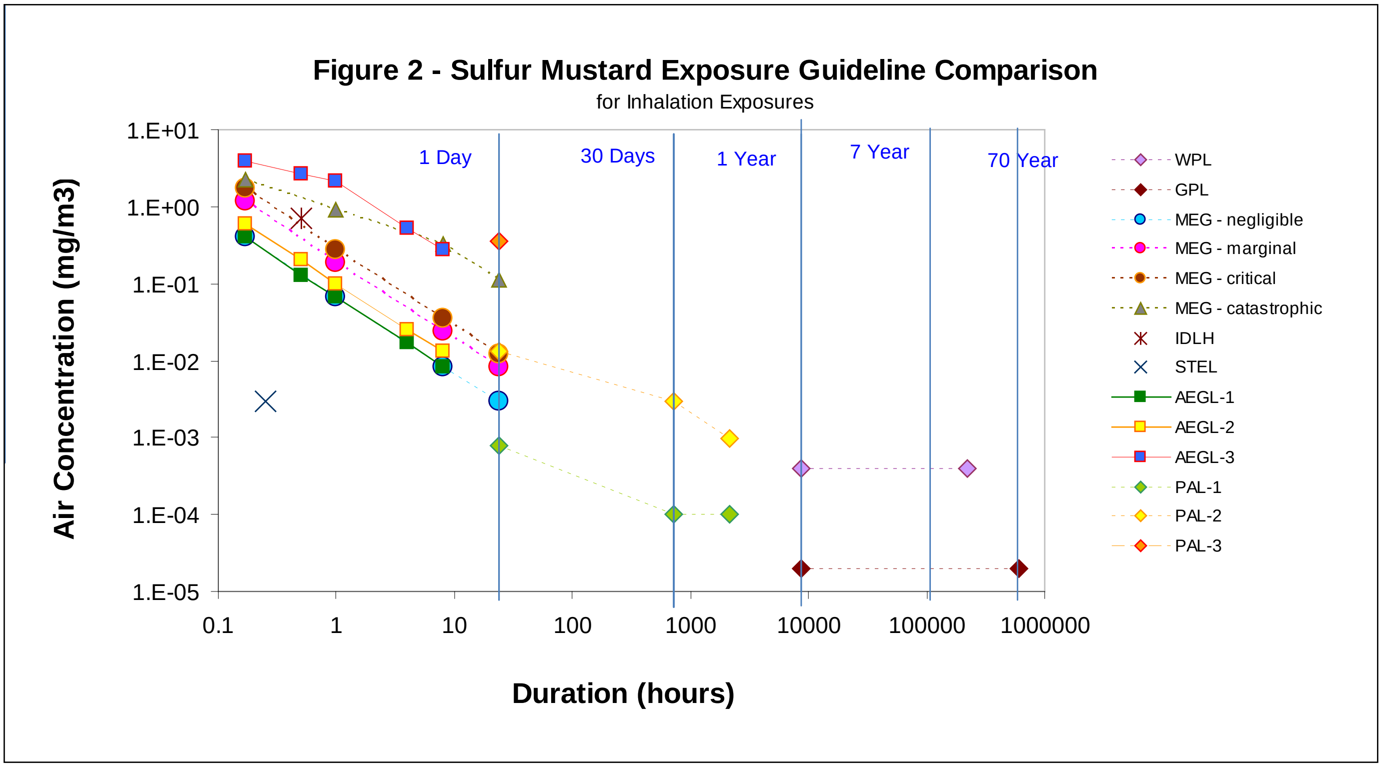
[5] Preliminary Remediation Goals (PRG), risk based goals for surfaces calculated via EPA's Risk Assessment Guide for Superfund (RAGS) methodologies, available at http://www.epa.gov/oswer/riskassessment/ragse/

NA = not available due to rapid decomposition of agent in water

Figure 1. Proposed Clearance Process



[8]



WPL = Worker Population Limit

GPL = General Population Limit

MEG = Military Exposure Guideline

IDLH = Immediately Dangerous to Life and Health

STEL = Short-Term Exposure Limit

AEGL = Acute Exposure Guideline Level

PAL = Provisional Advisory Level

[8] USAEP 2009, Graphical Arrays of Chemical-Specific Health Effect reference Values for Inhalation Exposure, EPA/600/R-09/061, September 2009

Interim Clearance Guidance for Environments Contaminated with Bacillus anthracis

The draft version of the *Interim Clearance Guidance for Environments Contaminated with Bacillus anthracis* was developed by the Centers for Disease Control (CDC) and the US Environmental Protection Agency (EPA) and is not part of the WARRP program. It has been re-printed here simply as an example of a clearance strategy that could be used to support a scenario similar to the WARRP *Bacillus anthracis* scenario in Denver. The document is currently undergoing revision; however, the clearance goal described in the document will remain the same. When finalized, the document will be available on CDC's anthrax website.

The strategy set forth here is intended as an interim guide for public health and environmental Federal responders. It represents knowledge from best practices and available science. Because this is an EPA/CDC document, unlike the chemical and radiological clearance strategies created as part of WARRP, the strategy will be managed and updated jointly by EPA and CDC as new information becomes available. The incident command/unified command (IC/UC) is ultimately responsible for developing site- and incident- specific clearance strategies. It is highly recommended for anyone developing a clearance strategy to consult with their federal, state, local, private sector, and volunteer organizations to develop an appropriate strategy. Any clearance strategy should also be based on the biological agent that is released and the site specific conditions of the region where the release takes place.

This document may not be applicable or appropriate for releases of different agents, or at different locations, or under different circumstances.

Interim Clearance Strategy for Environments Contaminated with *Bacillus anthracis*

July 2012

Disclaimer:

The strategy set forth here is intended as an interim guide for public health and environmental Federal responders. It represents knowledge from best practices and available science. This strategy will be reviewed biennially as new information becomes available. The incident command/unified command (IC/UC) is ultimately responsible for developing site- and incident- specific clearance strategies.

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The Environmental Protection Agency (EPA) and the Centers for Disease Control and Prevention (CDC) have developed this interim clearance strategy to aid Incident Command/Unified Command (IC/UC) in clearing a building or an outdoor environment after an incident involving contamination with *Bacillus anthracis* (*B. anthracis*). The strategy is based on the best available science and most practical approach, and is intended for use by public health and environmental Federal responders supporting the IC/UC responding to a *B. anthracis* incident.

For the purpose of this document, the clearance strategy is defined as the approach used to meet a pre-defined clearance goal and the associated process to determine that the goal has been achieved. Developing and implementing a clearance strategy for the purpose of remediating indoor and outdoor areas after contamination is a critical environmental and public health need. Ultimately, the clearance decision generally rests with the local or state public health officials or property owner(s).

Purpose:

If a *B. anthracis* incident occurs in the United States or within its territories, the public health and environmental response communities must work collaboratively during the response to most effectively address the risks posed by the incident. The ultimate goal is to effectively and efficiently remediate the environment so that the local or state public health officials or private building owners can make follow-on decisions. The remediation phase of a response includes characterization, decontamination, and clearance as defined in the Office of Science and Technology Policy (OSTP) draft document, *Planning Guidance for Recovery Following Biological Incidents*. (OSTP, 2009)

To that end, a group of experts from CDC and EPA met to discuss the current state-of-the-science on risk assessment, sampling strategies, decontamination technologies, and operational logistics as they relate to the development of a clearance strategy. The *Interim Clearance Strategy for Environments Contaminated with Bacillus anthracis* was developed as a result of this meeting and is a living document that will be updated as the state-of-the-science changes. This strategy document is complementary to the broader overarching draft OSTP document previously mentioned. The OSTP document recommends that "the collective, professional judgment of technical experts, applied within the context of the concerns of stakeholders, should be used to set clearance goals appropriate to the site-specific circumstances."

Overview:

Based on a number of considerations as well as the current state-of-the-science, EPA and CDC recommend that, "no detection of viable spores" is the best practicable clearance goal. This is consistent with previous recommendations provided by the National Academy of Sciences in *Reopening Public Facilities after a Biological Attack* (2005). This strategy is intended for clearing indoor and outdoor settings and relies on a site-specific targeted (sometimes referred to as judgmental) sampling strategy. Culture-based analysis is currently the best available method for determining the presence of viable *B. anthracis* spores. Appropriate environmental sampling and decontamination strategies should be selected to achieve this clearance goal. This approach was determined, through research and experience in responding to prior *B. anthracis* incidents, to:

1. Be the most effective and efficient method to collect useful data for decision-making;
2. Reduce the potential for exposure to potentially infectious spores; and,
3. Lessen the impact of the incident by expediting the remediation phase through sampling strategies and decontamination process verification data that minimize risk and enhance confidence in decision-making.

Beyond the continued limitations in sampling and detection, sufficient data do not exist on the efficacy of decontamination technologies to generally support the elimination of clearance sampling. Moreover, data related to dose-response relationships are limited, preventing experts from estimating risk of exposure and subsequent risk of disease from numeric clearance sampling results.

The strategy to ascertain achievement of this recommended clearance goal relies on a combination of data sources and may include epidemiological data, environmental targeted sampling data, intelligence reports, agent fate modeling, data from decontamination efficacy studies, biological indicators as a marker of decontamination effectiveness (where appropriate), and measurement of appropriate decontamination parameters such as contact time, relative humidity and temperature. The use of this information will contribute to a rapid and more complete representation of the incident and lead to informed decisions regarding public health actions and remediation activities. Additional risk reduction measures such as vaccination, antimicrobial prophylaxis, administrative and engineering controls will be considered, as environmental sampling alone may not provide a full picture as to the risks involved.

The clearance strategy may be adjusted based on the site- and situation-specific nature of the incident. The UC/IC will make the final decisions on remediation approaches[1].

Note: *The best available science will be considered when making sampling and analysis decisions. EPA and CDC acknowledge the limitations of sampling and analytical detection limits. While EPA and CDC use the term "no detection of viable spores," it is recognized that in both the indoor and outdoor environments there may be viable residual spores present below the current sampling and analytical detection limits.*

[1] This cleanup process does not rely on and does not affect authority under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), 42 U.S.C. 9601 et seq. and the National Contingency Plan, 40 CFR Part 300.

Indoor Clearance Guidance

Indoor remediation (which includes characterization, decontamination, and clearance) has been well studied over the past ten years. The clearance goal of "no detection of viable spores" as confirmed with sampling methods compatible with culture-based analysis should generally be used. In order to increase confidence in the data from targeted sampling, EPA and CDC recommend that trained field responders should use surface sample collection methods for which there are available validated laboratory processing methods. Sample collection methods for field responders that are based on validated laboratory processing methods can be accessed at: http://www.cdc.gov/niosh/topics/emres/surface-sampling-bacillus-anthracis.html. EPA and CDC recognize that not all analytical methods are validated and that the existing validated methods may not work in all circumstances. Notably, they are limited at present to use on smooth, non-porous surfaces. This reality requires the IC/UC to consider use of other commonly acceptable sampling and analysis methods in consultation with environmental sampling subject matter experts and the receiving laboratories. With these considerations in mind, it is recommended that the IC/UC develop a site-specific sampling plan with a preference for targeted sampling during the characterization and clearance phases. This approach will facilitate a more efficient characterization and clearance strategy.

EPA has determined from experience and studies that fumigation is the best decontamination methodology for large facilities with *B. anthracis* contamination. However, decisions regarding decontamination technology and strategy should be made on a site- and situation-specific basis, including considerations such as decontamination technology capacity and availability, building use, and type and extent of contamination. EPA intends to select or recommend the most cost effective and efficacious decontamination technology(ies) based on these considerations. Since a wide range of appropriate decontamination technologies exist, the lab and field efficacy data will be used to build confidence that the selected decontamination technology will lead to achievement of the clearance goal. The more efficiently the site is remediated, the lower the risk to the public.

Outdoor Clearance Guidance

The ability to assess the extent of contamination, knowledge of spore fate and transport, historical experience and efficacy of decontamination technology will likely be more limited for an outdoor setting. Therefore, a modified approach to meeting the clearance goal is recommended for outdoor environments. However, the public health and environmental aims to reduce the exposure risk through a reduction in spore load remain the same as the indoor environment. As in the indoor setting, the IC/UC should develop a site-specific sampling plan with a preference for targeted sampling during the remediation phase. The clearance goal of "no detection of viable spores" as confirmed with air sampling methods compatible with culture-based analysis should be used. It should be noted that characterizing the extent of contamination and efficacy of decontamination in an outdoor setting is inherently problematic and subject to considerable uncertainty especially at the detection levels of concern to public health. This scientific uncertainty, and the lack of previous experience in clearing an outdoor environment, may ultimately require a more conservative approach. Additional lines of evidence (e.g., epidemiology, animal monitoring, and agent fate and modeling and additional types of environmental sampling) may be used to clear the area of concern, and inform the need for any additional remediation activities. CDC and EPA recognize that validated air sampling methods do not currently exist, which requires the IC/UC to consider use of other commonly acceptable sampling and analysis methods in consultation with environmental sampling subject matter experts and the receiving laboratories.

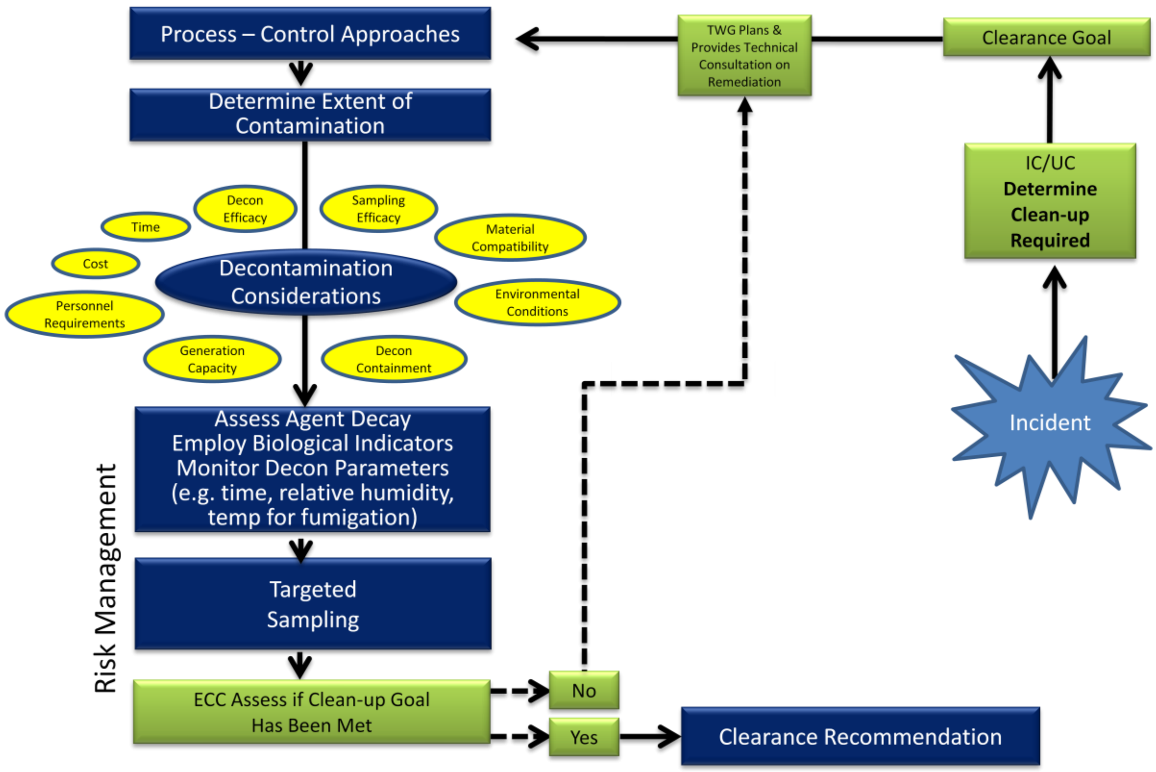
Follow-on environmental sampling and long-term health monitoring may be employed to further evaluate potential anthrax-related symptoms and disease.

Note: *Environmental factors must be taken into account in developing the clearance strategy for each incident.*

ANNEX A

Clearance Strategy

An overview of the process and considerations is pictured below:



At the time of an incident, Federal technical consultation or response may be warranted[2] to remediate the site for re-occupancy and re-use by the public.

The IC/UC evaluates the decontamination options available on a site- and scenario-specific basis to determine the most efficacious method to address the contamination. In so doing, the IC/UC must consider the extent of contamination, risk to the public, scientific uncertainty, requirements of the available decontamination options, and the associated risks and benefits with each option. Factors including response objectives such as cost and timeliness are also considerations. The IC/UC may stand-up a Technical Working Group (TWG)[3] to assist with planning and provide technical consultation

[2] EPA is activated to an incident when the state/local responsible authorities make a request and FEMA tasks EPA through a mission assignment or EPA responds under the National Contingency Plan using its Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) authority.

[3] Technical Working Group (TWG)

The Technical Working Group is an optional advisory group of multi-disciplinary technical experts and scientists that provides input to planning and implementing remediation. The TWG may include selected representatives from regarding the remediation operations. Once the decontamination strategy has been implemented, responders have several tools at hand to aid in the determination of decontamination efficacy. To verify that the decontamination requirements are met, process controls associated with the decontamination application can be developed and utilized. For example, verifying that certain criteria (e.g., contact time, relative humidity, temperature, etc.) were met during decontamination can inform and increase confidence in the effectiveness of the remediation. Specifically, for some fumigants, biological indicators (BIs), such as spore strips, can be placed in contaminated areas prior to decontamination and analyzed post-decontamination for viability. Current BIs provide an indication of failure to meet successful conditions, but not necessarily that conditions were sufficient for environmental decontamination. Improved BIs that indicate success are in development. To further strengthen the evidence of the decontamination strategy, targeted environmental samples should be collected that focus on both the most relevant exposure pathways and on the areas most difficult to decontaminate. The IC/UC may also elect to utilize an Environmental Clearance Committee (ECC)[4] to act as an advisory body, providing an independent peer-review of all clearance data and a recommendation as to whether or not the clearance goal has been achieved.

After using multiple lines of evidence to demonstrate that the decontamination strategy has been effective at reducing the presence of viable spores, the site then can be considered "cleared."

federal, state, local, and tribal agencies, and experts from the private sector or universities based on the technical needs identified by the IC/UC. The TWG is strictly an advisory group to the Incident Command, and is not a decision-making body. The TWG provides advice and guidance on such issues as the sampling and analysis plan; selection of the appropriate remediation process and conditions for its implementation; development of procedures for a variety of issues that may arise to address releases and other emergencies during the remediation process; and waste management activities (Emanuel et al. 2008).

[4] Environmental Clearance Committee (ECC)

The environmental clearance committee (ECC) is an optional independent group of experts that conducts a comprehensive review of the overall remediation process to make recommendations to the IC/UC on whether the clearance goals have been met. Members of the ECC may be representatives from the local, county and/or state public health agencies, the facility or property owner, local government, and subject matter experts from the Federal government. Although the ECC makes recommendations to the IC/UC the final recommendation that clearance goals have been achieved will ultimately be determined by the IC/UC (Emanuel et al. 2008).

Interim Clearance Strategy for Environments Contaminated with Cesium-137

The *Interim Clearance Strategy for Environments Contaminated with Cesium-137* document was developed by the Environmental Remediation Operations Working Group (EROWG) as a separate, stand-alone deliverable to the Wide Area Resiliency and Recovery Program (WARRP). It has been published by WARRP under this heading and is listed in the WARRP Product Reference Guide. This document was developed with input from the combined membership from the EROWG, which included federal, state and local partners and was designed specifically for the scenario of a release of a Cesium-137 Radiological Dispersal Device in Denver, Colorado under WARRP. It is representative of what the Denver community might do under this scenario and should not be considered policy or guidance. It may be a useful starting point for other local governments to develop their own clearance strategies, but the EROWG highly recommends that anyone developing a clearance strategy consult with their federal, state, local, private sector, and volunteer organizations to develop an appropriate strategy. Any clearance strategy should also be based on the radiological agent that is released, the nature and extent of the release and the site specific conditions of the region where the release takes place.

This document is contained in this National Guidance for use as an example and may not be applicable or appropriate for releases of different agents, or at different locations, or under different circumstances. New policies or guidance may also be more relevant than those referenced in this document.

Wide Area Recovery & Resiliency Program (WARRP)

Interim Clearance Strategy for Environments Contaminated with *Cesium-137*

July 2012

1. Purpose and Scope Statement

This paper reflects a sample approach for state and local recovery managers considering the radiological clearance levels to be implemented following the terrorist detonation of a Cs-137 Radiation Dispersal Device (RDD) in downtown Denver. The clearance strategy discussed in this paper address the range of values pertaining to public health and safety, debris management, business, agriculture and environmental concerns. These values help the affected community define the goals for site and incident specific clearance, so that the physical, social, political, cultural, and economic infrastructure of that community can be expeditiously recovered. The range of values discussed in this paper is consistent with accepted risk assessment processes that bridge dose-and-risk criteria.

The overall intent of this document is to assist planners and recovery workers with effectively recovering a community to viability (restore population, industry, commerce and the environment) to pre-event/near pre-event levels within a target period that is commensurate with the size, scope, and urgency of the recovery needs. The process described in this paper is designed to support a recovery timeframe from the Denver WARRP scenario with a goal of twelve to eighteen months. For critical infrastructure and other essential portions of the city, as designated by the decision makers and community, a shorter time frame may be possible. For less inhabited or non critical areas, the time frame may be longer. The time frame for recovery operations will be based on a phased approach that is technically and socio-economically driven and involves the inclusion of multiple stakeholders and the general public. Because recovery is both time and budget sensitive, it is imperative that the community address the range of values, and have agreement, before a disaster strikes. Pre-event clearance level concurrence is key to a community's resiliency and speedy recovery. As such, technical and socio-economic considerations (inclusive of stakeholders and public input) are factored into this approach

2. Documents

Radiological cleanups have been accomplished in multiple locations around the world over several decades. The sites have been large and small, urban and rural and have contained a plethora of radionuclides. The details on some of these cleanups are contained in the documents discussed in the Bibliography attached to this document. The document list also contains information pertaining to how the National Response Framework describes a radiological site cleanup approach with Federal agencies performing work consistent within their established roles, responsibilities, and capabilities all compatible with the Incident Command/Unified Command (IC/UC) structure embodied in the National Incident Management System (NIMS). The document list is not meant to be exhaustive. A brief synopsis is included with each document and is meant to assist the reader in selecting documents for further reading. The selected documents can be classified into 6 main categories. One group reports on the cleanup of specific sites: those containing only cesium-137 (Goiania) and those containing ^{137}Cs and other radionuclides (Chernobyl). Another group contains documents relevant to site survey procedures, laboratory and field measurements, and risk assessment processes; yet another provides documentation on site cleanup and recovery criteria/guidelines. A "general reference" group of documents provides background information about ^{137}Cs, RDD planning guidance, and federal regulations. The sixth group of documents generally describes public health care of radioactively contaminated patients and models that estimate excess cancer risks. There is also a list of internet sites containing information on one or more of the preceding categories.

3. Discussion

The overall intent of this document is to assist planners and recovery workers with effectively recovering a community to viability (restore population, industry, commerce and the environment) to pre-event/near pre-event levels within target periods that are commensurate with the size, scope, and urgency of recovery needs. For purposes of this scenario, the goal is to recover Denver from the WARRP scenario (found in Appendix A) within twelve to eighteen months with possible shorter recovery times for some areas. The recovery will take a phased approach, in which critical infrastructures and regions can be prioritized over less critical ones, to allow for the greatest impact towards recovering the community to viability. There may also be less essential areas that cannot be fully recovered to pre-event conditions within the 18 month time frame, but will be addressed in later phases of the recovery. This paper recognizes that recovery to normal living conditions is in fact conditional and that what is considered "normal" will change over time. Given the realities of the situation, decision makers will likely work with inhabitants to determine the new "normalcy."

Inhabitants of contaminated areas often face difficult personal choices concerning their future, and are particularly confronted by the dilemma of whether to leave or to stay. Experience shows that it is difficult to answer this question solely on the basis of radiation protection considerations. Many personal aspects enter into the balance; people living in contaminated areas are generally very reluctant to leave their homes, and hope to improve their living conditions. This situation calls for decision makers to develop protective actions, cleanup targets and consider initiatives to enhance the quality of life of the residents of the contaminated areas. Recovery experience from the Chernobyl incident have demonstrated that direct involvement of inhabitants and local professionals in management of the situation is an effective way to improve the recovery and rehabilitation process (Lochard, 2007). This requires regular information on the radiological situation, and the successes and difficulties with implementation of protection strategies. It is the responsibility of the decision makers (both national and local) to create the conditions and provide the means favoring the involvement and empowerment of the population. This is done by taking local social and economic living conditions into account to provide individuals with information, thus allowing them to understand and assess their personal situation and to maintain vigilance with the objective to improve their daily life and to protect themselves and their offspring for the future. The aim of the decision makers should be to help individuals regain control of their lives, in which radiation protection against the existing contamination is a factor to add to several other factors affecting the rehabilitation of living conditions.

For the purposes of this document, state and local planners have defined “normalcy” to be 80% of pre-event conditions as follows:

- 80% displaced population returned
- 80% industry operational
- 80% agricultural lands released from quarantine
- 80% infrastructure intact
- 80% other aspects of recovery completed (Example: recognizing that the WARRP notional scenario involves significant damage to the United States Mint, as well as the complete destruction/demolition of the Anshutz Medical Center, 80% infers complete removal of debris, and either actual, or imminent, rebuilding of these facilities).

When considering what values to select from the range of clearance levels, it is important that local jurisdictions, with public and other stakeholder involvement, arrive at a consensus before an incident occurs, to the extent possible. Clearance levels for various sectors (see Section 5) should be adopted so they can be implemented in the late stages of response. Pre-selection of clearance levels is preferred and helps to promotes resiliency in the community. Public and business acceptance of clearance levels before an incident offers assurance that there is a recovery goal, the goal is attainable and the goal is consistent with the health and safety of individuals at home, at school and at work. The goal to be selected (clearance levels) should take into consideration the following factors: (1) time to recover, (2) cost of recovery, (3) public health, (4) business competitiveness, (5) environmental impact, (6) acceptability to non-impacted communities, and (7) political-social drivers. The clearance levels goal(s) should be mutually agreed to and directed toward the recovery of the damaged community to a state that existed prior to the offending incident. For this scenario, and in reference to the seven factors identified above, state and local planners have prioritized the factors with a short justification, and ranking (primary, major, significant):

- ***Time to recover:*** Acknowledging public health will be maintained, this is the *primary* emphasis of recovery, to ensure an impacted community can recover in a timely fashion
- ***Public health***: This is a *primary* emphasis of recovery, to promulgate a recovery that ensures the public is safe. This factor includes the assurances an evacuated population needs before a return to residences and workplaces can occu***r***
- ***Cost of recovery***: While ensuring public health, this is a *major* emphasis of recovery, to keep recovery costs as low as possible
- ***Business competiveness***: This *is a major* emphasis of recovery, to help business be re-established and competitive (ensuring products are not boycotted or rejected)

- ***Environmental restoration***: This is a *significant* emphasis of recovery, acknowledging the importance of a clean environment, but only so far as the public is safe (this does not mandate “every radioactive atom be removed”, or “no radiation above background”)
- ***Acceptability to non-impacted communities***: This is a *significant* emphasis of recovery, it diminishes any negative concerns about the impacted community and reduces potential shunning of the population or its products
- ***Political/social drivers***: This is a *significan*t emphasis of recovery, to maintain calm and credibility among the population and ensuring supportive political leadership

These specific factors are relevant not only for the determination of acceptable clearance levels for the sectors affected by the event, but also for the development of the comprehensive recovery plan for the entire impacted area.

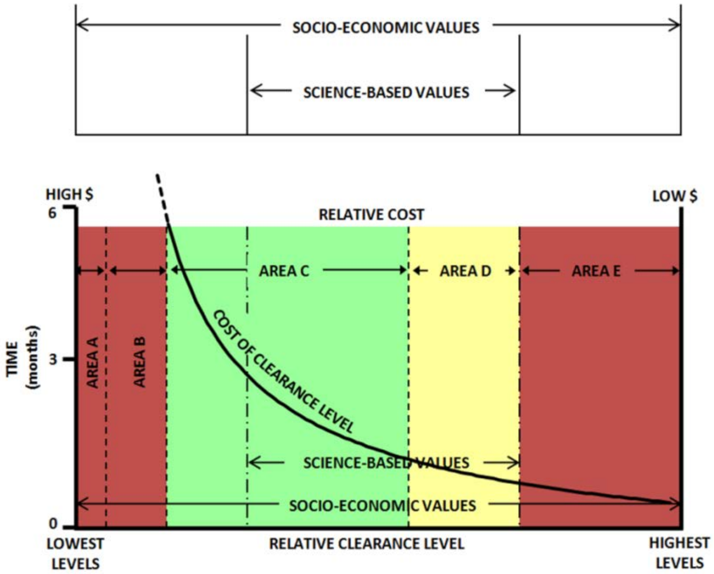
4. Dose- and Risk-based Clearance Levels

The clearance levels discussed in this paper are found in further detail in the original documents as shown in the bibliography. The range of the clearance levels is sector-based specific. In other words, agricultural considerations are different than residential, which are different than transportation. There is no single clearance level that will satisfy multi-sector considerations. An acceptable, negotiated range of values will be necessary - and delineated - in the late response phase in order to promulgate an immediate and effective recovery (as was done in Goiania, Brazil).

It is possible to graphically display the spectrum of clearance levels from various perspectives. The technically-based levels should be bounding, but also include other considerations, principally the political/social and business desires (which include the factors described above), presumably at opposite ends of the spectrum. For example, debate exists over technically sound levels, with the most conservative values espousing the lowest levels, where the political and social drivers may be associated. By comparison, the highest values will likely be associated with business-friendly perspective that encourages a quicker return to productivity.

The resultant illustration may look more like the one on the following page:

Figure 1. Recovery Cost Continuum



Area	Cost	Time for Initial Phase	Socio-Economic	Scientific & Medical
Area A	Too costly	Too long to achieve	Unjustified	Unjustified
Area B	Costly	Achievable in 6 months	Extreme	Unjustified
Area C	Within acceptable costs	Achievable in 6 months	Acceptable	Extreme – Acceptable
Area D	Within acceptable costs	Achievable in 6 months	Acceptable – Extreme	Justified
Area E	Least costly	Achievable in 6 months	Extreme	Unjustified

Site characterization and delineation of measurable residual quantities, above background concentrations associated with the cleanup goals must be derived taking into account radiological exposures and corresponding doses resulting from external and internal irradiation and intake of Cs-137 from all potential pathways and through all environmental media (e.g., building surfaces, soil, ground water, surface water, sediment, air, animals or plants). These values typically are derived considering reasonably anticipated future land use and publically inhabited areas, agricultural food production and supply, drinking water, and commerce patterns (See Section #5, below, "Sectors").

Dual Federal and State regulations and legislation governing radiological materials has been previously addressed in Denver and the State of Colorado at sites such as Denver Radium, Shattuck Radium, and Rocky Flats Environmental Technology Sites. These sites utilized a variety of public land-use criteria (ranging from residential to wildlife refuge) and regulations such as CERCLA (Comprehensive Environmental Response, Compensation, and Liability Act), SDWA (Safe Drinking Water Act), UMTRCA (Uranium Mill Tailings Radiation Control Act), Nuclear Regulatory Commission (NRC) and the State of Colorado NRC Agreement State status which utilizes "as low as reasonably achievable" (ALARA) practice. The key to setting appropriate remediation goals involved building a long-term protective public health and environmental criteria comparing lifetime cancer risk criterion with annual dose criterion through the use of an effective risk communication process. Risk communication and the involvement of the public in the recovery process is a key issue in building community trust necessary for implementing satisfactory remediation levels. Federal, state, and local regulatory agencies should bring together a broad group of stakeholders, e.g., residents, local business owners, local government officials and others interested in the processes that will be required to restore their communities to the agreed upon criteria. The credibility of a community group is a function of its inclusiveness. It must represent all stakeholder interests to ensure it is a voice for the entire community rather than a few interested parties. Empowering individuals to assist in the process is important and effective. The affected local community will need to be involved until the site remediation activities are complete, and possibly beyond that if institutional and engineering controls are placed on some subareas of the site.

Dose and risk criteria currently established in regulations are important starting points for choosing remediation levels, for either intermediate or life-time levels, such as those found in NCRP# 146, Appendix C (October, 2004) and those shown in the table below:

Table 1. Comparison of Published Clearance Values

Agency/ Organization	Standard (above background level)	Reference	Risk per 30 years†
OSHA, NRC, DOE	5,000 mrem/yr (worker)	29 CFR 1910; 10 CFR 20; 10 CFR 835	7.5×10^{-2}
NRC	100 mrem/yr (public)	10 CFR 20.1301	1.5×10^{-3}
DOE	100 mrem/yr (public)	10 CFR 835.208	1.5×10^{-3}
ATSDR	100 mrem/yr (public)	Toxicological Profile for Ionizing Radiation (Chronic MRL)	1.5×10^{-3}
EPA	10 mrem/yr (air pollution) (public)	NESHAPS 40 CFR 61	1.5×10^{-4}
ICRP	100 mrem/yr; or if >100, not to exceed an average of 100 mrem/5 yrs (public)	ICRP Publication 60	1.5×10^{-3}
NCRP	100 mrem/yr continuous exposure (public)	NCRP Report 116	1.5×10^{-3}
NCRP	360 mrem/yr from background (public)	NCRP Report 116	5.4×10^{-3}

†Based on a fatal cancer risk of 0.0005 per rem risk. The EPA default exposure duration is 30 years (Risk Assessment Guidance, Part B).

Abbrev: OSHA=Occupational Safety and Health Administration; NRC=Nuclear Regulatory Commission; DOE=Department of Energy; mrem/yr=millirem per year]; MRL=minimal risk level; NESHAPS=National Emissions

Decision makers must consider not only the socio-political-economic recovery implications (e.g. costs, resources required, level of societal disruption) but they must also select clearance values that reduce the dose to the individual (dose avoidance) and the potential long-term cancer risks to the communities' public health (adverse risk reduction). The residual risk from the criteria chosen is dependent upon post-cleanup contamination and exposure levels, future land use assumptions, future occupancy and activities, dose-and-risk assessment methodologies, as well as uncertainties associated with site characterization and dose and risk assessments. Denver and the State of Colorado has used public stakeholder involvement and pragmatic processes to select and implement clearance levels for Superfund sites that addressed societal needs, to include protection of the public health and the environment, using both a dose-and-risk criteria. While much can be learned from past processes, decision makers should be aware of the unique differences inherent in the terrorist attack scenario.

5. Sectors

A site or area may reasonably be anticipated to support a range of uses, so cleanup goals (time frame and clearance levels) may be different for different subareas of the impacted area.

Publically Inhabited Areas: Decisions for prioritizing recovery assume that any site use by the public will be considered as an area of unrestricted access and use. This would typically cover areas such as: residential homes, critical infrastructure and key resources (CIKR) and business areas, and outdoor recreational areas.

Agricultural food production and supply: This sector's recovery is focused upon the reduction of dose-risk to the general public from the consumption of contaminated food items, restoration of agricultural productivity in the contaminated areas, and returning public confidence in the safety of food products and its food supplies.

Drinking water: This sector's recovery is focused on the radionuclide concentration in drinking water as supplied to the public, i.e. at the tap not in open air water reservoirs, surface water-ways, or private cisterns. The sector is predominately managed for the reduction of contamination in drinking water and subsequent ingestion doses by those consuming water supplied to the public.

Areas of special significance: Buildings or other places of religious, historical, national, or regional significance may require separate consideration when determining appropriate cleanup levels. Proper realistic exposure scenarios and model parameters must be used to insure that the clearance levels for these buildings and areas allow for their continued use as much as possible.

6. Implementation of cleanup and clearance [1]

[1] This cleanup process does not rely on and does not affect authority under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), 42 U.S.C. 9601 et seq. and the National Contingency Plan (NCP), 40 CFR Part 300. This document expresses no view as to the availability of legal authority to implement this process in any particular situation.

Final recovery after RDD incidents would involve the collection, monitoring, and assessment of large amounts of radiological data from contaminated soils, building, infrastructural, and agricultural debris. This information, coordinated thru Federal, State, and local field personnel in the Federal Radiological Monitoring and Assessment Center would provide finished data analyses and interpretation products to decision makers (Appendix 3, Federal Register Notice, DHS, 1August 2008). These final decisions would enable the reconstruction of buildings, re-establishment of infrastructure and return of the populace and community businesses.

To do this, agreed upon exposure values, based on radiation dose, risk or other suitable quantity should be established that are commensurate with the site-specific recovery needs. There will be inherent conflict between achieving maximum dose or risk reduction and minimizing cleanup cost and time. The lower the dose or risk goal, the more time, money and effort are required to achieve it. A phased approach will need to be utilized to initially target the most critical infrastructure and areas. Priority should then be given to actions that maximize exposure reduction and minimize cleanup time. Existing cleanup reference levels or goals may be useful as the starting point for the process. In determining cleanup goals for specific locations, a process which recognizes the many factors inherent in such decisions should be used. As part of an ongoing iterative process, cleanup goals are informed by the feasibility of cleanup strategies and specific cleanup strategies adjust as experience is gained. This process must include input from the relevant community. Some of the factors that might be considered include community risk tolerance, proposed future land use, and expected occupancy. There must be balance between the desired levels of exposure reduction with the extent of the measures necessary to achieve it.

Although it may take years to achieve the final cleanup goals for all land uses, re-occupancy of the affected area will be possible when interim cleanup can reduce short-term exposures to acceptable levels during the time it takes to achieve the long-term goals. There may be institutional or engineering controls placed on some portions of the site to prevent potential exposures until further active remediation, radioactive decay, or natural weathering allow the site to meet cleanup goals. An example of an institutional control might be a restriction on planting vegetable gardens to avoid ingesting radio-nuclides that may be taken up by the plant roots from the soil. An example of an engineering control to limit exposures might be adding a layer of pavement or cement over ^{137}Cs gamma emanation that may have become fixed in place by sorbing onto the street and sidewalks. This may be an iterative process. As experience is gained, adjustments may be required to achieve long-term goals.

Regardless of the prioritization of the recovery sectors, the desirable outcome is to fully restore the city by means of a systematic decontamination and reconstruction program. Criteria used to prioritize are factors with which tradeoffs between alternatives are assessed so that the best option will be chosen, given site-specific data and conditions. Local acceptance will be a key component of a fully transparent approach to long-term remediation and cleanup. Factors to consider in determining cleanup actions are (Federal Register Notice, DHS, 1August 2008):

- Areas impacted (e.g., size, location relative to population).
- Types of contamination (e.g. radiological).
- Other hazards present (e.g. hazardous materials)

- Human health risk.
- Public welfare.
- Ecological risks.
- Clearance actions already taken in earlier restoration activities.
- Projected land uses.
- Preservation or destruction of places of historical, national, or regional significance.
- Technical feasibility.
- Wastes generated and disposal options and costs.
- Costs and available resources to implement and maintain remedial options.
- Short-term effectiveness.
- Long-term effectiveness.
- Timeliness.
- Public acceptability, including local cultural sensitivities.
- Economic effects (e.g., on employment, tourism, and business).
- Intergenerational equity.
- The ability of a remedy to maintain reliable protection of overall human health and the environment over time.
- Assessing the relative performance of treatment technologies on the toxicity, mobility or volume of contaminants.
- The success or effectiveness of the cleanup or remediation as the cleanup progresses (contaminant removal).
- Addressing the adverse impacts on human health and the environment that may be posed in the time it takes to implement the remedy and achieve the community-based remediation goals.
- Evaluating the technical and administrative feasibility of the remedy, including the availability of materials and services needed to implement each component of the option(s) chosen.
- The cost of each alternative, including the estimated capital and operation and maintenance costs, and net present value of capital and operation and maintenance costs.
- Local community and State concurrence with the remedy.

7. Recommendation

In the particular situation being used for this case study, ^{137}Cs is one of the more heavily studied and one of the more easily detected and measured radionuclides. The community, in conjunction with technical experts, and state, local and federal officials needs to reach agreement on the acceptable clearance value. The range of clearance values for remediation and recovery should account for all possible receptor(s) exposure pathways combined, and expressed in terms of radiological dose-and/or-risk criteria. These criteria must clearly transverse through current risk management processes that bridges dose-and-risk thereby using measurable radiological exposure/dose criteria "*in situ*" for delineation and protection of public health and the environment. These criteria must recognize current Federal, State, and local applicable regulations and standards. In the United States, a range of 1 in a population of ten thousand (10^{-4}) to 1 in a population of one million (10^{-6}) excess cancer incident outcomes is generally considered protective for both chemical and radioactive carcinogenic contaminant exposures. This range is the regulatory standard generally used in the context of EPA Superfund response actions. The Nuclear Regulatory Commission's decommissioning and decontamination process outcomes are usually in or near this range as well. A similar risk range may be appropriate for NPP, RDD, or IND events that affect areas of comparable size. However, such risk ranges may not be practically achievable for major incidents that result in the contamination of very large areas. An example is the ongoing response at the Fukushima Daiichi Nuclear Power Plant, which covers an area the size of Connecticut. In making decisions about cleanup goals and reference levels for a particular event, decision makers must balance the desired level of exposure reduction with the extent of the measures that would be necessary to achieve it, in order to maximize overall human welfare. The final outcome is a pragmatic risk management process that incorporates public stakeholders to arrive at a remedy that protects public health and the environment.