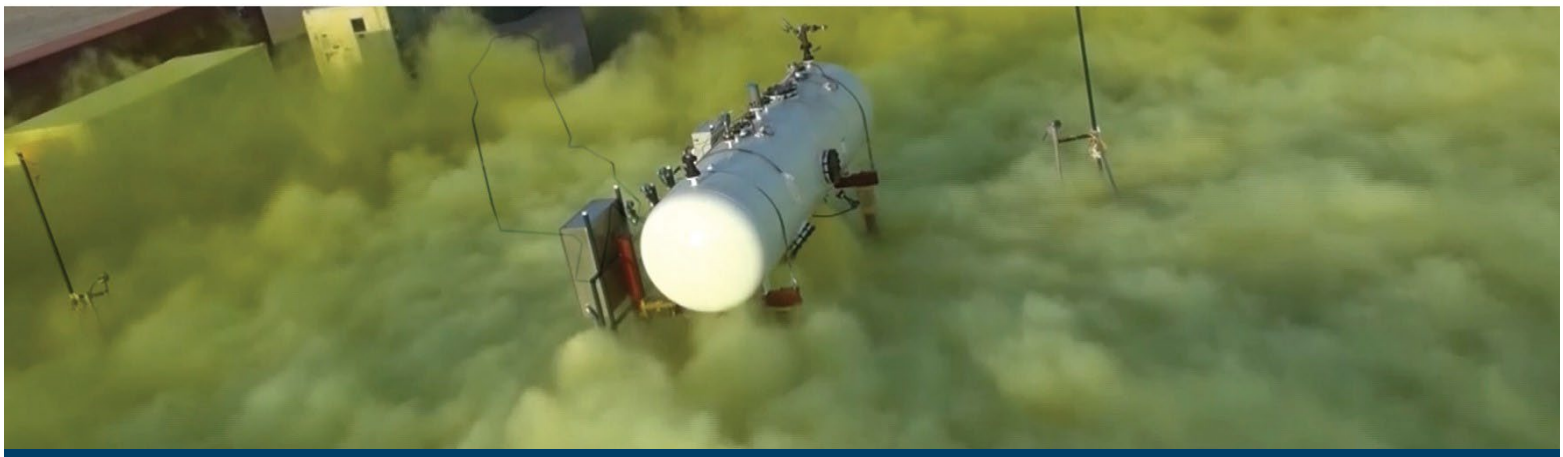

Planning and Decision Framework for Chemical Incident Consequence Management

July 2022

FEMA

Record of Change

Date	*Action Type (Review or Revision)*	*Printed Name*	*Signature*
07/21/2023	This document has been updated as of 07/21/2023 to reflect the reorganization of the FEMA Chemical, Biological, Radiological, and Nuclear (CBRN) Office to the Office of Emerging Threats (OET). No other changes to the document content have occurred.		

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Planning and Decision Framework for Chemical Incident Consequence Management (July 2022)

This *Planning and Decision Framework for Chemical Incident Consequence Management* (also referred to hereafter as the "Framework") reflects recommendations appropriate for the state of science and national incident management doctrine at the time it was developed. Due to the evolving nature of some of the information provide in this document, it is recommended that this be considered an interim framework that should be updated in response to future re-evaluations of the guiding science and national incident management doctrine.

About this Guidance

This document describes a general consequence management[1] planning and decision framework for government and non-government planners, emergency managers, and decision-makers in assessing risk, planning, and executing activities required to respond to and recover from a nationally significant or large-scale hazardous chemical incident in a domestic, civilian setting.[2]

Originally chartered by the National Science and Technology Council (NSTC) and its Subcommittee on Decontamination Standards and Technologies, this guidance document was developed by the Chemical Incident Consequence Management Working Group, led by the Department of Homeland Security (DHS) Science and Technology Directorate (S&T) Mission Capability Support (MCS) Office. The working group included representatives from other DHS components (Cybersecurity and Infrastructure Security Agency [CISA], Countering Weapons of Mass Destruction Directorate [CWMD], Federal Emergency Management Agency [FEMA], and the U.S. Coast Guard [USCG]; Department of Defense (DOD); Department of Health and Human Services (HHS) (Office of the Assistant Secretary for Preparedness and Response [ASPR], Centers for Disease Control and Prevention [CDC], and the National Institute of Occupational Health and Safety [NIOSH]); and the Environmental Protection Agency (EPA). Future editions of this guidance, including appropriate interagency coordination, will be sponsored by the DHS FEMA.

This *Planning and Decision Framework for Chemical Incident Consequence Management* is intended to complement two additional publications that support multi-jurisdictional, multi-agency planning for chemical incident response and recovery: *Key Planning Factors for Recovery from a Chemical Warfare Agent Incident* (DHS S&T, Summer 2012)[3] and *Key Planning Factors and Considerations for Response to and Recovery from a Chemical Incident* (DHS FEMA, currently under final

[1] This document focuses on a particular subset of consequence management activities critical to chemical incident response and recovery. Specifically, these include: 1) characterization of potential contamination of the general area and specific site(s) impacted by the incident; 2) general area and site-specific remediation; and 3) clearance for re-entry/re-occupation of general areas or specific sites contaminated by hazardous chemicals.

[2] For purposes of this document, the designation “nationally significant or large-scale incident” is used to distinguish such incidents from more less consequential, day-to-day responses. A “nationally significant or large-scale incident” generally refers to an incident that because of the magnitude, complexity, toxic potency or deliberate nature requires federal assets and exceeds the capability of state, local, tribal, or territorial (SLTT) agencies.

[3] This document identifies and describes select Key Planning Factors to aid in recovery planning for wide-area chemical warfare incidents. Key Planning Factors represent focus areas that are most important to examine prior to the occurrence of an incident. Key Planning Factors can also substantially influence the recovery process by improving public health and safety, increasing the rate of recovery, reducing recovery costs, addressing major resource limitations, or informing critical decisions.

development).[4] Together, the guidance and best practices provided in this family of documents represents a holistic approach to Whole Community all-hazards chemical incident planning.

Please refer comments and questions to the FEMA Office of Emerging Threats (OET) at oet@fema.dhs.gov.

[4] This document provides guidance and serves as a reference for federal regional and SLTT departments and agencies that are responsible for incident planning for chemical incidents. The document includes strategic, operational, and tactical for consideration in the development of response and recovery plans for a chemical incident.

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Executive Summary

This document provides a framework for federal, state, local, tribal and territorial (FSLTT) government and non-governmental and private-sector authorities for use in planning and expediting decisions regarding technical incident characterization, remediation, and site re-use/re-occupancy in the aftermath of a nationally significant or large-scale hazardous chemical release. Together, the National Incident Management System (NIMS), National Response Framework (NRF), National Disaster Recovery Framework (NDRF), and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) provide the general integrated structure for incident command, control, and coordination during such incidents. This integrated structure is based on a fundamental premise – namely, conducting incident management activities at the lowest jurisdictional level possible, augmented by other expertise and resources (including a Federal On-Scene Coordinator [OSC]), as appropriate. Based on the size, scope, and complexity of the incident, additional federal government assistance, including technical capabilities and other resources, may be required to support the response to and recovery from a chemical incident. Federal response and recovery activities are synchronized using the operational constructs detailed in the Oil and Chemical Incident Annex (OCIA) to the Federal Interagency Operational Plans (FIOPs) for Response and Recovery.[5]

Consistent with the NIMS and Incident Command System (ICS) doctrine, the technical planning and decision framework presented in this document is intended to support the multi-agency Unified Command (UC)[6] and other Whole Community senior decision-makers that will be engaged in the management of nationally significant or large-scale chemical incidents. As more agencies representing unique authorities, capabilities, and resources become involved in response and recovery efforts, unified objectives-setting and decision-making are critical.[7]

The framework discussed in this document embraces the concept of a flexible, multi-attribute, site-specific planning and decision process that considers and balances many factors. For example, this process consists of both qualitative and quantitative assessments applied at each stage of site-level consequence management, including site characterization, implementation of the chosen cleanup

[5] This guidance provide in this document is intended to complement, not affect or alter any existing federal authority, including, but not limited to 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.

[6] NIMS defines “Unified Command” as “An ICS application used when more than one agency has incident jurisdiction or when incidents cross political jurisdictions.” Based on the key doctrinal notion that ICS is scalable based on the size, scope, and complexity of a given incident, this document is focused on how the technical information contained herein can be used to support incident planning and decision making rather than provide prescriptive guidance on how such planning and decision processes will be structured/operationalized via the ICS.

[7] The U.S. Environmental Protection Agency (EPA) has decades of experience in hazardous materials response and cleanup of contaminated sites. An integral part of this experience is the development of environmental, health-based exposure levels that guide different facets of response and cleanup activities. In addition, many agencies develop a variety of environmental, health-based exposure guidelines, which are discussed in Appendix A.

alternative, and site re-use/re-occupancy activities. This process also provides for the incorporation of the collective professional judgment of technical experts and expectations set by key FSLTT stakeholders to determine a range of decisions in these areas appropriate to site-specific circumstances across a range of potential large-scale incident scenarios. Factors assessed as part of this process include: the extent of outdoor versus indoor contamination, potential magnitude and severity of risk posed by the contaminant, demographics and size of populations affected, site location and area geography, meteorological conditions, cost, and other socioeconomic and environmental factors.

This document is organized into five principal sections as described below:

1. Introduction: Provides information on the background, purpose, scope, audience, and organizational structure of this document.
2. Operational Phasing and Planning Framework: Provides an overview of key decision process guidelines, operational phasing, and an overarching planning and decision framework for chemical incident consequence management.
3. Hazardous Chemicals and Their Characteristics: Identifies the types and characteristics of hazardous chemicals to help inform both the immediate response and longer-term remediation and re-occupancy decisions.
4. Principles of Risk Assessment for Hazardous Chemicals: Provides background information on risk assessment considerations for hazardous chemicals.
5. Key Elements in Clearance Decision-Making: Presents points of consideration for each of the key activities required for successful characterization, remediation, and re-use/re-occupation of areas/sites impacted by a large-scale chemical incident, as well as references that provide further scientific or expert guidance.

A list of general references, a glossary of terms, and appendices providing additional sources of information and example scenarios and real-world case studies complete this document.

1. Introduction

1.1. Overview

Domestic chemical incidents, including hazardous materials (HAZMAT) releases and oil spills, are relatively commonplace and occur on a frequent basis throughout the country. While most incidents are smaller-scale in nature with minimal emergency response, hazardous waste removal, and environmental remediation required, others can develop into complex, multi-jurisdictional incidents with serious consequences regarding public health and safety and the environment. Such complex, high-consequence incidents require a well-coordinated response and recovery effort among private sector responsible parties (RPs); state, local, tribal, and territorial (SLTT) governments; nongovernmental organizations (NGOs); and the federal government. Of particular note, such incidents will also necessitate significant technical decision support, including specific subject matter expertise and risk-based decision methodologies and tools, regarding a wide range of environmental hazard assessment, remediation, and wide area- or site-specific re-occupancy processes.

Chemical incidents, including toxic environmental releases, may stem from multiple sources including onshore and offshore facilities related to oil production; transportation infrastructure (including rail, highway, maritime, and pipelines infrastructure); chemical manufacturing, processing and storage facilities; and chemical end-use locations. Available statistical data indicates that most chemical incidents, including environmental releases, are caused by human error or technological failure. Less common causes include terrorist attacks or criminal acts of sabotage or chemical theft/diversion, such as in a deliberate contamination of the public water supply or public or private land. In addition, natural disasters such as hurricanes and earthquakes can cause chemical incidents of various types with high-order consequences over a broad area.

1.2. Purpose

This document describes a general consequence management planning and decision framework for use by government and non-government planners, emergency managers, and decision-makers in assessing risk, planning, and executing actions required in the response to and recovery from a nationally significant or large-scale hazardous chemical incident in a domestic, civilian setting.[8]

Collectively, government agencies and private-sector entities working across jurisdictional levels have decades of experience responding to and recovering from incidents involving accidental or naturally-caused chemical releases, as well as cleaning up legacy industrial sites with significant levels of HAZMAT contamination present. This *Planning and Decision Framework for Chemical Incident Consequence Management* recognizes this experience and existing governmental and non-governmental expertise in the HAZMAT incident response and recovery arena. The specific focus of this document is to facilitate

[8] This guidance does not affect any existing authority, including, but not limited to, 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. This document expresses no view as to the applicability of appropriate legal authorities in any particular incident situation.

technical planning and decision-making in response to complex, large-scale, and high-consequence chemical incidents regardless of cause.

The guidance provided in this document is intended to augment existing national doctrine and plans for all-hazards incident response and recovery, including but not limited to: NIMS and the Incident Command System (ICS), National Response Framework (NRF), National Disaster Recovery Framework (NDRF), Federal Interagency Operational Plans (FIOPs) for Response and Recovery, Oil and Chemical Incident Annex (OCIA) to the FIOPs for Response and Recovery, and various other FSLTT emergency response and disaster recovery plans. NIMS ICS doctrine is used within this document to facilitate response and recovery discussion, as ICS serves as the standardized incident organizational structure for the management of all incidents. However, the language and descriptions of ICS within this document are not prescriptive, as ICS must be flexible and adaptable for implementation by all FSLTT stakeholders. Additionally, technical risk assessment and planning guidance and best practices discussed in this document are intended to support the multiple command, control, and coordination structures set forth in federal statute (e.g., the Comprehensive Environmental Response, Compensation and Liability Act [CERCLA], 42 U.S.C. 9601 et seq. and the National Oil and Hazardous Substances Pollution Contingency Plan [NCP], 40 CFR Part 300, as well as SLTT laws and ordinances relative to chemical incidents).

This framework is intended as a starting point for planners as well as responding technical advisors in determining and implementing scenario-specific consequence management strategies. This includes how to best determine and select protective, health-based exposure levels for various exposure conditions and scenarios, while promoting a cost-effective, fiscally sound, and socio-economically responsible remediation effort. This framework is also meant to help decision-makers formulate timely, effective, and equitable consequence management decisions in the face of incomplete data and high levels of uncertainty, as often occurs in the early phases of an incident involving hazardous chemicals. Finally, this document does not address all aspects of a public health emergency; instead, it provides a focused chemical incident consequence management approach pertinent to response and recovery efforts.

1.3. Background

After a nationally significant or large-scale hazardous chemical release has occurred, cleanup and recovery activities will follow some of the same basic procedures that govern the response to smaller-scale HAZMAT incidents. However, a nationally significant or large-scale incident necessarily will involve the collaboration of multiple FSLTT agencies and out-of-area resources. This is especially true regarding the selection of an appropriate remediation strategy based on the nature of the incident and how and when to deem the site ready for resumed use/re-occupancy, either with or without limitations.

Chemical Incident Consequence Management Goals

- Preserve and protect the lives and health of the public, first responders, and remediation personnel

- Protect the environment
- Preserve property and infrastructure
- Minimize social and economic impacts

Decisions made during the response to and recovery from a nationally significant or large-scale chemical incident should be timely, prioritize lifesaving and human health and safety activities, and strive to stabilize Community Lifelines to protect human health and the environment and minimize significant socioeconomic impacts. Additional considerations include establishing and maintaining public confidence; preserving physical property and the flow of goods and services; ensuring civil rights and environmental justice;[9] and facilitating the rapid restoration and recovery of critical infrastructure, services, industry, business, and public activity. Efforts to minimize health and environmental impacts and achieve key socioeconomic objectives should be undertaken in a clear, consistently agreed-upon manner by the many agencies and other key stakeholders involved.

Typically, no single, absolute remediation criteria or approach level will fit all scenarios or individual areas of concern, but the perception that there are inconsistencies among agencies separately addressing specific aspects of a response can occur if consensus is not achieved. Perceived inconsistencies can lead to confusion and public distrust in high-concern/high-anxiety situations that require clear and transparent communication. Yet, it should be acknowledged that hazardous chemical health-based exposure criteria and corresponding remediation approaches will likely evolve during different phases of the response and recovery effort. (e.g., "immediate" action levels may be applicable to the initial response, while more stringent cleanup levels may be appropriate for the sustained response and longer-term recovery).

The planning and decision framework presented in this document is intended to be applicable to most large-scale chemical contamination incident scenarios, regardless of cause. Comprehensive planning among all agencies and clear, consistent communication and coordination between agencies and between RPs and government agencies at all levels and the general public throughout all phases of the response and recovery effort are essential. This notion is reinforced and strongly encouraged by national guidance documents such as the NRF and the Response FIOP and its supporting annexes, including the OCIA.[10]

Key Objectives of this Document

- Promote protection of human health and safety during the response to and recovery from nationally significant chemical incidents

[9] For additional information related to environment justice and equity refer to: Executive Order 12898, Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations; Executive Order 13985, Advancing Racial Equity and Support for Underserved Communities Through the Federal Government; and Title VI of the Civil Rights Act of 1964.

[10] NRF, Response FIOP and its annexes, are available at https://www.fema.gov/national-preparedness-resource-library.

- Facilitate incident planning and decision-making during such incidents
- Establish clear and consistent general guidelines that can be used to appropriately tailor the consequence management strategies to the specifics of the scenario at hand
- Facilitate interagency coordination during the response to and recovery from a nationally significant chemical incident
- Provide criteria for the determination or selection of appropriate environmental, health-based exposure levels and other safety criteria levels as applicable to various conditions and scenarios
- Promote cost-effective and socio-economically responsible remediation strategies and methods, including appropriate waste management considerations to safeguard public health and the environment

1.4. Scope

The response to and recovery from a nationally significant or large-scale chemical incident requires substantial FSLTT and non-governmental coordination, resource support, and decision making across a variety of critical consequence management activities, including, *but not limited to*:

- Public Health and Safety, including Life-saving, Emergency Medical Treatment, and Mental Health and Well-being;
- Evacuation and Mass Care;
- First Responder Safety and Protection;
- Decontamination & Clearance Sampling
- Hazardous Waste (HAZMAT) Remediation and Management;
- Critical Infrastructure and Services Restoration; and
- Fatality Management.

This Decision Framework presented in this document focuses on a particular subset of consequence management activities critical to chemical incident response and recovery. Specifically, these include: 1) characterization of potential contamination of the general area and specific sites impacted by the incident; 2) general area and site-specific remediation; and 3) clearance for re-entry/re-occupation of general areas or specific sites contaminated by chemical HAZMAT.

Scenarios covered under this Framework may include multiple types of contaminants and contaminated surfaces (e.g., air, surface water, drinking water, ground water, septic systems, soil, and porous and nonporous surfaces in buildings or open areas), or they may involve a single or multiple environmental media (e.g., water, as a result of an attack on water treatment facilities). Scenario-specific factors can

transport contaminants far beyond their initial release point. Decontamination of people, food, plants, and animals are specifically excluded from this framework.[11]

Additionally, site security plans are required for some chemical facilities under the Chemical Facility Anti-Terrorism Standards, managed by the Cybersecurity and Infrastructure Security Agency (CISA). However, considerations for these plans are excluded from this framework, as they do not serve or support emergency response and recovery operations.

1.5. Audience

The intended audience for this document includes FSLTT government officials, as well as non-governmental and private-sector decision-makers who conduct, oversee, or are legally responsible for the characterization and remediation of an area or specific site(s) contaminated by hazardous chemicals following a nationally significant or large-scale release. Such groups could include private sector companies, government agency officials, elected and appointed officials, incident commanders, emergency managers, health and safety officials, and others charged with characterizing potential general area or site-specific contamination and/or making on-site remediation and re-occupancy decisions.

It is recognized that SLTT officials as well as individuals and organizations from the private sector will have important site-specific knowledge regarding existing response infrastructure and procedures for hazardous chemical release events. Additionally, private sector entities may also be considered "responsible parties" for important response and recovery activities under current U.S. law and regulation. The information provided in this document is intended to help improve risk-based decision making and the application of common approaches across agencies/organizations at all levels of governance.

1.6. Organization of Document

This document is organized into five sections:

1. Introduction: **Provides information on the background, purpose, scope, audience, and organizational structure of this document.**
2. Operational Phasing and Planning Framework: **Provides an overview of key decision process guidelines, operational phasing, and an overarching planning framework for chemical incident consequence management.**

[11] For more information about the decontamination of people, refer to Patient Decontamination in a Mass Chemical Exposure Incident: National Planning Guidance for Communities (2014).

3. Hazardous Chemicals and Their Characteristics: **Identifies the various types and characteristics of hazardous chemicals to help inform both the immediate response and longer-term remediation and re-occupancy decisions.**
4. Principles of Risk Assessment for Hazardous Chemicals: **Provides background information on risk assessment considerations for hazardous chemicals.**
5. Key Elements in Clearance Decision-Making: **Presents points of consideration for each of the key activities required for successful remediation and re-occupation of areas/sites impacted by a large-scale chemical incident, as well as references for further scientific or expert guidance.**

Substantial additional references and background information are provided in the appendices. Appendix A discusses available hazardous chemical-specific exposure guidelines (environmental health-based levels) and factors to consider when selecting appropriate types of values to apply at each stage of an incident (e.g., emergency response, remediation activities, establishing remediation goals, and making clearance decisions). Appendix B presents example scenarios and case studies based on real-world incidents and exercise events.

The procedures described in the appendices are based primarily on historical cases of large-scale HAZMAT responses and large-scale exercises involving chemical incident scenarios. It is assumed that those officials involved in the decision-making process will have (or will be advised by individuals who have) appropriate background and field experiences regarding the technical aspects of chemical incident consequence management which is the focus of this document. The approaches as outlined in Appendix B do not replace or eliminate the need for the informed judgment of competent risk assessors and managers for site-specific decision-making.

2. Operation Phasing and Planning Framework for Chemical Incident Consequence Management

2.1. Background/Overview

Nationally significant or large-scale incidents involving hazardous chemicals present unique challenges. The incident likely may occur without warning. The nature of the incident may or may not be immediately evident or understood and its scope and complexity may overwhelm local resources. As the incident likely will cross jurisdictional boundaries, there may be confusion regarding the specific authorities relevant to the incident, deconfliction of ICS[12] leadership roles and responsibilities, processes for public warning and communication, etc. Additionally, law enforcement, forensic, and attribution activities related to terrorist or criminal acts may impact consequence management activities and decision-making processes. Decisions will often have to be agreed upon by multiple agencies operating within a unified command structure as well as their elected leadership. Further, although numerous standards and regulatory guidelines exist to shape consequence management strategies, there is no absolute contamination level, remediation approach, or site clearance/reoccupation criteria that is universally applicable to every large-scale chemical incident.[13] Therefore, coordination between FSLTT agencies and with appropriate private-sector entities, especially RPs, is critical to ensure that the hazardous chemical consequence management process is acceptable, effective, and equitable, yet with sufficient flexibility to ensure consideration of various incident-specific characteristics. These challenges can be addressed by comprehensive risk assessment and planning, understanding and codifying organizational roles and responsibilities, conducting exercise activities,[14] and developing a defined, well-organized and agreed-upon approach to chemical incident consequence management decision-making.

This section provides an overview of key decision process guidelines, operational phasing, and an overarching planning framework for chemical incident consequence management.

2.2. Planning and Decision-Making Process Guidelines

Consequence management planning and decision-making for chemical incidents should not be static or prescriptive; rather, it should involve a flexible process that includes situation-specific considerations and the most current understanding of science and engineering and other technical factors. A flexible process

[12] ICS is a standardized on-scene emergency management construct specifically designed to provide an integrated organizational structure that reflects the complexity and demands of single or multiple incidents, without being hindered by jurisdictional boundaries. ICS, as established in the NIMS, can expand to meet response needs regardless of the scope or scale of the incident. Visit the National Incident Management System (2017) document for more information.

[13] U.S. General Accounting Office (2003). Rail Safety and Security: Some Actions Already Taken to Enhance Rail Security, but Risk-Based Plan Needed. GAO-03-435.

[14] Visit the Homeland Security Exercise and Evaluation Program (HSEEP) webpage for more information.

is needed in which numerous factors are considered to achieve an end-result that balances local needs and desires, health risks, costs, technical feasibility, socioeconomic justice and equity, and other factors.

Principles that underpin chemical incident consequence management decision processes include:

- Transparency – The basis for consequence management decisions should be well understood by all key stakeholders and the public at large to the extent legally possible.
- Inclusivity – All relevant stakeholders should be involved in decision-making activities, including communities of color, low-income communities, and other underserved and historically marginalized communities.
- Effectiveness – Technical subject matter experts should analyze site remediation and clearance for re-use/re-occupation options, assess various technologies and methodologies, and inform goal/strategy development and specific courses of action to implement the strategies selected.
- Joint Accountability – Final decisions regarding the selection of appropriate consequence management goals, strategies, and implementing activities should be made jointly by FSLTT officials participating in the Unified Command, in concert with SLTT elected/appointed leadership, as appropriate.

2.3. Incident Response and Recovery Generic Operation Phases

The OCIA to the Response and Recovery FIOP describes the process and organizational constructs that will be utilized by Federal departments and agencies for responding to oil spills or chemical release threats or incidents. Other stakeholders such as SLTT government agencies; nongovernmental organizations (NGOs); and the private sector may also find the OCIA to be a useful document that supports and complements their planning efforts in responding to and recovering from nationally significant or large-scale chemical incidents.

The OCIA complements the Response and Recovery FIOP by providing additional federal guidance specific to oil/chemical incidents, including spills and releases (in the air, ground, and water/maritime domains), along with major chemical HAZMAT-related fires and explosions. In addition, the OCIA mirrors the FIOP by using a similar concept of operations for delivering response and recovery core capabilities during an incident while highlighting the unique attributes of oil/chemical incidents of various types, including acts of terrorism.

Under the Response and Recovery FIOP, incident operations are divided into phases as shown in Figure 1: Phase 1 (Pre-incident), Phase 2 (Response), and Phase 3 (Recovery).

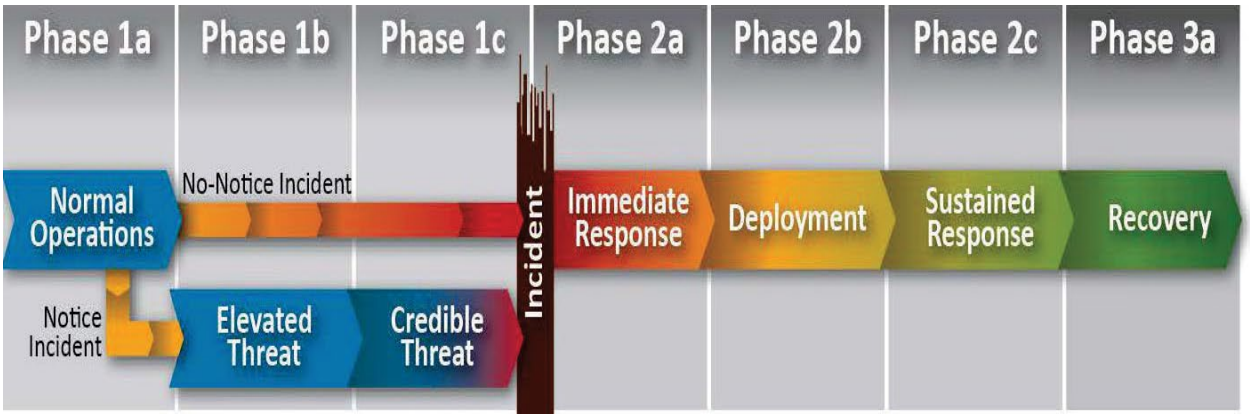

Figure 1: Operational Phases of Oil/Chemical emergencies as described in the OCIA to the Response and Recovery FIOP

Per the OCIA, operational activities corresponding to the operational phases for the response to and recovery from a chemical incident vary based upon the size, scope, and complexity of the incident, as well as the specific authorities used to manage the incident. As appropriate, operational phases may be adjusted, based on local conditions, to address the expected incident-specific environment and multi-jurisdictional resource needs. Additionally, the response to and recovery from a large-scale chemical incident typically will be characterized by multiple remediation and site re-occupation decisions and activities that may overlap or occur concurrently, so the concept of an absolute, strict step-by-step process or strict "linear" adherence to the operational phases presented above is not the intent. Rather, these phases above represent general groupings of activities that correspond to more generalized segments of the incident timeline. Chemical incident response and recovery must be conditioned by flexibility regarding the specifics of the incident at hand, with various operational phases overlapping to some degree.

Under Phase 1a (Normal Operations), FSLTT agencies, NGOs, and private-sector stakeholders assess risks, coordinate with each other, plan and train for chemical incidents, and maintain ongoing situational awareness. Phase 1b (Elevated Threat) &1c (Credible Threat) activities generally include, but are not limited to:

- Monitoring and assessing suspicious activities reports.
- Analyzing and modeling potential incident impacts to chemical infrastructure, analyzing the market impacts to the economy, and determining the effects of disruption to other critical infrastructure (CI) of a potential threat or incident.
- Conducting regular coordination calls among EPA, USCG, and other appropriate federal agencies and obtaining situational awareness and discussing threat reporting with chemical and other potentially affected industry representatives and SLTT agencies.

- Determining through the FBI if a potential threat is related to crime or terrorism and sharing that information with SLTT law enforcement and other relevant response-based teams (e.g., HAZMAT teams, etc.).

Phases 2a and 2b (Immediate Response and Deployment) involve multi-source incident notification/reporting, operational coordination between federal law enforcement and regulatory agencies, SLTT agencies, and private-sector entities and a host of other actions focused on saving lives, meeting basic human needs, protecting the environment, and supporting initial recovery activities. These phases also include taking action to make an initial characterization of the incident (including determining general extent of contamination), formulating initial protective actions recommendations for responders and the public based on existing FSLTT regulations, deploying specialized teams and assets, conducting initial impact assessments, providing medical and logistics augmentation, sharing incident-related information, etc.

Phase 2c (Sustained Response) normally covers a period of approximately 30 days that extends from the onset of the incident. Key activities conducted in this phase include, but are not limited to:

- Coordination among FSLTT governments, RPs, and other affected entities to identify potential cascading impacts and stabilize key community lifelines.

- Continued support to first responder and public needs including, but not limited to, ensuring personal safety and protection, containing damage to the environment, supporting mass care operations, and communicating critical information to the public including estimated time of remediation, addressing hazardous waste issues, etc.

- Coordination to ensure public protective measures conform to environmental modeling and established protective action recommendations.

Phase 3 (Long-term Recovery Operations) typically begin during the response phases (Phases 2a through 2c) and include preparations to support longer-term health and safety needs, assessment of long-term damage and mitigation options, infrastructure restoration, and longer-term environmental remediation. Each SLTT government defines its own goals for successful recovery based on its circumstances, challenges, vision, and priorities. Such goals generally include ensuring the return of displaced survivors, reestablishment of essential services, and the remediation of key environmental issues. Recovery activities may last for an extended period of months or years.

In most chemical incidents, the transition from response to recovery operations is not necessarily clear, and consequence management begins within response as decisions are made in real time. Such decisions also ultimately impact the recovery process. Hence, decision-makers should consider the longer-range consequences that decisions made in the earlier phases of the response may have on later phases. For example, protection levels that were selected to protect first-responders during Phases 2a and b of the response may not be sufficient for the longer-term exposures that could occur during resumed use/re-occupancy of a contaminated site.

2.4. Chemical Incident Consequence Management by Operational Phase

As specified above, this document focuses on a specialized subset of consequence management activities critical to chemical incident response and recovery: 1) characterization of potential contamination of the general area and specific sites impacted by the incident; 2) general area and site-specific remediation; and 3) clearance for re-entry/re-occupation of general areas or specific sites contaminated by chemical HAZMAT. The table below provides a synopsis of these key consequence management activities as they relate to the operational phases discussed above. Real-world case studies and additional references providing illustrative examples of chemical incident consequence management activities by operational phase are provided in Appendix B.

Table 1: Chemical Incident Consequence Management Activities by Operational Phase.[15]

Chemical Incident Consequence Management Activities					
Immediate Response (Phase 2a)	Deployment (Phase 2b)	Sustained Response (Phase 2c)			Recovery (Phase 3)
		Characterization	Remediation	Clearance	
▪ Receive and assess initial chemical incident information ▪ Conduct initial notifications and ICS activations ▪ Establish key FSLTT and RP POCs ▪ Identify suspect release site(s) ▪ Conduct initial (rapid) release modeling and site security operations ▪ Relay key initial risk information to appropriate agencies ▪ Support initial public communications and messaging, focusing on warnings and	▪ Deploy specialized assets and teams with gross field level instrumentation ▪ Determine agent type, concentration, and viability (as able based on instrumentation available) ▪ Conduct initial area/site-specific incident characterization and initial risk assessment ▪ Conduct initial site containment ▪ Perform additional release modeling and analysis, including	▪ Perform detailed characterization of hazardous chemical(s) involved in the incident ▪ Perform detailed characterization of affected area/site(s) ▪ Conduct extensive environmental sampling and analysis ▪ Conduct supplemental health and environmental risk assessments ▪ Develop procedures to	▪ Develop and implement site/area containment plan ▪ Effect source reduction, as practical ▪ Establish decontamination parameters ▪ Develop and implement remediation (decontamination and clean-up) plan ▪ Develop and implement waste management plan ▪ Support ongoing risk communication	▪ Conduct clearance sampling and analysis ▪ Establish clearance goal and develop collaborative clearance courses of action ▪ Support continued risk communica-tion	▪ Implement re-use/re-occupancy decision ▪ Seal/cap, decommissi on, or demolish if necessary ▪ Conduct environment al and public health monitoring, as required ▪ Support ongoing risk communicati on

[15] As this section focuses on a specifically defined subset of consequence management activities that occur following the onset of a chemical incident, Phase 1a-c activities are not included in this table.

recommended protective actions	extended downwind impacts analysis ▪ Conduct initial screening sampling ▪ Support ongoing risk communication and updates to recommended protective actions and worker health and safety actions	manage investigation derived waste ▪ Support ongoing risk communication			

Immediate Response (Phase 2a). The Immediate Response phase typically is characterized by the unknowns and/or uncertainties associated with the immediate aftermath of the release. The source of the release may still be active and may be covert. Covert release or chemicals whose presence is difficult to detect, may result in significant cross-contamination, which can lead to the need to perform more extensive remediation activities. In general, the priority focus in this phase is on lifesaving and first aid actions such as evacuations, sheltering-in-place, protecting emergency workers, patient decontamination, and emergency medical treatment.

Deployment (Phase 2b). In this phase, initial incident characterization is undertaken to define areas/sites that require decontamination. Initial characterization activities may be based on rough estimates (e.g., visibility of a plume, emergency response guidelines), plume models, or even information from visual or odor indicators or gross level field instrumentation results reported by first responders. If the hazardous chemical has been identified, the IC/UC may be able to use other field instrumentation and/or more precise chemical dispersion models that provide estimates of the extent of the spread of the hazardous chemical. However, field instruments may only be able to provide information on whether the hazardous chemical is present above a certain concentration, rather than providing the concentration itself. Likewise, the detection limit of the instrument (the concentration at which the instrument can detect the hazardous chemical) may be quite high; in some cases, it may be higher than the concentration at which responders are likely to show symptoms of exposure.

During Phase 2b and 2c, the IC/UC and other senior leaders may be supported by a technical/environmental planning team(s) and/or executive committees comprised of FSLTT agencies and other organizations with authorities, roles, and responsibilities in chemical incident consequence management. Such groups typically are established to advise the IC/UC on technical issues brought to light during initial incident characterization and other assessment and initial decision-making activities (e.g., protective exposure level determinations). Such groups typically expand in size and focus to include additional expertise to address other issues and needs that arise as the response evolves (e.g., development of remediation strategies, methodologies, etc.).[16] See Section 2 below for further detail.

Sustained Response (Phase 2c). This phase of the response encompasses the detailed characterization of the site including determining the extent of contamination and other impacts, decontamination and cleanup planning and plan implementation, determining appropriate clearance criteria, and conducting final restoration and remediation of the site for proper resumed use/re-occupancy.

During this phase, additional site and other incident data will be gathered through a variety of different site characterization activities. Examples of such activities include:

[16] Based on the key doctrinal notion that ICS is scalable based on the size, scope, and complexity of a given incident, this document is focused on how the technical information contained herein can be used to support incident planning and decision making rather than provide prescriptive guidance on how such planning and decision processes will be structured/operationalized via the ICS.

- Developing detailed description and dimensions of the areas affected (natural or man-made);
- Estimating the extent of potentially contaminated surface areas and the volume of potentially contaminated materials using maps, building blueprints (including HVAC systems and building interconnections), and water distribution system maps (including connections and components of water and wastewater distribution systems);
- Identifying material types: nonporous (e.g., glass, metals), semi-porous (e.g., walls, concrete), or porous (e.g., ceiling tile, carpet);
- Identifying populations exposed, potential human exposure pathways (e.g., inhaling contaminated air, skin contact with contaminated surfaces or water, drinking water) and exposure parameters (e.g., intake rates and time-activity patterns);
- Documenting environmental conditions during and after the contamination event (e.g., ambient temperature, humidity, exposure to sunlight, cloud cover, wind speed and direction, rate and directional flow of water, rainfall);
- Applying mathematical models to characterize the fate and transport of contamination (e.g., air, ground water, and surface water models); and
- Conducting waste management activities.

Based on the outcomes of the characterization activities identified above, in the areas affected by the release, the IC/UC may need to revise assessments of suspected areas of contamination as established during earlier phases of the response. Unlike in the case of the immediate response, in this phase the bounding of these areas is likely to be based upon the results of strategic sampling plans and precise, laboratory-based, analytical methods. Outputs of this process would not only indicate if a hazardous chemical was detected, but would also provide a quantitative estimate of the contamination present in the affected environmental materials and surfaces (e.g., building surfaces, soil, ground water, drinking water, surface water, air).

Regarding Phase 2c remediation activities, various decontamination technologies and procedures may be implemented to remediate the impacted sites. Such activities necessarily will be iterative in nature, with ongoing decontamination activities and re-characterization of the decontaminated areas to assess if additional measures must be implemented, until acceptable clearance levels are reached. Decontamination technologies may use mechanical/physical, chemical, or natural degradation/natural attenuation methods to physically remove, chemically treat, degrade, or naturally dissipate the hazardous chemical contaminant(s).[17] In addition, every decontamination technology produces waste, and the amount and character of waste is dependent on not only the contaminant, but also the specific

[17] Environment Canada (2005). Report EE-176, Review of Decontamination and Restoration Technologies for Chemical, Biological, and Radiological/Nuclear Counter-terrorism, CRTI-IRTC.

decontamination technology employed. A partial listing of decontamination technologies for specific chemical warfare agents (CWAs) for surface "hot spots," large volume spaces, and sensitive equipment is provided in Section 5.

Optimally, the following end-states are achieved when Phase 2C is completed:

- Contaminated facilities are identified and successfully decontaminated for safe re-use and re-occupancy;
- All hazardous and non-hazardous waste materials are removed and successfully managed in accordance with FSLTT environmental regulations;
- Facilities, equipment, and/or materials, unable to be safely decontaminated to established levels, due to a variety of factors, are demolished and corresponding waste streams properly disposed of in accordance with FSLTT environmental laws and regulations;
- Chemical incident remediation efforts are completed within a reasonable timeframe (as established by identified FSLTT senior leaders and stakeholders) to minimize economic and public health impacts to the affected communities; and
- Remediation personnel (both government and private entities) conducting cleanup and HAZMAT disposal activities are protected and show no signs of adverse health effects as a result of such activities.

Recovery (Phase 3). During this phase, final decisions are made regarding longer-term remediation issues and resumed use/re-occupancy of contaminated sites and facilities. Consideration should also be given to plans for determining if long-term environmental monitoring is required to ensure that clearance levels are maintained over time and whether it is necessary to institute longer-term site controls or restrictions. Continued risk communication is important during the remediation phase to inform the public and help them make decisions regarding themselves and their families and to maintain trust between the public and government decision-makers.

2.5. Planning Documents

Below are examples of some key topical planning documents typically developed to support chemical incident consequence management priorities across the operational phases discussed in detail above.

- **Quality Assurance Project Plan (QAPP)** – The QAPP establishes the site-specific data quality objectives of the project.
- **Health and Safety Plan (HASP)** – The HASP establishes the overall site-specific safety requirements, work areas, places of refuge, site control, emergency evacuation routes, emergency decontamination procedures, and emergency medical treatment. It specifies necessary emergency equipment including PPE and ensures proper training, medical surveillance, chemical protective clothing, and

post-emergency response operations.[18] The HASP also includes a weather plan that establishes actions for pending weather events which could impede response and recovery. The HASP establishes the overall site-specific safety requirements, work areas, and levels of personal protection equipment (PPE).

- **Ambient Air Monitoring Plan (AAMP)** – The AAMP establishes air monitoring and sampling frequency and spatial distribution to ensure the safety of the response workers and adjacent public population. It can also be used to determine the migration of plumes and direct evacuation or shelter-in-place actions. It can also combine real-time air monitoring with air samples that will be submitted for subsequent analysis. The AAMP is typically utilized to support a number of different consequence management activities across operational phases of the response and recovery effort.[19]

- **Sampling and Analysis Plan (SAP)** – The SAP establishes the number and spatial distribution of samples in all matrices (air, soil, water, materials) during site remediation. The AAMP may be incorporated into the SAP.

- **Remedial Action Plan (RAP)** – The RAP establishes the decontamination technologies and methods to be used to remediate the site.

- **Waste Management Plan (WMP)** – The WMP identifies necessary decision-making processes and available information for management of the waste generated from the contamination incident and remediation efforts. Representatives from the appropriate treatment, storage, and disposal facilities should be identified early in the initial stages to provide information on waste characterization requirements. States may have more stringent regulations on CWA-generated waste than the Federal government; this will require further input from waste receivers and regulators.[20] Hazardous waste activities will need to be regulated, and how compliance with appropriate regulations or permits will be accomplished needs to be planned for and a risk communications strategy developed.

[18] See https://www.osha.gov/emergency-preparedness/hazardous-waste-operations/preparedness. Also see OSHA 1910.120 in general and this webpage in particular on OSHA HAZWOPER: https://www.osha.gov/emergency-preparedness/hazardous-waste-operations/background. Additionally, the Superfund Amendments Reauthorization Act (SARA) of 1986 required OSHA to issue regulations protecting workers engaged in hazardous waste operations. OSHA's Hazardous Waste Operations and Emergency Response (HAZWOPER) standards (in general industry, 29 CFR 1910.120; and construction 29 CFR 1926.65) established health and safety requirements for employers engaged in these operations, as well as responses to emergencies involving releases of hazardous substances. HAZWOPER requires that employers follow specific work policies, practices, and procedures to protect their workers potentially exposed to hazardous substances. The standards provide employers with the information and training criteria necessary to ensure workplace health and safety during hazardous waste, emergency response, and cleanup operations involving hazardous substances. HAZWOPER aims to prevent and minimize the possibility of worker injury and illness resulting from potential exposures to hazardous substances.

[19] Note: Ambient air monitoring is most applicable for volatile or highly volatile chemicals.

[20] U.S. Environmental Protection Agency (2018). Best Practices to Minimize Laboratory Resources for Waste Characterization During a Wide-Area Release of Chemical Warfare Agents.

- **Data Management Plan (DMP)** – A DMP outlines a comprehensive approach to data management to ensure that data collection produces a consistent data set to enhance understanding and communication of an evolving conceptual site model (CSM). A consistent approach for collecting, processing, and analyzing data facilitates the decision-making team's data transfer and integration, which allows for more effective sharing among data partners, users, and project stakeholders.

These planning documents are created and used during different phases of response and recovery, and individual documents can be used for multiple purposes and may be updated multiple times as the response and recovery effort evolves. For example, often one SAP will be developed to support characterization activities, and another to support clearance activities. Each of the individual types of plans discussed above will have tailored data collection requirements that will need to be included in an overarching data collection/records management plan. Additionally, each type of plan should include environmental justice considerations based on the outcomes of detailed analysis of potential underserved and underrepresented communities impacted by the incident.

Additional planning guidance documents may be found at the EPA On-Scene Coordinator website. Further, the Worker health and Safety Support Annex to the NRF provides federal guidance to FSLTT response and recovery organizations in assuring worker safety and health during incidents requiring a coordinated Federal response.[21]

2.6. Illustrative Planning and Decision Process for Chemical Incident Consequence Management

An effective approach to chemical incident consequence management encompasses multiple key elements—involving Whole Community partners, stakeholders, and technical expertise;[22] accurately understanding the hazard(s) involved and its impacts on people, infrastructure, and the environment effects; developing and implementing appropriate remediation strategies based on carefully considered course of action (COA) analysis; and determining and documenting how resources will be applied during the incident characterization, remediation, and site clearance processes.

[21] This annex describes coordination mechanisms, policies, and processes to provide technical assistance for response/recovery worker safety and health management activities that include anticipation, identification, and mitigation of response/recovery risks and hazards. These mechanisms also include the assessment and analyses of health risks from occupational exposures, to facilitate incident risk management for response and recovery workers. See: Worker Health and Safety Support Annex (fema.gov)

[22] Partners are directly involved in the accomplishment of a plan's mission. They provide needed resources or capabilities, and share in the risk of the mission, which means they hold some or all responsibility for meeting one or several objectives during an incident. Stakeholders include organizations and individuals who are vested in how a plan is designed and in the outcomes of executing the plan, but who do not have direct responsibilities that contribute to the completion of the mission. Stakeholders provide support to ensure that FEMA operational plans are complete, inclusive, and technically accurate. Participation in the planning process also benefits stakeholders by heightening their awareness of threats and hazards, as well as anticipated actions across the various operational phases of the response and recovery effort.

This section describes a generic planning and decision process that FSLTT Whole Community response and recovery leadership can use to achieve the desired end-states for chemical incident consequence management as defined in this document. This process includes four primary steps:

- Step 1: Form Required Planning Teams;
- Step 2: Understand the Situation;
- Step 3: Determine Chemical Incident Consequence Management Goals and Objectives (both overarching and plan-specific); and
- Step 4: Plan Development.

This multi-step process applies to the various consequence management-related plans described in Section 2.4 above, among various others that may be required as the incident response and recovery effort evolves.

This process is drawn from the *FEMA Operational Planning Manual (FOPM*), FEMA P-1017, which provides a basic template for risk-based planning and decision making that can be easily tailored to support integrated chemical incident consequence management needs. This process can be used to support pre-incident deliberate planning as well as real-time crisis action planning (across various types of plans, including, but not limited to, those described in Section 2.4 above) that accounts for actual incident impacts and incident-specific resource needs. It also encompasses a Whole Community focus to ensure necessary partner and stakeholder engagement and that appropriate and sufficient research, technical analysis, and risk assessments are conducted to support to achieve the desired end-states. The various plans developed through this process in support of consequence management needs will require consistent and thorough evaluation and update across operational phases to identify any gaps which such plans did not account for sufficiently based on the specifics of the incident scenario. Hence, the consequence management planning process is also iterative in nature requiring flexibility among the various stakeholders involved in the process.

Additional technical references and background information that correspond to the individual process steps identified above are provided in the appendices to this document. Appendix A discusses available hazardous chemical-specific exposure guidelines (environmental health-based levels) and factors to consider when selecting appropriate types of values to apply at each stage of an incident (e.g., characterizing the incident, establishing consequence management goals, selecting remediation strategies and methods, and making clearance decisions). Appendix B presents example scenarios, operational phasing, and case studies based on real-world incidents and exercise events.

2.6.1. STEP 1—FORM REQUIRED PLANNING TEAMS

SLTT jurisdictions engaged in chemical incident consequence management, particularly in situations involving both wide area and site-specific contamination (including the contamination of critical infrastructure facilities where operational disruption likely will have significant impacts to one or more jurisdictions and surrounding communities), must rely heavily on the engagement and participation of

multiple partners, stakeholders, and SMEs. Active engagement among appropriate Whole Community agencies and organizations will help ensure: (1) partner and stakeholder issues and concerns are addressed sufficiently in the consequence management planning and decision process, and (2) acceptability of consensus end-states (as described more generally in this document, but specific to the given incident) for consequence management activities such as safe re-use and re-occupancy of contaminated areas and specific sites (to include accepting loss of facilities, equipment, and materials for proper waste disposal if successful decontamination is not achievable).

Planning and decision making regarding chemical incident consequence management comprises three primary elements: an established UC and other jurisdiction-specific senior leadership teams, a core planning team, and a collaborative planning team. These three elements are distinguished by their specific roles and responsibilities in the planning and decision-making process.

UC and Other SLTT Senior Leadership Teams

Nationally significant or large-scale chemical incidents may have significant impacts within a single jurisdiction or, more likely, across multiple SLTT jurisdictions. Such incidents will involve the establishment of a UC structure to facilitate incident management and resource coordination across involved jurisdictions and responding agencies. The composition of the UC will vary based on incident size, scope, complexity, and the specific agencies/organizations and SMEs that need to be engaged at various points in the response and recovery effort. The UC structure will also be directly linked to SLTT appointed and elected officials and private sector officials with key decision authorities pertinent to the overall response and recovery effort. Collectively, the established UC and other SLTT leadership, supported by senior technical advisors, as needed, represents the approval authority for plans and planning products developed to support chemical incident consequence management needs. Regardless of the subject of the specific plan being developed, planners must engage pertinent senior leadership with the intent of securing direction, approval, and document validation throughout the entire planning process. The UC and other pertinent senior leaders, along with relevant technical SMEs, will convene at pivotal junctures during the planning process to review and approve the current state and future direction of the various plans considered.

Core Planning Team

In the context of chemical incident consequence management, a Core Planning Team is established to engage relevant partners and stakeholders and provide an orderly structure for the planning effort, integrating all the elements of the planning process and relevant technical expertise to meet the goal and supporting objectives, deliverables, and schedule for the specific plan under consideration. The Core Planning Team also is responsible for facilitating subordinate technical working groups charged with specific aspects of plan development and ensuring the quality of the deliverables created.

The reporting structure for the Core Planning Team will be determined by the IC/UC. The Core Planning Team may also provide support to any technical SMEs assigned directly to the ICS Command Staff or elsewhere within the ICS organization established for the incident.

The Core Planning Team is overseen by a team leader designated by the IC/UC leadership. Once assigned, the team leader begins determining the composition of the Team. Core Planning team members generally possess either specific jurisdictional authority or planning expertise and experience based on the type of plan being considered (e.g., site decontamination, clean-up, hazardous waste management, etc.). Once established, the planning team leader communicates expectations and plan milestones, schedules, and responsibilities to the group.

Collaborative Planning Team

The Collaborative Planning Team works under the direction of the Core Planning team and includes individuals identified by the IC/UC as representing a specific program area, capability, technical area of expertise, or organization pertinent to chemical incident consequence management planning.

Team members are responsible for the development and accuracy of deliverables assigned to them by the Core Planning Team throughout the planning process.

The Collaborative Planning Team may include SMEs from FSLTT agencies; NGOs; and private-sector partners (including RPs) who have specific authorities, responsibilities, and/or capabilities pertinent to consequence management or who may have a significant stake or responsibility in the execution of the operational plan being developed. Team members should be able to speak with authority on policy, capabilities, and resources, provide technical expertise, and help ensure accountability as it relates to their parent agency or organization.

Collaborative planning team members may be called upon to:

- Provide information regarding their parent organization's authorities, roles and responsibilities, technical capabilities, resources, etc.;
- Provide functional and technical expertise and conduct or facilitate outreach to relevant analysis;
- Develop strategies and tactics related to plan implementation; and
- Develop COAs and present briefings for senior leader approval.

Members of a Collaborative Planning Team focused on chemical incident consequence management typically represent the following types of organizations and/or functional expertise:

- Facility and property owner(s)/operator(s) of contaminated facility or facilities;
- Local planning commissions;
- SLTT-level public health, environmental protection/equity and justice, and waste management organizations;
- Federal Environmental Protection Agency (EPA) representative(s);
- Federal Occupational Health and Safety Administration (OSHA) representative(s);
- Federal Centers for Disease Control and Prevention/Agency for Toxic Substances and Disease Registry (ATSDR);
- Public Information Officer (PIO)/Strategic risk communication organizations;
- HAZMAT/waste management consultants and/or clean-up firm(s);
- Community-based organization(s); and
- Others as required based on the incident scenario and UCG needs.

Scoping the Plan

The Core Planning Team should scope all relevant consequence management plans based on the identified issue, hazard, or threat that needs to be addressed within or across specific operational phases of the response and recovery effort. This includes, but is not limited to, the specific types of plans identified in Section 2.4 above. Specific critical information requirements (CIRs) pertinent to such plans typically are developed in the context of particular incident that, in turn, are used in scoping a plan. For a nationally significant or large-scale chemical incident, these CIRs normally will include, but are not limited to, the following:

- What was the definitive chemical(s) involved in the incident?
- What are the toxicological properties and environmental fate and transport of those chemical(s)?
- Which facilities (both homes, government facilities and businesses) and publicly accessible areas are suspected or confirmed to have chemical contamination present?
- What specific areas of those facilities or specific materials, and equipment were determined as either suspected or confirmed to have contamination?
- Are these suspected or confirmed contaminated facilities, materials, and equipment privately-owned or government-owned, and who will be responsible for performing clean-up and waste removal, appropriately?
- For both personnel and equipment decontamination, what methods were found effective to prevent contamination spread or cross-contamination?
- What are the required decontamination materials, supplies, and equipment required to conduct clean-up and waste removal operations?
- Are there existing standards for defining sufficient decontamination levels for the chemical(s) involved, and what are the acceptable methodologies to detect and quantify those levels?
- Are there cost limitations in performing decontamination and waste removal for the areas impacted, and “who pays?”
- Are there specific cultural, ethnic, environmental justice, or socio-economic considerations when performing decontamination and waste removal operations?

Additionally, proper scoping the plan and associated requirements will guide planners in identifying partners, stakeholders, and SMEs that should be involved in the planning process. Such individuals are identified and included as the planning process evolves; the planning team leader will be responsible for managing the level and breadth of their engagement.

Engaging the Whole Community

Engaging the Whole Community experience has shown that it takes all aspects of a community (non-profit; the private sector; community-based organizations; and the public, including survivors) -- not just the government -- to effectively prepare for, protect against, respond to, recover from, and mitigate large-scale chemical incidents. The aspects of a UCG involved in chemical incident consequence management, therefore, must sustain and further strengthen its already strong partnerships and relationships, and effectively mobilize and support resources, expertise, and capabilities from all levels of government, the private sector, the non-profit community, and the public. The UCG should work with partners and stakeholders from every sector to enable communities to develop collective, mutually

supporting consequence management strategies and methods. Engaging the whole community in the planning process can provide the added benefit of bringing together diverse points of view and developing atypical avenues of support.

2.6.2. STEP 2—UNDERSTAND THE SITUATION

This step in the planning and decision process emphasizes the importance of understanding the situation before developing or updating plans related to chemical incident consequence management. In chemical incident response, situational assessment includes the incorporation of information on the specific chemical(s) involved, facilities and other items contaminated, the extent of contamination, impacts on public health and the environment, and other CIR described previously.

Information Analysis Process

Information analysis is the process planners use to inform both strategic and operational decisions. Based on the scope of the plan, various aspects of the collective planning team are engaged to identify, research, collect, and assess the information that will drive decision making and provide a factual basis for the specific plan under consideration. Information analysis is a collaborative effort that depends on teamwork and cooperation among all planning team members, including leadership, partners, stakeholders, and SMEs.

The information analysis process encompasses two main areas: 1) research and 2) analysis.

Research

Research occurs throughout the planning process to help refine the intent, scope, and objectives of specific plans and implementation tasks that are developed to address various consequence management needs. Research also helps to identify secondary and tertiary effects of the incident on people, infrastructure, and the environment. For example, if a specific decontamination method is used to remediate a specific chemical(s) of concern, what are the degradation by-products? Are these products toxic to human health and/or the environment? Is there then a requirement to remove the degradation product after primary decontamination is performed? Comprehensive research is essential in the development of specific plan components.

The planning team leader will scope the extent of the research required based on the size, scope, and complexity of a given chemical incident. Research that is specific to chemical incident consequence management needs should include the following:

- Contamination issue regarding workers and the public;
- Specific facilities, materials and equipment determined to be contaminated;
- Extent of area and site-specific contamination (e.g., all rooms, just floors, concentrations);
- Building components of contaminated facilities, materials and equipment (e.g., concrete, linoleum, wood, metal, glass, porous or nonporous);
- Weather conditions (may impact contamination spread or possibly degradation);
- Topographical characteristics of suspected or confirmed contaminated areas;

- Political, cultural, ethnic, and socioeconomic considerations involving suspected or confirmed contaminated areas and/or sites;
- Transportation corridors for personnel and equipment (both manual, light, heavy or medium mobile vehicles);
- Access to water and power; and
- Known methods & required and effective decontaminants and materials.

The following major information categories should be considered when conducting research for chemical incident consequence management:

- Operational Environment;
- Authorities and Capabilities; and
- Resource Limitations and Shortfalls;

The operational environment encompasses the environment and geography of the areas requiring characterization, remediation, and decisions regarding site re-use/re-occupation. This encompasses relevant demographic, historical, cultural, and socioeconomic factors, political sensitivities, and the area geography. Also included are the incident footprint, political boundaries (e.g., city and county or property lines) and other factors that may impact how remediation and other necessary activities may be implemented. Large geographic areas or complex political boundaries may require planners to consider unique ways to structure the incident organization to effectively support consequence management operations. Finally, operating environment considerations includes research on the contaminants, proposed decontamination methodologies and equipment, and potential for decomposition products resulting from certain decontamination methods or from exposure to various potential weather conditions.

Capabilities are the means to accomplish the remediation effort successfully. Capabilities not only include equipment, training and supplies to conduct certain decontamination and cleanup activities, but also, rely on authorities, policies, programs, staff, funding and available resources to implement those capabilities.

Resource limitations and shortfalls are limitations that restrict the way in which a resource(s) can support consequence management activities. This may include, for example, water or power access, or limited materials to support the operation of certain types of decontamination equipment.

Analysis

Analysis involves the detailed examination of information in order to gain a clearer understanding of the situation and surrounding environment. Analysis also helps to drive the development of specific planning products. The planning team conducts analysis of the information they have collected through the research process in order to have a clear understanding of what the plan must address, and a factual basis for the facts, assumptions, and decisions reflected in the plan.

Based on the information collected during the research process, subsequent analysis should be able to provide the following information:

- Geographic locations of confirmed contaminated areas based on field surveys;
- Geographic locations of suspected, but not yet confirmed contaminated areas;
- Known composition of materials suspected (e.g., concrete, linoleum);
- Estimated square footage or volume of contaminated areas, materials, and equipment;
- Identification of areas and types/sizes of facilities, equipment and materials that have a high probability of being decontaminated effectively; and
- Identification of areas and types/sizes of facilities, equipment and materials *not likely* to be decontaminated either due to the complexity, size, and/or significant costs incurred.

Analysis also supports the development of potential strategies/methodologies to accomplish key consequence management tasks:

- For areas not deemed appropriate for remediation, the identification of disposition options (e.g., demolition/removal for waste disposal);
- Based on the size and physical geometry areas or specific sites targeted for remediation, an estimate of the amount and type of equipment, supplies. and materials required to conduct remediation operations;
- Identification of government versus private owner/operator responsibilities and funding for decontamination, hazardous waste removal, and other services;
- Identification of either government and/or contracted performers to implement selected remediation strategies;
- Identification of downstream areas where chemical(s) of concern and/or decontaminant may flow and cause significant impacts; and
- Identification and estimation of the duration of critical infrastructure impacts that may result from select remediation activities.

Critical facts and assumptions are identified as an outcome of the analysis process. Plans are based on substantiated facts such as the nature of the threat or hazard and anticipated operational impacts. Assumptions represent information accepted by planners as true in the absence of facts. The use of assumptions allows planners to further characterize the specifics of the incident at hand, identify potential response requirements, and move forward with or refine the planning process.

Planners should compile the results of the analysis process into planning factors. Planning factors encompass physical effects, operational impacts, facts, and assumptions which result from the careful study of the specific incident scenario the plan is intended to address. As a tool for placing research and analysis in operational context, planning factors help ensure that planners develop appropriate COAs for relevant tasks and activities.

Planning factors may have both qualitative and quantitative aspects. In the context of chemical incident consequence management, planning factors may be expressed as follows:

- Contaminated facilities include the following:
    - Building A (Exterior and 3 stories and estimated 10,500 square feet);

- Building B (Exterior and 1st floor only estimated at 2500 square feet);
- Parked vehicles around Buildings A and B (Approximately 50 vehicles (e.g., 10 pickup trucks, 20 sedans, 10 motorcycles, 10 commercial 4-wheel trucks); and
- Common areas, sidewalks, and outdoor parking around Buildings A and B (approximately 20,000 square feet).

- Decontamination capability determined effective:
  - Chemical XXX estimated 5000 gallons;
  - Estimated personnel: 300 personnel trained and qualified; and
  - Estimated time for decontamination: 30 calendar days operating 10 hours per day (daytime only).
- Estimated decontamination costs: >$5 million

Planners should also identify anticipated shortfalls/challenges as part of the analysis process. The following are typical examples:

- Limited quantities of water or decontamination solution available at any given time to perform remediation;
- Political, social or ethnic sensitivities to the areas requiring decontamination (e.g., statutes, paintings, computers, records);
- Availability of trained and qualified personnel to perform decontamination; and
- Maintaining site security.

2.6.3. STEP 3—DETERMINE GOALS AND OBJECTIVES

In this step, planners determine the operational priorities, develop the mission statement, describe the end state, identify relevant timelines, and establish goals and objectives for the plan under consideration. These plan components are important to define what mission success will look like in a given consequence management effort. This effort culminates in an information analysis brief (IAB) developed for the IC/UC and other senior leaders to seek further guidance and gain approval for further plan development including COA development.

Describe the End State

The end state describes the desired situation that will exist when a given chemical incident consequence management plan is successfully implemented and all supporting operations are concluded. The IC/UC and other Whole Community senior leaders typically determine the end state; the planning team may refine the end state to provide more specific detail to meet senior leader expectations.

Examples of end-states for chemical incident consequence management include the following:

- "Contaminated facilities are effectively decontaminated to verified safe levels for re-occupancy, and uncontaminated items not able to be decontaminated are removed as hazardous waste in accordance with Federal and SLTT environmental regulation."
- "All remediation activities have been successfully completed, site-specific re-occupation criteria have been established and approved in accordance with Federal and SLTT environmental regulations, and site re-occupation is underway based on protocols and timelines established by appropriate authorities."

Develop the Mission Statement

The mission statement defines a plan's purpose, primary operational objectives, and the key measure or measures of the plan's success. It also demonstrates the manner in which the intent and scope of the plan will be addressed, based on the incident scenario and the physical and operational impacts. More than any other element of a plan, a clear definition of the mission (and supporting tasks) enables unity of effort and consistency of purpose among the groups and activities involved in both developing and executing the plan. The mission statement should be a short paragraph or sentence that describes what must be accomplished to achieve success clearly articulating the elements or essential tasks related to "who, what, when, where, and why" of the plan.

The Core Planning Team, with input from the Collaborative Planning Team, presents the mission statement to the UCG and other senior leaders for review and approval, typically as part of the IAB process. Specific steps for developing the mission statement include the following:

- Identify the specified and implied tasks the planning team is trying to address;
- Identify the mission-essential tasks from among these specified and implied tasks (defined as a task(s) of such importance that without its completion the mission will fail; and
- Combine the purpose, end state, and mission essential tasks into a specific and measurable description of the mission objectives.

Once these steps are completed, the Core Planning Team should verify that the mission statement answers the following questions:

- Does it clearly articulate the end state or result of the plan under consideration?
- Does it reflect the goals or objectives that the plan is intended to accomplish?
- Does it identify who is responsible for plan implementation?

Develop Objectives

Incident objectives ultimately establish what the execution of the plan needs to achieve. Understanding the situation, developing corresponding requirements, and determining priorities are vital in this process. Objectives should be clearly stated and include attainable outcomes toward which every task is directed. Objectives define operational requirements that the organization must meet to achieve success.

Objectives often also identify who is responsible, timelines, and a general geographic location or area to which the objectives apply. Planners should endeavor to make each objective measurable, as approved objectives will drive the type or amount of capability that will need to be provided.

The Core Planning Team must ensure that objectives support accomplishing the plan's mission. Objectives should reflect an understanding of the operational environment and the problem, while describing an approach for achieving the desired end state. As the planning process continues, planners translate the objectives into tasks that directly support the overall mission.

Identify Key Tasks

Chemical incident consequence management, dependent on geographic extent, complexity, number of sites impacted, etc., typically involves the following key time-phased activities:

- Assessment and Evaluation (e.g., identification of all areas potentially contaminated to include materials of the facilities, equipment or grounds);
- Deployment and Staging (e.g., ground and decontamination equipment, personnel, vehicles);
- Preparation (e.g., removal of items deemed unable to be effectively decontaminated to make areas accessible that can be decontaminated, set-up of equipment or personnel decontamination corridors);
- Operations (e.g., conduct of specific remediation activities);
- Evaluation and Corrective Action (e.g., verification that determined "safe" levels achieved in decontamination process and if not, another decontamination effort is employed);
- Re-use/re-occupancy of remediated areas/sites; and
- Demobilization.

Brief Senior Leaders

During the IAB, the planning team leader and other members of the team present the results of research and analysis in an organized manner and review the threat or hazard in terms of community and operational impacts. The IAB represents a key decision point for leadership to approve, modify, or redirect the intent of the plan under consideration.

The IAB is intended to ensure Senior Leadership: (1) concurs that the core planning team has conducted the appropriate research and analysis to enable a comprehensive understanding of the situation; (2) approves the analysis conducted; and (3) directs planners to proceed with the planning process.

The IAB typically includes the following:

- Identification of Core and Collaborative Planning Team members;
- Detailed information reflecting the research/analysis accomplished, including situation, geography, incident impacts, capabilities, risks, resources, modeling, and simulations;
- Detailed information on applicable SLTT jurisdictions, mission partners, and stakeholders, demographic and socioeconomic factors, risks, and capabilities;
- Facts and assumptions;

- CIRs;
- Mission statement;
- Desired end state;
- Operational phases;
- Quantifiable draft incident objectives and mission-essential tasks; and
- Planning factors (include data such as population demographics [e.g., affected population, number of casualties and fatalities] and structural impact to the affected area).

The UCG and other FSLTT senior leaders approve the IAB allowing the initiation of COA development.

2.6.4. STEP 4—PLAN DEVELOPMENT

COA Development

COAs provide the IC/UC and other senior leaders with options to consider and, ultimately, select. A fully developed COA explains who does what, and when, to achieve the desired outcome. It also identifies the resources, capabilities, and information requirements to carry out an identified strategy.

The Core Planning Team, supported by the Collaborative Planning Team and other relevant SMEs (e.g., private contractors charged with performing remediation efforts), develops, evaluates, and ultimately recommends COAs for IC/UC and other senior leader review/approval. The recommended COA or COAs must represent the best way of achieving the end state, mission, and objectives laid out in the previous step of the planning process.

Depending upon the scale and complexity of chemical consequence management efforts, there may only be one COA presented, representing a fairly "straight forward" approach with no anticipated deviations expected to achieve the given end state, mission, and objectives. However, in large-scale chemical incidents characterized by significant size and complexity, several COAs may be required to be developed, evaluated, and, in some cases, a few COAs executed either at the same time or across operational phases of response and recovery.

All COAs developed must meet the following criteria:

- Suitability: Does it accomplish the objective or mission, and comply with the senior leader's intent?
- Feasibility: Will it work within established authorities, capabilities, and limitations?
- Acceptability: Does the solution justify the cost? Does it consider things like environmental equity and justice?
- Distinguishability: Is it distinct from the other options presented?
- Completeness: Does it fully incorporate plan objectives and tasks, along with major resource requirements (including staff, teams, facilities, supplies, equipment and transportation)?

COA Analysis

Assessment criteria provide planners with benchmarks for estimating each COA's potential for success, and for weighing the risks and benefits associated with each COA presented. Assessment criteria are

characteristics against which the planning team analyzes and scores each option, resulting in a profile of each COA that provides relative strengths, weaknesses, risk, and values in different categories.

Assessment criteria may entail a qualitative approach. This approach accommodates uncertainties in the operational environment (e.g., unsure of whether all areas were determined to have been contaminated). Examples of a qualitative assessment criteria may include the following:

- Timeliness: COA provides an efficient process to accomplish remediation within matter of weeks;
- Effectiveness: COA uses proven decontamination process found to reduce contaminant levels or at least neutralize the contaminants' potential health effects; and
- Wastes Generated: COA will generate minimal hazardous and non-hazardous wastes.

Assessment criteria may entail a quantitative approach. This approach requires a well characterized and fairly stabilized operational environment (anticipating less or no changes over time). Examples of a quantitative assessment criteria may include the following:

- Timeliness: COA provides an efficient process to accomplish remediation within 15 calendar days;
- Effectiveness: COA uses a proven decontamination process found to reduce contaminant levels to less than 0.01% of the detected amounts, or below detectable levels; and
- Wastes Generated: COA will generate less than 25 metric tons of both hazardous and non-hazardous wastes.

Once the assessment criteria are developed, the planning team develops criteria ratings. Each criterion selected by the workgroup will need to be further broken out into measurable ratings. Typically, a rating system from one to five provides a sufficient level of detail to distinguish between COA scores, but does not represent a greater degree of specificity than the planning team can determine. A notional rating system template is provided below.

Notional Rating System

Rating 5: Highest and describes the best score a COA could receive for the criteria established.

Rating 4: High and describes a highly effective rating under the criteria established.

Rating 3: Medium and describes the conditions of an acceptable rating under the criteria established.

Rating 2: Low and describes the unacceptable rating under the criteria established.

Rating 1: Lowest and describes the lowest or worst rating a COA can receive under the criteria established.

Depending upon the plan's approved end state, mission, objectives, the planning team also may decide to assign weighted numerical comparisons to the various ratings. For example, if the planning team determines that "timeliness" is a criterion that should be weighted higher than "wastes generated," a multiplier may be applied to the timeliness rating. Otherwise, the planning team may wish to treat all criteria in a non-weighted numerical comparison.

Other assessment criteria methodologies may include the following:

- Qualitative Narrative Technique: The planning team summarizes comparison of all COAs by analyzing strengths and weaknesses, or advantages and disadvantages; and
- Plus/Minus/Neutral Comparison: Positive means a positive influence in meeting criteria, negative means a less than optimal influence in meeting the criteria, and a "0" means a neutral influence.

The following represent key considerations in selecting the appropriate COA comparison techniques:

- Numeric Comparison
    - Planning efforts have sufficient time to generate detailed information that will allow the team to thoughtfully and accurately assign numerical values for each COA by defined criteria; and
    - The UCG has defined high-priority guidance regarding objectives and criteria, which make weighting of COAs an important consideration.
- Narrative Comparisons
    - Planning efforts have sufficient time to generate detailed narrative information regarding COAs; and
    - COAs are multi-faceted and require detailed descriptions to show how they are distinct from one another.
- Plus/Minus/Neutral Comparisons
    - Planning efforts have less time and need to rapidly assign values to COAs is more critical; and
    - More detailed information regarding individual COAs is unavailable.

COA Recommendation

The planning team recommends COAs to the IC/UC and other appropriate FSLTT senior leaders based on the evaluation criteria developed. The COA recommendation takes into account the risks and benefits of each COA presented. The planning team may recommend a particular COA to senior leaders even if the factors such as cost are high, but the COA represents a more effective approach (e.g., the COA includes an extensive decontamination technique where determined safe levels are achieved, but requires the most expensive equipment, personnel, and supplies to implement). In addition, the COA with the highest score may not necessarily be the best option for recommendation, but having the scoring criteria allows the COA workgroup to consider each criterion, the overall score of each COA, and identify the best option for recommendation. In the context of chemical incident consequence management, various COAs may be selected for implementation, but in a timed phase approach. Therefore, the planning team should not take a "one and done" perspective when making COA recommendations.

COA Decision Brief

The COA brief typically includes the following key components:

- Incident Situation (e.g., type and extent of contamination, areas and sites impacted, vulnerable populations impacted, etc.)
- Mission statement
- Senior leader's intent
- Objectives
- Operational phases
- Planning factors
- CIRs
- List of participants in COA planning
- COA development and evaluation (including COAs not selected)
- Recommended COAs
  - Operational concept
  - Resources required
  - Core Capabilities engaged
- Path forward (timeline and next steps)

2.7. Community Lifelines: The HAZMAT Lifeline

FEMA introduced the Community Lifelines concept in the fourth edition of the National Response Framework issued in October 2019. This concept is explained further in the Community Lifelines Toolkit published in August 2020. The Community Lifelines concept provides a comprehensive, repeatable construct to enable rapid characterization and stabilization of an incident, minimize further cascading impacts, and chart an effective and efficient path to incident response and community recovery. Various aspects of this approach can be used to inform the chemical incident consequence management planning and decision framework as described above.

The Community Lifelines construct uses a step-by-step process and built-in tools for assessing the condition of lifelines, defining stabilization goals, and developing lines of effort (LOEs) to guide specific response actions. The four major steps that comprise this process are:

- Assess lifeline condition by component/subcomponent
- Establish stabilization targets
- Develop Lines of Effort (LOEs) and apply to Incident Action Plans (IAPs)
- Develop recovery outcomes

Figure 2 provides an overview of this process, beginning with situation assessment and culminating with stabilization and recovery.

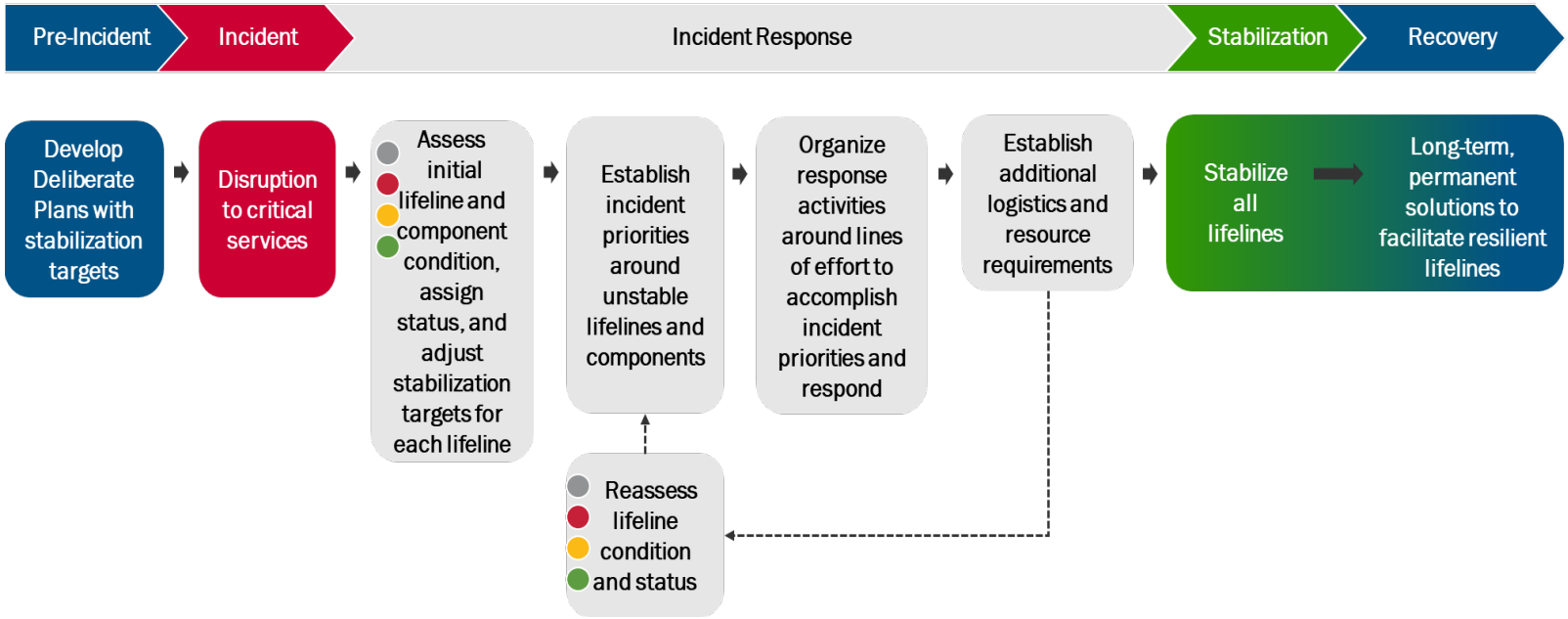

Figure 2: Incident Response Using Community Lifelines

Within the overall Community Lifelines construct, the HAZMAT Lifeline is most directly applicable to chemical incident consequence management. The HAZMAT Lifeline provides a means for identifying, prioritizing, and addressing HAZMAT threats and impacts to public health, the environment, and/or critical infrastructure operations.

Emergency managers at various jurisdictional levels often utilize Community Lifelines to inform pre- and post-incident planning products and processes, including pre-identified stabilization targets for each lifeline, including the HAZMAT Lifeline. During an incident, pre-identified stabilization targets are re-assessed and updated based on actual lifeline impacts and stabilization projections related to a realized incident. Stabilization targets, in turn, inform planning and drive key leadership decisions and prioritization of response resources and actions, including the development of strategies, operational priorities, and objectives. Generic stabilization targets for the HAZMAT Lifeline may include the following:

- All contaminated areas/sites are identified and secured from unauthorized entry and egress;
- Decontamination and waste management plans have been developed for areas/sites affected as well as the decontamination of authorized personnel conducting response operations;
- Sampling and analysis methods are determined and operations are conducted by qualified teams and personnel to determine achievement of designated clearance levels; and
- Clearance levels are established to inform the re-occupancy of impacted facilities.

LOEs are specific mission-sets required to stabilize lifelines. They provide a useful structure for visualizing and prioritizing tasks to reach individual stabilization goals. Examples of generic LOEs for the HAZMAT Lifeline may include the following:

- Assessment of/reporting on contaminated facilities, materials, and equipment;
- Health and safety of site worker and responder personnel;
- Decontamination of facilities, materials, and equipment;
- HAZMAT waste management; and
- Area/site-specific re-occupation clearance.

Figure 3 provides an example of example of applying a “clearance” LOE and supporting tasks to achieve a defined end state using the HAZMAT Lifeline construct.

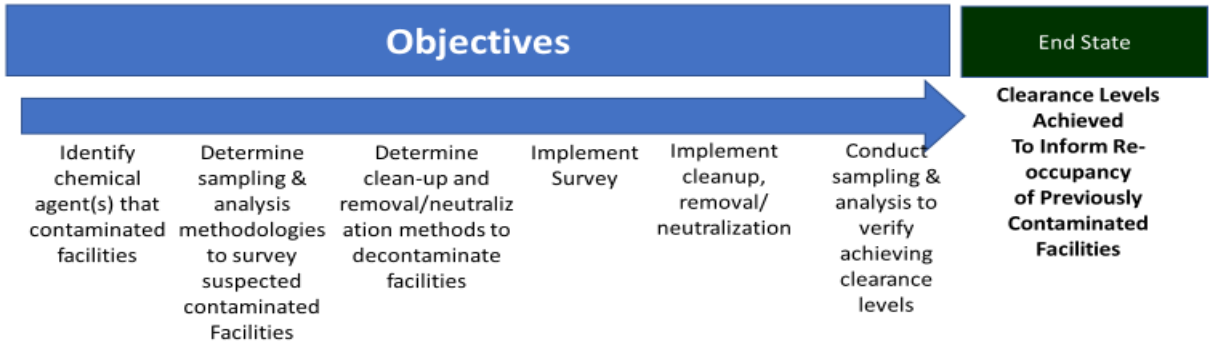

Figure 3: Applying the HAZMAT Lifeline Construct to Chemical Incident Consequence Management

When all lifelines are stabilized, including the HAZMAT Lifeline, the mission focus shifts to a primary focus on recovery outcomes, although response and recovery efforts occur simultaneously throughout the incident. A community's long-term recovery needs will vary depending on the scenario, context, and location of the chemical HAZMAT incident, as well as the incident's impacts on the local population, critical infrastructure, and the economy. With the immediate hazard addressed during the response, recovery planning for chemical incident consequence management focuses on key actions needed to achieve the following:

- Continue to assess and protect human health and safety in the areas impacted by the incident;
- Restore/rebuild and/or re-occupy residential areas and critical infrastructure facilities and associated services;
- Mitigate further disruption of and rejuvenate the economy; and
- Continue to monitor and minimize further damage to the environment and complete the safe disposal of HAZMAT.

2.8. Risk Communication

Risk communication is a vital component of risk analysis and is critical to effective risk, crisis, and consequence management in the aftermath of a nationally significant or large-scale chemical incident. The goal of effective risk communication is to share information among key partners and stakeholders—including first responders, technical experts, and elected/appointed community leaders—and inform the public about what can and is being done to reduce risks. Risks should not be over- or under-stated. Communication should deliver practical information and response guidance based on government and public responsibilities that flow from the incident. First responders and trusted community leaders should deliver these messages in a simple and straightforward manner.[23] Risk communication is a continuous

[23] U.S. Centers for Disease Control and Prevention (2014). Crisis and Emergency Risk Communication. Department of Health and Human Services.

process because knowledge about the risks may be fragmentary at first but increase over time. Effective risk communication builds public knowledge and trust over time across all operational phases of the response and recovery effort.

> "Through risk communication, the communicator hopes to provide the audience with information about the expected type (good or bad) and magnitude (weak or strong) of an outcome from a behavior or exposure. Typically, risk communication involves a discussion about adverse outcomes, including the probabilities of those outcomes occurring." – *U.S. CDC, 2014*

In response to a nationally significant or large-scale incident, a JIC, where personnel coordinate incident-related public information activities, should be established immediately. The JIC serves as the central point of contact for all news media. Public information officials from all participating agencies co-locate at, or virtually coordinate through, the JIC. A JIC provides quick, accurate public information throughout the response and cleanup process. In addition, the JIC works closely with elected officials, community leaders, local hospitals and health officials, social and support groups, advocacy groups, news media, private-sector partners,[24] and other involved stakeholders all the way through the return-to-use decision. Under the NRF, an information officer develops and releases information about the event to the news media and to all agencies and organizations involved. Regular and succinct public messaging will be critical to establish and maintain public confidence.

Public information regarding the complex technical, scientific, and risk issues arising from chemical incidents is challenging. This is particularly true in the face of the uncertainties involved in these incidents. However, by carefully placing the hazards of an incident into perspective for the public, appropriate risk communication can make complex scientific information accessible and understandable to a layperson. One effective approach to do this is to ensure that risk communication occurs in phases, with the content synchronized with the incident timeline. That is, there should be a preparation stage where a risk communication plan and strategy is developed, including public messages that anticipate varying and continuously evolving areas of concern during each phase of a given incident. EPA risk communication guidelines address the use of social media during and following response and clean-up activities.[25]

When risk communication is effective, it serves as a platform for discussing risks and goals with the public. In this way, risk communication is an approach for "scientists and public health professionals to provide information that allows an individual, stakeholders or an entire community, to make the best

[24] Private-sector partners are a key recipient of, and often contributors to, incident relevant information and should be included. The establishment of the Emergency Support function ESF #14 shows the importance of private-sector entities in response and remediation efforts and the sharing of information. For information on ESF #14 visit https://www.fema.gov/media-library/assets/documents/25512

[25] U.S. EPA (2012). Superfund Community Involvement Tools and Practices.

possible decisions about their well-being, under nearly impossible time constraints, while accepting the imperfect nature of their choices."[26]

On the other hand, releasing incorrect, undocumented, inconsistent, or misleading information to the public causes confusion and leads to mistrust. Decision-makers must be especially careful when communicating uncertain information and information about the evolving situation to avoid undermining the trust of stakeholders.[27] When a decision-maker maximizes communication about the goals of the response and cleanup processes, the decision-maker gains public trust, minimizes confusion, and fosters cooperation from the stakeholders and citizenry. These benefits will reduce the human, economic, and social costs of the incident.

Communication plans should also ensure access to information and for all communities, including underserved communities and those protected by law (e.g., race, color, national origin, religion, sex, age, disability, English proficiency and economic status). Communication efforts should also include outreach mechanisms resulting in engagement with community organizations and local partners that serve persons with disabilities, limited English proficiency, and underserved communities in the development and review documents and messaging.

There is also the potential that some information about certain chemical agents may be exempt from the Freedom of Information Act (FOIA) and cannot be shared with the public.[28] Caution will need to be taken when communicating to ensure this information is safeguarded.

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 various operational phases of chemical incident response and recovery is paramount to ensuring public understanding and trust, which in turn will contribute to the overall success of the response.

[26] U.S. Centers for Disease Control and Prevention. (2014). Crisis and Emergency Risk Communication. Department of Health and Human Services.

[27] U.S. Substance Abuse and Mental Health Services Administration (SAMHSA). (October, 2019). Communicating in a Crisis: Risk Communication Guidelines for Public Officials.

[28] FOIA Exemptions are available at https://www.dhs.gov/foia-exemptions.

3. Hazardous Chemical and Their Characteristics

3.1. Overview

This section provides information on hazardous chemicals and their characteristics which can be used to inform various aspects of the planning and decision process described in Section 2 above. Hazardous chemicals include chemical warfare agents (CWAs), toxic industrial chemicals (TICs), and other compounds such as some types of drugs and pharmaceuticals. Some TICs can also be classified as CWAs (e.g., hydrogen cyanide and phosgene). Cleaning up hazardous chemical incidents effectively requires a clear understanding of their toxicity, key physical and chemical properties, sources of exposure, routes of exposure, the persistence of the chemical hazards and reactivity with other substances, as well as the prevailing environmental conditions and characteristics of the materials and surfaces impacted by the specific hazardous chemical incident.

Previously, the development and testing of CWAs was focused on their battlefield effects. This resulted in well-documented data as to the concentrations required to cause injury and death to unprotected individuals. More recently, agencies of the federal government (such as the Department of Defense [DOD], Centers for Disease Control and Prevention [CDC], and EPA) have initiated research programs to obtain toxicological information on low-level exposure to CWAs.[29] While these studies are providing much-needed information regarding the effects of low-level and long-term exposures, definitive results for all CWAs are not available at this time.

3.2. Chemical Warfare Agents

CWAs (as defined by the Chemical Weapons Convention) may be classified by their physiological effects on humans, routes of exposure, and duration of hazard (persistence) (see Table 2). Classification by physiological effect yields choking (pulmonary agents), nerve, blood (cyanide compounds), blister (vesicants), or central nervous system (CNS)-acting agents (see Table 3 for example chemicals).[30, 31, 32]

[29]National Research Council (2005). Review of the Department of Defense Research Program on low-level exposures to chemical warfare agents. National Academies Press. Washington, D.C.

[30] U.S. Department of Defense, Joint Chiefs of Staff (2018, October). Operations in Chemical, Biological, Radiological, and Nuclear Environments. Appendix A: Chemical Hazard Considerations. Joint Publication 3-11.

[31]Environment Canada (2005) Report EE-176, Review of Decontamination and Restoration Technologies for Chemical, Biological, and Radiological/Nuclear Counter-terrorism, CRTI-IRTC.

[32]U.S. Department of Health and Human Services (2001). Managing Hazardous Material Incidents (MHMI). Volume III. Public Health Service, Agency for Toxic Substances and Disease Registry.

Table 2: Chemical Warfare Agent Classifications

Classification method	Agent classification
Physiological effect	Choking Nerve Blood Blister CNS-acting
Route of exposure	Inhalation Ingestion Absorption through skin and/or mucous membranes
Duration of hazard	Persistent Non-persistent

Persistent agents can be generally described as being low in volatility; they can remain on surfaces or in environmental materials and surfaces for several days, weeks, or longer, presenting long-term inhalation and contact hazards. Non-persistent agents can generally be described as highly volatile; they do not remain on surfaces for extended periods of time and can be considered short-term contact and inhalation hazards.[33] However, even non-persistent agents can remain for extended periods on certain media, such as polymeric or porous substances, and in enclosed spaces. Therefore, the length of time any chemical contaminant persists will depend on what materials and surfaces have been contaminated, the state of matter of the chemical (e.g., liquid, solid, gas), and environmental conditions (temperature, humidity, etc.). Additionally, some CWAs can degrade into hazardous/toxic by-products.

Routes of Exposure

There are three main routes of exposure for chemical agents into the body: inhalation, absorption, and ingestion.

Inhalation occurs when a plume of toxic gases, vapors, aerosols (mists) or particulates (dusts or liquid droplets) are drawn (inhaled) into the lungs. Although inhalation is possible for all chemical agents, it is more of a risk with chemical agents having high volatility and low boiling points, such as the G-agents and many toxic industrial gases (e.g., chlorine, ammonia, phosgene).

Absorption is the transport of chemicals from outer surfaces into the body through contact with the skin (dermal). Chemical agents that remain in liquid form due to their chemical and physical properties present the greatest risk for dermal absorption. Although absorption is possible for all chemical agents, it is more of a risk with chemical agents having low volatility and high boiling points,

[33]World Health Organization (2004). Public health response to biological and chemical weapons: WHO guidance. 2nd ed. Geneva, Switzerland.

such as the sulfur mustard, V-agents and Novichoks. A secondary route of absorption is ocular, where chemicals are absorbed directly into the body through the eyes from liquid splashes or contaminated vapors or atmospheres.

Ingestion occurs when contaminated foods and water are consumed. Smoking and other hand-to-mouth activities can also lead to the ingestion of chemical agents. Although ingestion is possible for all chemical agents, it is more of a risk with chemical agents having low volatility and high boiling points, such as the sulfur mustard, V-agents and Novichoks.

While a chemical agent with high volatility and low boiling point presents the greatest risk of inhalation from contaminated plumes, these plumes can recondense as liquids and become absorption and ingestion risks at significant distances from the initial release site.

Another, but more uncommon route of exposure, is injection, where a chemical agent is introduced into the body through an injury, open cut, puncture, or intravenously.

Table 3: Examples of Chemical Warfare Agents and Their Physiological Effect Classifications

Agent name	Symbol	Physiological effects	Chemical Abstract Service Number
Carbonyl chloride (phosgene)	CG	Choking	75-44-5
Diphosgene	DP	Choking	503-38-8
Chloropicrin	PS	Choking	76-06-2
Tabun	GA	Nerve	77-81-6
Sarin	GB	Nerve	107-44-8
Soman	GD	Nerve	96-64-0
Cyclosarin	GF	Nerve	329-99-7
O-Ethyl S-(2-diisopropylaminoethyl) methylphosphonothiolate	VX	Nerve	50782-69-9
Novichok	A-230	Nerve	2387496-12-8
Novichok	A-232	Nerve	2387496-04-8
Novichok	A-234	Nerve	2387496-06-0
Hydrogen cyanide	AC	Blood	74-90-8
Cyanogen chloride	CK	Blood	506-77-4
Sulfur mustard	HD	Blister	505-60-2
Nitrogen mustard	HN-1	Blister	538-07-8
Nitrogen mustard	HN-2	Blister	51-75-2
Nitrogen mustard	HN-3	Blister	555-77-1
Lewisite	L	Blister	541-25-3
3-Quinuclidinyl benzilate	BZ	CNS-acting	6581-06-2

Choking (or pulmonary) agents target primarily the airways. They irritate the eyes and respiratory tract, damage the lung and associated tissues, and cause pulmonary edema (also known as “dry-land drowning”). Early symptoms of exposure to choking agents include coughing, choking, a feeling of tightness in the chest, and nausea. Examples include carbonyl chloride (CG, or phosgene), diphosgene

(DP), and chloropicrin (PS). There is no antidote for choking agents. Treatment is supportive.[34, 35] Most choking agents are, generally, non-persistent.

Nerve agents include some of the most toxic CWAs. All of these agents affect the nervous system by inhibiting the enzyme acetylcholinesterase (AChE). Without functioning AChE, the neurotransmitter acetylcholine builds up and over-stimulates muscles, glands and other structures. Symptoms of nerve agent exposure include miosis (contraction of the pupils), headache, runny nose, salivation, and tightness in the chest. Symptoms of severe exposure include generalized muscular twitching, weakness or paralysis, convulsions, and cessation of respiration. The onset of symptoms for inhalation exposure ranges from seconds to minutes, and for cutaneous exposure from minutes to hours. Nerve agents also can have a cumulative health effect due to a slow metabolism in the body. Examples of nerve agents include tabun (GA), sarin (GB), soman (GD), cyclosarin (GF), *O*-Ethyl *S*-(2-diisopropylaminoethyl), methylphosphonothiolate (VX), and Fourth Generation Agents (FGAs) or "Novichok" agents.[36] Atropine, pralidoxime chloride (also called 2-pyridine aldoxime methyl chloride [2-PAM Cl]), diazepam, and idazolam

[34]U.S. Army, Marine Corps, Navy, & Air Force (2016). Multi-Service Tactics, Techniques, and Procedures for Treatment of Chemical Warfare Agent Casualties and Conventional Military Chemical Injuries. ATP 4-02.85/MCRP 3-40A.1/NTRP 4-02.22/AFTTP(I) 3-2.69.

[35]U.S. HHS (2001). Managing Hazardous Material Incidents (MHMI). Volumes III. Public Health Service, Agency for Toxic Substances and Disease Registry.

[36]Information specific to a Novichok/FGA response can be accessed at the U.S. Department of Health and Human Services site, https://chemm.hhs.gov/nerveagents/FGA.htm. Documents include the following: *Fourth Generation Agents: Safety Awareness for First On-Scene Responders*, *Fourth Generation Agents: Reference Guide*, and *Fourth Generation Agents: Medical Management Guidelines*.

are available as antidotes to nerve agent poisoning.[37–42] The G-series agents tend to be non-persistent to moderately persistent, while VX and FGAs are considered highly persistent.

Blood agents interfere with oxygen use at the cellular level. They represent inhalation, ingestion, and dermal hazards, entering the bloodstream and other body tissues where they exert one of two effects. Some, such as hydrogen cyanide (AC), cyanogen chloride (CK), and other cyanide-containing compounds, act as cellular poisons and disrupt the oxidative metabolism of cells, while others, e.g., sodium fluoroacetate and arsine, induce hemolysis of red blood cells. Symptoms of blood agent exposure (e.g., to CK) include giddiness, headache, faintness, confusion, palpitation, chest pain, difficulty breathing, convulsions, loss of consciousness, and cardiac arrest. Lacrimatory (tearing of the eyes) effects are also shown with CK. Agent-specific antidote therapies are available to treat exposure to some blood agents; however, most require treatment soon after exposure.[43] Blood agents tend to be less persistent than other chemical agents.

Blister agents (or vesicants) generate reddening and blistering of any exposed part of the body. Some of these agents may also damage respiratory and gastrointestinal (GI) mucous membranes. Examples of blister agents include sulfur mustard (HD), nitrogen mustard (HN), Lewisite (L), and phosgene oxime (CX). Often, the physical effects from exposure to a blister agent may not be obvious for hours. However, exposure to Lewisite will yield almost immediate pain. As with nerve agents, a cumulative effect occurs with blister agent exposures. Blister agents are persistent. Decontamination of the exposed area as soon as possible is critical to prevent tissue damage. Effective treatment regimen includes reducing exposure and providing supportive care. Silverlon wound dressings (impregnated with silver) are FDA-cleared to

[37] U.S. Army Medical Research Institute of Chemical Defense (2007). Medical Management of Chemical Casualties handbook. 4th ed. Aberdeen Proving Ground, MD: Medical Research Institute of Defense.

[38]Environment Canada (2005). Report EE-176, Review of Decontamination and Restoration Technologies for Chemical, Biological, and Radiological/Nuclear Counter-terrorism, CRTI-IRTC.

[39]U.S. Army, Marine Corps, Navy, & Air Force (2016). Multi-Service Tactics, Techniques, and Procedures for Treatment of Chemical Warfare Agent Casualties and Conventional Military Chemical Injuries. ATP 4-02.85/MCRP 3-40A.1/NTRP 4-02.22/AFTTP(I) 3-2.69.

[40]U.S. Food and Drug Administration, Center for Drug Evaluation and Research (2002). Approved Labeling for Antidote Treatment-Nerve Agent, Auto-injector.

[41]U.S. HHS (2001). Managing Hazardous Material Incidents (MHMI). Volume III. Public Health Service, Agency for Toxic Substances and Disease Registry.

[42]Nerve agent medical countermeasures are continuously developed as part of the Chemical and Biological Defense Program. Advances are coordinated through the *Public Health Emergency Medical Countermeasures Enterprise* (PHEMCE) and other teams that include Defense and domestic organizations.

[43]For treatment information visit Blood Agents on the Chemical Categories landing page at: https://emergency.cdc.gov/agent/agentlistchem-category.asp and https://chemm.hhs.gov/bloodagents.htm.

treat skin injury caused by sulfur mustard. Lewisite exposure can be treated using dimercaprol (British Anti-Lewisite), a chelating agent.

Central Nervous System CNS-acting acting chemicals such as analgesics, anesthetics, and sedatives target the central nervous system and cause respiratory depression and other CNS depressive effects. Fentanyl and fentanyl analogs are well-known CNS-acting chemicals that are opioid receptor agonists. Fentanyl is highly potent; the amount of fentanyl in a lethal dose is similar to that for traditional nerve agents. [44, 45] Naloxone is an opioid receptor antagonist that counters all opioid receptor agonists.

3.3. Toxic Industrial Chemical

Toxic industrial chemicals (TICs) are hazardous chemicals that are used in many diverse sectors of industry and agriculture. The availability of TICs potentially allows for a greater likelihood of accidental or deliberate release of these agents compared to CWAs. Tables 4 and 5 are lists of representative, acutely toxic chemicals that are of particularly high concern due to toxicity and/or availability. These lists are not intended to be exhaustive. More information about chemical threats linked to specific industries is available from the DHS Chemical Facility Anti-Terrorism Standards program and from local industrial partners.[46]

Table 4: Examples of Acutely Toxic Industrial Chemicals – Ingestion Hazards*

Class	Representative chemicals	Chemical Abstract Service Number
Organophosphates	Methamidophos	10265-92-6
	Monocrotophos	6923-22-4
	Phosphamidon	13171-21-6
Cyanides	Potassium cyanide	151-50-8
	Sodium cyanide	143-33-9
Mercury compounds	Mercuric chloride	7487-94-7
Arsenic compounds	Sodium arsenite	7784-46-5
	Acrolein	107-02-8

[44]Organisation for the Prohibition of Chemical Weapons (OPCW). (2018) Aerosolization of Central Nervous System-Acting Chemicals for Law Enforcement Purposes. Review Conference. Fourth Session.

[45]OPCW. (2019). Central Nervous System (CNS)-Acting Chemicals.

[46]Chemical Facility Anti-Terrorism Standards, 6 C.F.R. § 27. (2007, April).

Class	Representative chemicals	Chemical Abstract Service Number
Miscellaneous organics (also acute contact hazards)	Acrylonitrile	107-13-1
	Chlorohydrin (3-chloro-1,2-propanediol)	96-24-2
	Nicotine	54-11-5
	Phenol	108-95-2

*The list is not in priority order nor is it exhaustive of all ingestion hazards

Table 5: Examples of Acutely Toxic Industrial Chemicals – Inhalation Hazards*

Chemical	Chemical Abstract Service Number
Acrolein	107-02-8
Acrylonitrile	107-13-1
Allyl alcohol	107-18-6
Ammonia	7664-41-7
Arsine	7784-42-1
Boron trifluoride	7637-07-02
Bromomethane (methyl bromide)	74-83-9
Bromine	7726-95-6
Carbon monoxide	630-08-0
Chlorine	7782-50-5
Cyanogen chloride (CK)	506-77-4
Diborane	19287-45-7
Dimethylamine	124-40-3
Ethylene oxide	75-21-8
Fluorine	7782-41-4
Formaldehyde	50-00-0
Hydrazine	302-01-2
Hydrogen chloride (hydrochloric acid)	7647-01-0
Hydrogen cyanide (AC)	74-90-8

Chemical	Chemical Abstract Service Number
Hydrogen fluoride (HF)	7664-39-3
Hydrogen selenide	7783-07-5
Hydrogen sulfide	7783-06-4
Methylamine	74-89-5
Methyl mercaptan	74-93-1
Methyl isocyanate	624-83-9
Methyl hydrazine	60-34-4
Nitric acid	7697-37-2
Nitrogen dioxide	10102-44-0
Parathion	56-38-2
Phosphine	7803-51-2
Phosgene (CG)	75-44-5
Phosphorus trichloride	7719-12-2
Phosphoryl trichloride (phosphorus oxychloride)	10025-87-3
Propylene oxide	75-56-9
Sulfuric acid	7664-93-9
Sulfur dioxide	7446-09-5
Sulfur trioxide	7446-11-9

*The list is not in priority order nor is it exhaustive of all inhalation hazards.

3.4. Toxic Syndromes

For clinicians, a more practical way of categorizing hazardous chemicals is by toxic syndrome or toxidrome.[47] Each toxidrome describes the characteristic toxic effects elicited by the chemicals within a group, serving as a set of clinical "fingerprints." Illnesses from exposure to any of the chemicals associated with a given toxidrome are treated similarly. Common toxidromes with example chemicals that cause them are defined in Table 6. It should be noted that a chemical incident likely could involve a

[47]More information on Toxic Syndrome may be found at https://chemm.hhs.gov/toxicsyndromes.htm

mixture of chemicals which can complicate the identification of the substances causing the health effects and/or environmental contamination.

Table 6: Common Toxic Syndromes or Toxidromes

Common Toxic Syndromes or Toxidromes
Acute exposure to solvents, anesthetics, or sedatives (SAS)
Central nervous system depression leading to a decreased level of consciousness (progressing to coma in some cases), depressed respirations, and in some cases ataxia (difficulty balancing and walking)
Examples: gasoline, benzene, toluene, xylene, carbon tetrachloride, methylene chloride, freon, nitrous oxide, benzodiazepines, barbiturates
Anticholinergic
Under-stimulation of cholinergic receptors leading to dilated pupils (mydriasis), decreased sweating, elevated temperature, and mental status changes, including characteristic hallucinations
Examples: BZ (3-quinuclidinyl benzilate), atropine, hyoscyamine, scopolamine
Anticoagulants
Alteration of blood coagulation that results in abnormal bleeding indicated by excessive bruising, and bleeding from mucous membranes, the stomach, intestines, urinary bladder, and wounds, as well as other internal (e.g., intracranial, retroperitoneal) bleeding
Examples: coumadin, brodifacoum, bromodialone, diphacinone
Cholinergic
Overstimulation of cholinergic receptors leading to hyperactivity of target tissues, including hypersecretion ("leaking all over," with tearing, increased nasal secretions, increased salivation, copious bronchial secretions, and sweating) from exocrine glands and miosis (pinpoint pupils), bronchospasm (wheezing), and hyperperistalsis (leading to nausea, vomiting, cramping, and diarrhea) from smooth muscle in the eye, the respiratory tract, and the gastrointestinal tract, respectively. Activation and subsequent fatigue of skeletal muscle produce initial twitching, progressing to weakness and usually flaccid paralysis, and activation and subsequent fatigue of neurons in the brain, which are responsible for initial agitation, tremors, choreoathetoid (dancing and writhing) movement, seizures and convulsions, progressing to paralysis of the respiratory center in the medulla and cessation of breathing.
Examples: tabun, sarin, soman, VX, aldicarb, methomyl, chlorpyrifos, parathion, Novichok agents
Convulsant
Central nervous system excitation (GABA antagonism and/or glutamate agonism and/or glycine antagonism) leading to generalized convulsions
Examples: hydrazines, tetramethylenedisulfotetramine, picrotoxin, strychnine

Common Toxic Syndromes or Toxidromes
Irritant/Corrosive
Immediate effects range from minor irritation of exposed skin, mucous membranes, pulmonary, and GI tract to coughing, wheezing, respiratory distress and more severe GI symptoms that may progress rapidly to systemic toxicity
Examples: ammonia, chlorine, phosgene, riot control agents, mustard agents, Lewisite, hydrofluoric acid, methylene chloride
Knockdown
Disrupted cellular oxygen delivery to tissues may be caused by simple asphyxia due to oxygen displacement by inert gases, hemoglobinopathies (e.g., carbon monoxide, methemoglobin inducers), impairment of oxygen transport by the red blood cell, and/or impairment of the cell's ability to use oxygen (e.g., mitochondrial inhibitors such as cyanide). All these situations lead to altered states of consciousness, progressing from fatigue and lightheadedness to seizures and/or coma, with cardiac signs and symptoms, including the possibility of cardiac arrest.
Examples: cyanides, hydrogen sulfide, azides, rotenone, sodium monofluoroacetate, carbon monoxide, aniline, arsine, nitrogen
Opioid
Opioid agonism leading to pinpoint pupils (miosis) and central nervous system and respiratory depression
Examples: fentanyl and fentanyl derivates, diacetylmorphine
Stress Response/Sympathomimetic
Stress- or toxicant-induced catecholamine excess or central nervous system excitation leading to confusion, panic, and increased pulse, respiration, and blood pressure
Examples: mephedrone, amphetamines

3.5. Chemical Characteristics Affecting Incident Decision-Making

Decision-makers should have a clear understanding of the initiation and development of a chemical contamination incident for effective remediation of hazardous chemical contamination. They will need to take into account the characteristics of the hazardous chemicals released, the nature of the prevailing environmental conditions under which the incident is occurring, and the characteristics of the materials impacted by the hazardous chemical release.

All hazardous chemical incidents begin with the *release* of a hazardous chemical. The release occurs from a *source* into an environment, system or building resulting in environmental contamination and the potential for human exposure to the hazardous chemical. In turn, exposed persons may experience one or more adverse (or undesirable) effects. In hazardous chemical incidents, primary concerns are: (1) significant injury or death, and (2) loss of the use of property or infrastructure. The objective of

remediation is to: (1) mitigate casualties or severe injury, (2) address environmental concerns, (3) achieve decontamination of environmental materials and surfaces (e.g., soil, ground water, surface water, and drinking water) and infrastructure such as subways, buildings, stadiums, and offices, and, if possible, (4) return private and public property to their pre-incident uses. Remediation accomplishes this by reducing the amount of the hazardous chemical (and any toxic chemical degradation byproducts) in the environment to an acceptable level and, thereby, reducing contact between the hazardous chemical and the population.

In order to more accurately estimate the contamination spread from a nationally significant or large-scale release of hazardous chemicals, the physical and chemical properties of the chemicals released, the atmospheric and environmental conditions, the composition and nature of the impacted media, and the presence of other chemicals must be evaluated. This information can support emergency response activities; determine sampling locations; direct evacuation, shelter-in-place or restricted-use actions, and; provide data for air dispersion plume or water modeling efforts. Additionally, knowledge of the nature and composition of impacted indoor materials and surfaces can determine the most appropriate decontamination and/or waste management approaches to use. It is also important to consider that a covert release of a hazardous chemical may result in the spread of the chemical due to unintentional cross-contamination and/or fomite transport.

Physical and Chemical Properties. Key physical and chemical properties of hazardous chemicals will determine the dispersion and path(s) that the hazardous chemicals could take from the release source to the impacted site or a population. These paths will determine the potential exposure routes of concern for affected populations. Table 7 provides a partial list of key physical and chemical properties that are important to consider.

The persistence of a hazardous chemical should also be considered. Chemical persistence is determined by the rate at which a chemical volatilizes, breaks down, or dissipates. Persistent chemicals may continue to pose a hazard for days, weeks, or longer after a release by remaining as a contact hazard, or by slowly volatilizing and becoming an inhalation or ocular hazard. Persistent chemicals in solid, liquid, or droplet form may remain for even longer periods depending on environmental conditions such as temperature, moisture, and the types of materials contaminated. For example, HD, VX, and FGAs may persist for days, weeks, or longer.

Table 7: Key Physical and Chemical Properties

Properties	Comments
Vapor Pressure	The pressure exerted by a vapor when it is in equilibrium with its liquid or solid form; chemicals with high vapor pressure tend to be non-persistent.
Boiling Point	The temperature at which a liquid boils and turns to vapor.
Freezing/Melting Point	The temperature at which a liquid turns into a solid when cooled, or a solid will melt when heated. Some solids can sublime directly from the solid to the vapor phase.

Properties	Comments
Flash Point	The lowest temperature at which a liquid gives off vapor within a test vessel in sufficient concentration to form an ignitable mixture with the air near the surface of the liquid. The lower the flash point, the easier it is to ignite a liquid solvent.
Vapor Density	Density of the vapor compared to air (air = 1) is the tendency for a vapor to rise or sink in the air column. The vapor density is affected by barometric pressure.
Specific Gravity	Density of liquid compared to water (water = 1) is the tendency for a liquid to rise or sink in the water column.
Log K_{ow}	The octanol-water partition coefficient determines the extent to which a liquid will partition into either the aqueous (water) or organic phases.
Solubility in Water	A measure of the amount of chemical substance (liquid or solid) that can dissolve in water at a specific temperature.

The environmental component of this parameter, however, considers the form and amount of the chemical along with the environmental conditions. That is, the actual amount of time that a chemical remains on surfaces or within environmental materials and surfaces after a single release will depend on the characteristics of the hazardous chemical as well as the amount released, environmental conditions, and the nature of the contaminated materials and surfaces. For example, soils from specific locations will have differing properties. These differences must be considered during cleanup and may significantly affect technical aspects related to cleanup (e.g., if analytical data consistently fails quality control, soil matrix may need to be considered as a cause for such failures) and sampling and analysis plans may need to be modified accordingly.

Certain agents such as VX and L break down in the environment to other substances that pose potentially significant environmental or human health concerns as well. Separate sampling and cleanup for these constituents may be necessary. Other agents such as FGAs are more soluble and stable in water, maintaining their toxicity when dissolved. In addition, other hazardous constituents (e.g., dusts containing lead, dioxins, polychlorinated biphenyls, asbestos), though typically not acutely toxic, may be produced as collateral hazards if explosions or fires are involved. Time and weathering may be less effective in degrading persistent hazards, especially if large quantities are deposited. In such cases, more thorough sampling and decontamination may be necessary in order to allow resumed use/re-occupancy. The potential for cross contamination and longer durations of exposure are important considerations in cleaning up persistent chemicals. Collateral hazards may also include chemical impurities present as a result of manufacturing, laboratory synthesis processes, byproducts of long-term chemical storage, chemicals added to enhance physical or chemical properties or by-products of the decontamination process itself.

Atmospheric and Environmental Parameters. These parameters help to determine the spread of the hazardous chemicals in the environment. Reactions or interactions with the hazardous chemicals and the environment can increase or decrease overall toxicity or fate in the environment. Decision-makers should

have available to them appropriate modeling programs that can be used to predict the migration, extent, and fate of the hazardous chemical in the environment. These models incorporate the key physical and chemical properties of the hazardous chemicals with the site-specific environmental conditions and the nature of the impacted materials and surfaces itself to construct a representation to predict future spatial movement, direction, and concentrations of the hazardous chemicals. Atmospheric models incorporate environmental and topographic conditions and the prevailing meteorological data to construct a three-dimensional representation of the impacted outdoor areas. Many agencies have successfully used models to predict the movement of hazardous chemicals in environmental media. Modeling can be useful to direct cleanup activities and sampling efforts at all stages of an incident, as well as to advise decision-makers on possible evacuation, shelter-in-place, or restricted use actions. DHS has established the Interagency Modeling and Atmospheric Assessment Center (IMAAC) as the national resource for atmospheric modeling during national significant incidents. The National Oceanic and Atmospheric Administration and EPA have developed the Computer-Aided Management of Emergency Operations (CAMEO) modeling program—another atmospheric modeling program that is easy to use, incorporates simple assumptions and data inputs to calculate theoretical plume "footprints," and is used by many fire departments and first responders across the U.S. Similarly, surface water, ground water, and vadose zone (soil above the permanent ground water level) modeling programs can be used to construct models of impacted water, aquifer, and soil column matrices. The EPA and the United States Geological Survey (USGS) have numerous modeling programs to predict the movement of hazardous chemicals through surface waters, ground water aquifers, and the vadose zone of the soil column.[48] Consideration must also be given to environmental conditions that may have adverse effects on various sampling technologies and techniques. Tables 8 and 9 list some of the important atmospheric and environmental parameters to consider.

Characteristics of Impacted Materials and Surfaces. Decision-makers should be familiar with the key characteristics of the impacted materials and surfaces, both outdoors and indoors. A list of some examples of these characteristics can be found in Table 9. Decision-makers can use that information to determine the interaction of the hazardous chemicals with the impacted materials and surfaces, as well as predict potential sinks or reservoirs of materials that can influence the persistence of these chemicals in the environment or incident site. Indoor modeling programs can use floor diagrams; air exchange rates; HVAC system specifications; and building design criteria to construct a three-dimensional representation of the impacted infrastructure. The National Institute of Standards and Technology (NIST) has developed the CONTAM program, which is an indoor modeling program used to predict the migration of a vapor plume inside a building.[49]

Presence of Other Hazardous Chemicals. Other hazardous chemicals at the incident site, especially industrial sites, may react with and change the characteristics of the released hazardous chemical. These interactions can be either antagonistic or synergistic, reducing or increasing their impact at the site. The

[48]Examples of modeling programs can be found at the USGS modeling website https://toxics.usgs.gov/topics/applications.html.

[49] See CONTAM | NIST

decontamination materials may cause degradation to other hazardous chemical species. Understanding of these processes and the resultant hazardous chemical byproducts will assist risk managers in the complete and appropriate evaluation and management of the hazardous chemicals that may be present at different phases of the response.

Table 8: Key Atmospheric and Environmental Parameters

Parameter	Comments
Temperature	Higher temperatures will increase the rate of evaporation of the hazardous chemical as well as increase any chemical and physical reactions or interactions with the environment or impacted materials and surfaces.
Wind speed/variability and direction	Higher wind speeds will increase the rates of evaporation of the hazardous chemicals. Speed, variability, and direction can be used to model/predict the movement of the vapor plume to assist in possible evacuation or shelter-in-place actions. Plume modeling can also direct ambient air monitoring and sampling efforts.
Relative humidity/precipitation	Presence of atmospheric moisture and/or precipitation will influence the characteristics of the vapor plume. Water can react with some hazardous chemicals (hydrolysis), either increasing or decreasing their toxicity. Products of hydrolysis themselves may be toxic. Precipitation may physically wash away from/or dilute hazardous chemical on the impacted materials and surfaces or drive soluble chemicals deeper into porous materials.
Barometric pressure	High- and low-barometric pressure conditions can influence the characteristics of the vapor plume. Higher barometric pressures can also decrease the rates of volatility of hazardous chemicals.
Solar radiation/cloud cover	Higher solar radiation (lower cloud cover) will increase the chemical reactions (ultraviolet photolysis) of hazardous chemicals, either increasing or decreasing their toxicity. Products of photolysis themselves may be toxic. Higher solar radiation will also increase the rates of volatilization of the hazardous chemicals.
Stability category (boundary layer)	Determines the atmospheric “mixing” of vapors within the air column. Unstable categories will result in more mixing of the hazardous chemical plume. This can act to disperse and therefore dilute the vapors. Stable categories will result in less mixing in the atmosphere and can predict a temperature inversion where the hazardous chemical vapor plume could be held stagnant over the incident site.

Table 9: Key Characteristics of Impacted Outdoor/Indoor Materials and Surfaces

Outdoor/Indoor Materials and Surfaces	
Outdoor Materials and Surfaces	
Characteristic	**Comments**
Vegetation/soil cover/roughness	Can influence the hazardous chemical atmospheric plume by hindering movement, increasing mixing and reacting with vegetation surfaces.
Soil type/grain size/organic content	Physical and chemical characteristics of soils determine reactivity with hazardous chemicals, and control natural attenuation/biodegradation that may occur in soil media.
Topography	Features such as lakes, streams, hills, and valleys that can determine where the plume will move (i.e., a hazardous chemical with vapor density > 1 will sink and concentrate in valleys or low-lying areas in buildings).
Porous/nonporous materials	Porous surfaces and materials may adsorb more hazardous chemicals than nonporous surfaces and materials. This acts to retain the hazardous chemicals on porous surfaces and materials longer, adding to the persistence of the hazardous chemicals on the impacted media.
Organic/polymeric content	Materials with higher organic content, such as those with natural or synthetic polymers, may absorb more hazardous chemicals than those with lower organic/polymeric content. Absorption may be irreversible, complicating cleanup and decontamination efforts.
Anthropomorphic features	Man-made structures such as buildings, highways, bridges, and other infrastructure can obstruct movement of atmospheric plume and increase mixing.
Indoor Materials and Surfaces	
Characteristic	Comments
Porous/nonporous materials	Porous surfaces and materials may adsorb more hazardous chemicals than nonporous surfaces and materials. This acts to retain the hazardous chemicals on porous surfaces and materials longer, adding to the persistence of the hazardous chemicals on the impacted media.
Organic/polymeric content	Materials with higher organic content, such as those with natural or synthetic polymers, may absorb more hazardous chemicals than those with lower organic/polymeric content. Absorption may be irreversible, complicating cleanup and decontamination efforts.
Status of HVAC system (on/off/materials)	Depending on whether the HVAC system was on or off during the incident and what materials ductwork is constructed from, HVAC can be a conduit for the spread of the hazardous chemical through vapor deposition. HVAC can also be a sink for chemicals.

Outdoor/Indoor Materials and Surfaces	
Critical infrastructure	Structures or facilities that must be given priority during the cleanup and recovery phase due to their economic value, security, or other necessity.
Sensitive items/ electronics	Equipment or assets of a more sensitive nature, such as electronic, communication, or medical equipment, that may require less aggressive, less harsh decontamination methods and procedures.
Hot spots/surfaces	Areas or surfaces or high concentrations of contamination. May require more aggressive, harsher decontamination methods and procedures.
Large volumetric spaces	Large interior spaces such as auditoriums or transportation hubs that may require specific decontamination methods and procedures (e.g., fumigation, sprayers, or foggers).

3.6. Considerations for Defining the Extent of Contamination

A range of environmental chemical contaminant concentrations may exist throughout impacted areas that represent a conceptual range of risk management decisions and responses. At one end are levels of high contamination that clearly warrant a response action; at the other end are levels that are below health concerns. For some chemicals, chemical contaminant screening levels, such as the EPA Regional Screening Levels (RSLs), can identify the lower bound of the contaminant concentration spectrum — levels below which there is little or no concern for adverse health effects for the variety of exposure pathways that may impact potential site occupants (Figure 4). Appropriate remediation/cleanup goals for a particular site likely fall within this range depending on site-specific conditions.

These chemical-specific and site-specific screening levels can be used to help define the areas requiring further investigation and potential remediation; they can also help to evaluate the capabilities of field and laboratory-based analytical equipment and techniques that may be used to guide the decontamination efforts. Screening levels may be derived using risk-based methods; they may be based on natural or anthropogenic background levels of chemical constituents, or they may be based on other site-specific considerations.

Methods for deriving site-specific environmental exposure guidelines have been developed by EPA and others that can be applied to a variety of environmental contamination scenarios. Exposure guidelines that have a variety of applications during the response are discussed in Section 4 and Appendix A.

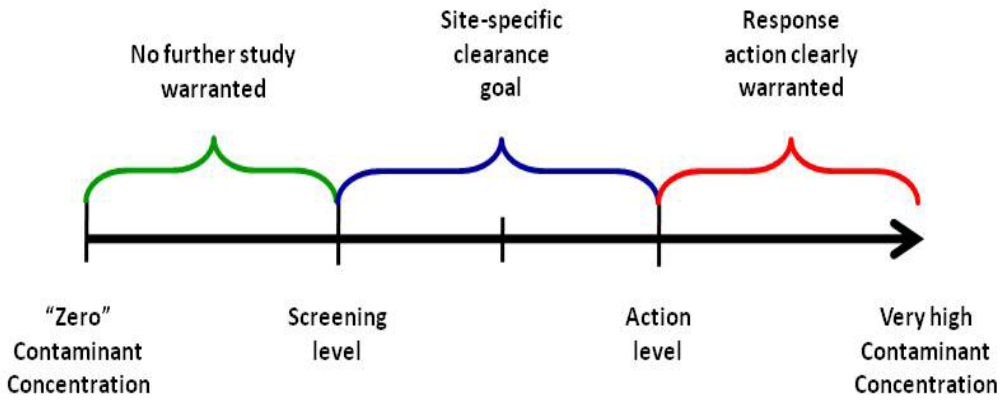

Figure 4: Adapted from USEPA, 1996, Soil Screening Guidance: User's Guide.

4. Principles of Risk Assessment for Hazardous Chemical

4.1. Overview

This section describes the risk assessment process and its relationship to risk management in the context of a hazardous chemical incident. The information provided in this section can be used to support various aspects of the planning and decision-making process described in Section 2 above. In general, risk assessment methods are used to evaluate the probability and consequence of exposure in a given chemical incident, for example: chemicals detected in the environment in terms of their inherent toxicity; how people may come into contact with the chemicals; the total dose to those exposed, and; who may be exposed now and in the future (e.g., response workers, children, the elderly, populations experiencing high and adverse human effects of environmental events, practices or programs). The results of the analysis are used by risk managers to determine if chemical contamination is at a magnitude requiring remediation/cleanup (human health risk above targets) and the appropriate scope of the response action.

In the context of a hazardous chemical release, different risk assessment methods may be used to support consequence management planning and decision making. As data on the nature and extent of contamination become available, safety and health experts will use certain risk assessment tools to evaluate the immediate threats to exposed populations and provide guidance for first responders on the type of PPE that may be necessary and other protective measures detailed in the HASP. In later phases of the response, other risk assessment tools will be used to evaluate the protectiveness of pre-calculated, health-based exposure guidelines, evaluate potential risks associated with residual contamination, and to derive protective clearance goals.

Overall, the effective remediation of hazardous chemicals following a hazardous chemical release depends on accurate information being factored into the risk assessment, such as the nature and extent of contamination; the inherent toxicity of the chemicals; how people come into contact with the chemicals; the exposure duration and frequency; the total dose; and who may be exposed now and in the future. However, adequate information is not always available, especially in the early stages of a response. A further complication can be the existence of classified toxicity information that cannot be shared freely, especially in the early stages of the response. As the amount and quality of the data used to develop risk-based estimates increases, uncertainty in decision-making decreases.

4.2. Risk Assessment Overview

Risk assessment, as defined by the National Academy of Sciences (NAS), is a systematic approach to organizing and analyzing scientific knowledge and information for potentially hazardous activities or for

substances that might pose risks under specified conditions.[50, 51] NAS describes the risk assessment paradigm as a process consisting of four major components: hazard identification, dose-response assessment, exposure assessment, and risk characterization. These components are described in more detail below. While the original NAS definition and paradigm reflect the risk assessment framework used today, risk assessment methodology has evolved to include new methods to reduce uncertainties and increase confidence in quantitative analyses.

It is important to recognize that risk assessment is not a single, fixed method of analysis. Risk assessment is an iterative process that involves identifying and filling data gaps in order to develop a more refined assessment of the risk. [52]

The National Research Council proposed a three-phase system to ensure risk assessments are comprehensive and connected to the problems/decisions identified to render the best set of risk management options: Phase I: Enhanced Problem Formulation and Scoping; Phase II: Planning and Assessment; and Phase III: Risk Management. Phase I identifies risk management options, Phase II risks are determined using risk-assessment tools, and Phase III information gathered is used to inform risk management decisions.[53]

Risk Assessment (Phase II), informs the Risk Management Process (Phase III), which integrates public health, political, social, economic, engineering, and other considerations into response decisions. The relationship between risk assessment and risk management is illustrated in the diagram below, first developed by the National Research Council (NRC) in 1994[54] (see Figure 5).

[50]National Research Council (NRC). (1983). Risk Assessment in the Federal Government: Managing the Process. National Academy Press. Washington, DC.

[51]National Council on Radiation Protection and Measurements. (1994). Advising the Public about Radiation Emergencies - a document for public comment: (Commentary no. 10).

[52]U.S. EPA (n.d.). About Risk Assessment. https://www.epa.gov/risk/about-risk-assessment

[53]National Research Council. (2009). Science and Decisions: Advancing Risk Assessment. National Academies Press. Washington, D.C.

[54]National Research Council. (1994). Science and Judgment in Risk Assessment. National Academy Press. Washington, D.C.

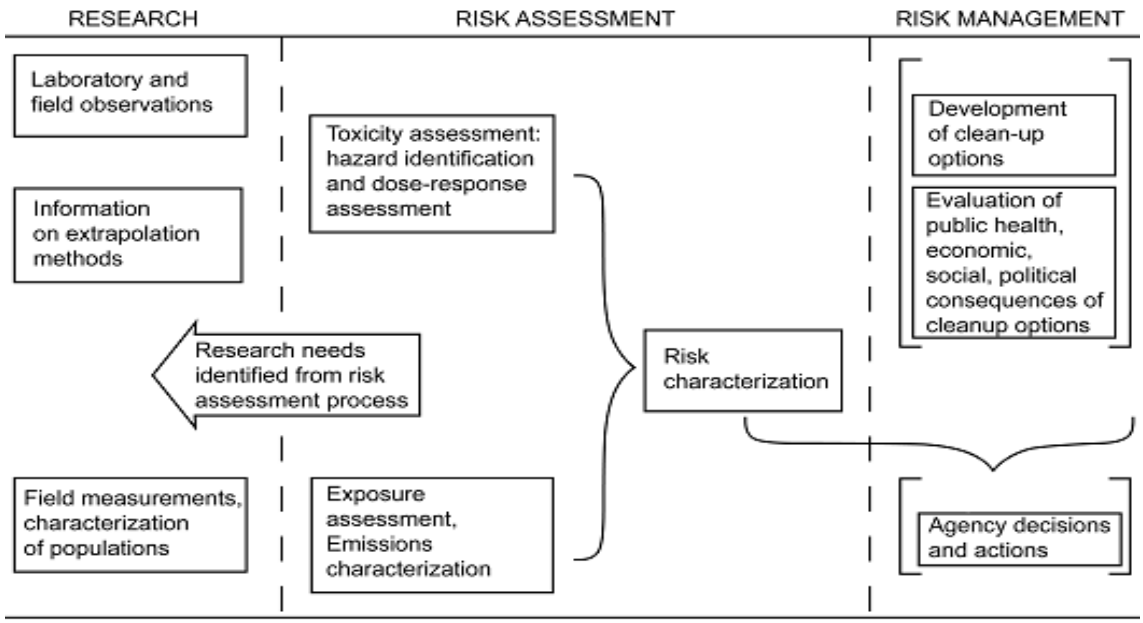

Figure 5: NAS Risk Assessment/Risk Management Paradigm with slight modifications to reflect applicability to this decision-making framework. The key elements of this process are described in greater detail in Section 5. Source: Adapted from NRC (1994).

Prior to conducting a risk assessment, environmental data must be collected and analyzed. This requires planning and scoping to determine sampling and analytical needs. However, since characterization of an impacted area is an iterative process, these needs may be revisited as more information is obtained. The DHS Chemical and Security Analysis Center (CSAC) has the capacity to run risk and consequence modeling available to assist U.S. planning and response organizations.

The four components of risk assessment are described below, with hazard identification and dose-response assessment combined under the heading of toxicity assessment.

4.2.1. TOXICITY ASSESSMENT

Toxicity assessment integrates information from the hazard identification and dose-response assessment components of risk assessment.

4.2.1.1 Hazard Identification

Hazard identification is the process of determining whether an adverse health effect is likely to occur in humans and whether exposure to a particular chemical can cause an increase in the incidence

of an adverse health effect in the near or long term (e.g., kidney failure, birth defects, cancer). Hazard identification involves characterizing the nature and strength of the evidence of causation.[55]

4.2.1.2 Dose-Response Assessment

The purpose of the dose-response assessment is to determine the relationship between the magnitude of exposure (may be expressed as an environmental concentration or internal dose) to a substance and the resultant changes in body functions (response) or health. From this quantitative dose-response relationship, toxicity values are derived that can be used to estimate the incidence of adverse effects occurring in humans at different exposure levels. Chemical risk assessments have conducted for some chemicals and the resulting toxicity values are available in published documents. Dose-response data are often used to derive these values. Chemicals may elicit different effects depending on the exposure route (oral, dermal, or inhalation), duration, and exposure concentration. Therefore, an appropriate evaluation of the dose-response relationship should consider the duration and exposure concentration for all relevant routes of exposure, when such data are available.

In the risk assessment, the dose to an exposed individual or group is compared to available toxicity values to estimate the potential for adverse health effects. Personal sampling for chemical exposures is the preferred method to estimate exposures; however, because it is not always possible to measure the actual dose on individual, concentrations in the environment are often used as a proxy for human exposure.

Just as exposure concentration is directly related to the dose an individual receives, the dose is directly related to the severity of injury. Besides severe injury and death, more subtle toxic effects are also considered adverse. Examples of these more subtle toxic effects include potential short-term effects such as impaired mobility or altered rates of basic physiological processes (e.g., respiration, heart rate), and potential longer-term effects such as decreased general or reproductive health, or the potential to develop cancer later in life.

Another important concept related to dose is the *exposure rate*. With some hazardous chemicals, the degree of damage is not simply dependent on the total dose received, but also on the rate at which the dose is received and the duration of exposure. This is especially true for chemicals that are metabolized relatively quickly into nontoxic metabolites. The type of adverse health effect associated with a hazardous chemical, the exposure rate, the duration of exposure, and the specific areas of the body exposed combine to determine the type and severity of injury.

4.2.2. EXPOSURE ASSESSMENT

The objective of the exposure assessment is to estimate the magnitude of actual or potential human exposures, the frequency and duration of these exposures, and the pathways by which humans may be exposed. Conducting an exposure assessment involves: 1) analyzing contaminant releases; 2) identifying

[55] See https://www.epa.gov/risk/conducting-human-health-risk-assessment#tab-2

exposed populations; 3) identifying all potential pathways of exposure; 4) estimating environmental concentrations for specific pathways; and 5) estimating contaminant intakes (i.e., doses) for each pathway. An exposure pathway is the course that a chemical takes from a source to an individual. Each exposure pathway includes a source or release from a source, an environmental concentration at the point of exposure, and an exposure route. If the point of exposure is some distance from the source, a transport medium (e.g., air) is also included. The exposure route is the way the individual encounters the chemical (i.e., through inhalation, ingestion and/or dermal contact). The route is important because the toxic effects of certain chemicals vary with different routes of exposure. For example, hydrofluoric acid can cause skin burns with dermal exposures and lung damage with inhalation exposure.

Physical and chemical properties influence the likelihood of human exposure. For example, volatile chemicals or gases that are readily dispersed can quickly affect relatively large areas and have the potential to impact a greater number of people. If a nonvolatile hazardous chemical is easily dispersible or readily forms an aerosol, it poses a risk of inhalation exposure in addition to the potential for direct contact exposure. Thus, managers need to be aware that measures taken to reduce inhalation exposures may not fully address the risks of exposure via other routes such as dermal contact or ingestion.

The distribution or pattern of hazardous chemical contamination in the impacted area is a crucial variable for exposure assessment. A sampling plan is executed to define the distribution of hazardous chemicals. If the distribution is understood, then the information can be used in risk management decision-making. Even though the distribution of a hazardous chemical is necessary information to understand the potential for exposure, such information does not constitute exposure assessment by itself; it is also necessary to identify the potentially exposed populations and characterize the frequency and duration of their exposures.

The mass of the chemical in the environment and the identification of the materials and surfaces that are contaminated will assist in estimating the magnitude of the problem and the potential routes of exposure. Unfortunately, it is possible that not all hazardous chemicals will be detectable in environmental samples. For example, some chemicals may degrade in the sample container so quickly that they are no longer present in a sample by the time the analysis is performed. Alternately, their presence might be masked by other environmental contaminants, or the methods for detection might not be sensitive enough to accurately quantify the chemical. The inability to detect a particular chemical that is known to have been released should not be interpreted as the absence of the chemical. Other sources of information, including epidemiologic and forensic evidence, should be evaluated in the context of what is known about the toxicant and specific nature of the incident in question to form a hypothesis of the distribution and intensity of contamination. Such information can then be used to inform the exposure assessment.

4.2.3. RISK CHARACTERIZATION

Risk characterization combines the information about toxicity and exposures to estimate the risk for developing adverse health effects. Risk characterization also serves as the bridge between risk assessment and risk management. Major assumptions, scientific judgments, and to the extent possible, the uncertainties associated with the risk assessment and the degree to which risks may be under- or

over-estimated are discussed and communicated to the decision-makers and the public.[56] All information that will help inform the risk management decisions (including uncertainties and ranges for exposure and/or effect data) should be communicated clearly.

Risk assessments can be initiated at different phases of the response and can be tailored to quantify and evaluate risk to different groups for different purposes. Risk assessments for workers will incorporate regulatory occupational standards enforced by OSHA and worker focused guidelines for protective measures that are different than the standards and guidelines for protective measures used in the general population risk assessment. 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 that have been developed by a variety of federal and state agencies: pre-calculated, health-based exposure guidelines (e.g., Acute Exposure Guideline Levels or AEGLs for short-term exposures; Regional Screening Levels for longer-term exposures; or Occupational Exposure Limits [OELs] and Immediately Dangerous to Life and Health [IDLH] values for occupational exposures). These health-based exposure guidelines are derived using equations that combine a toxicity value, a level of risk, and a set of exposure assumptions for a particular chemical, medium, and exposure scenario. Thus, the resulting health-based exposure guideline will be specific to a particular population and exposure scenario (Figure 6). For example, there are health-based exposure guidelines developed for workers that assume exposures lasting only 15 minutes and other exposure guidelines for exposures lasting 8 or 10 hours per day, 40 hours per week for a working lifetime. Likewise, there are exposure guidelines that are based on long-term/lifetime exposures to the general population that are meant to be protective of sensitive members of the population, such as children and the elderly. It should be recognized that all these approaches incorporate some degree of uncertainty in the estimated value. See Appendix A for more information.

In addition to the variables associated with the populations of concern, the exposure concentrations and the environmental persistence of the chemical contaminant may affect the magnitude of health risk associated with the exposure. One of the critical questions to be asked in performing a risk assessment associated with chemical remediation/cleanup is: “Will the hazardous chemical persist in the environment and pose a potential long-term health hazard?” The answer to this question will determine the duration of the potential exposure and the complexity and scope of the overall remediation operation. Therefore, integrating accurate information regarding persistence, total dose, toxicity, and exposure is critical to the formulation of a scientifically sound risk characterization and resultant remediation plan.

Although it may be preferred that technical staff supporting the IC develop scenario-specific remediation goals that include site- and situation-specific descriptors of exposure, in the absence of resources and site-specific information, pre-calculated, health-based exposure guidelines can provide a useful tool for risk assessors and decision-makers. However, it is important to clearly understand the basis for each

[56] In addition to the Risk Characterization material presented, the IC needs to consider the OSHA’s General Duty Clause and E.O. 12196 which covers Federal Employees.

exposure guideline to ensure that they are used appropriately in the response action. An overview and description of health-based exposure guidelines are presented in Appendix A.

EPA's Risk Assessment Forum has identified four distinct time intervals that can be used to determine appropriate levels of concern for toxicity from chemical exposures.[57] These include exposures for acute (<24 hours), short-term (1 to 30 days), long-term (30 days to several years), and chronic (up to a lifetime of repeated exposure) durations. Acute exposure guidelines are often prescribed for use during emergency response decisions such as evacuation/sheltering-in-place, or for emergency drinking water guidance. In modeling and some planning activities, the lowest of the acute (one-time single exposure) exposure guidelines have sometimes been used to demarcate the edge of a hazard area.[58, 59] That is, these values delineate the level below which there is little to no immediate hazard to first responders for acute exposure durations. These acute exposure duration guidelines can also be used to inform decision-making regarding potential exposures to the general population during evacuation. Based on this approach, it is assumed that locations with exposure concentrations below the acute exposure guideline are less hazardous compared to those areas with concentrations above the exposure guideline.[60]

Chronic or long-term exposure guidelines, which are based on long-term/lifetime exposures, reside at the other end of the exposure spectrum from the acute values.[61] Chronic exposure guidelines can be used as environmental screening levels or cleanup goals to evaluate chemical concentrations in different materials and surfaces and can assist in decisions regarding the extent of contamination or as a starting point for developing the ultimate clearance decision. In addition, a variety of risk assessment methods can be employed in developing risk-based, chemical-specific, site-specific radiation goals that can be used in conjunction with other site- and situation-specific information for making determinations concerning decontamination/remediation options.

[57]U.S. Environmental Protection Agency (2002). A Review of the Reference Dose and Reference Concentration Processes. Risk Assessment Forum. EPA/630/P-02/002F, 2002.

[58]Shaw, J. (2006). Response to a Chemical, Radiological, Nuclear or Explosive WMD Event. Annex C: Principles of Response to a Radiation Incident. Hartford, CT: The Capitol Region Metropolitan Medical Response System.

[59]U.S Army, Marine Corps, Navy, & Air Force (2001). Multiservice Tactics, Techniques, and Procedures for Nuclear, Biological, and Chemical Aspects of Consequence Management. FM3-11.21/MCRP 3-37.2C/NTTP 3-11.24/AFTTP (I) 3-2.37.

[60]New York Committee for Occupational Safety and Health Technical Working Group (2004). "Gold Standard" for Remediation of WTC Contaminations. New Solutions J. Environ. Occup. Health Pol. 14: 199-217.

[61]California Environmental Protection Agency (2000). Air Toxics Hot Spots Program Risk Assessment Guidelines. Part III: Technical Support Document for the Determination of Noncancer Chronic Reference Exposure Levels. Oakland, CA: Office of Environmental Health Hazard Assessment, Air Toxicology and Epidemiology Section.

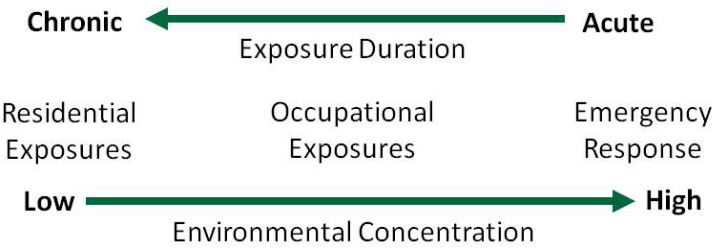

Figure 6: Exposure Concentration-Time Continuum

Recommendations for the exposure guidelines that are most appropriate for any given situation should take into consideration the complexities and uncertainties of these determinations in order to use the available exposure guidelines most appropriately. Additionally, exposure guidelines can also be used to evaluate the adequacy of the detection limits of field- or laboratory-based analytical methods used to determine the extent and magnitude of contamination. Ideally, the full range of existing exposure guidelines should be evaluated in the context with the exposure range for the site-specific information (population exposed, duration of exposure, etc.), underlying assumptions, and other factors described in this section before determining the final cleanup goal(s).

In terms of available exposure guidelines, a wide array of quantitatively derived human toxicity and health-based exposure limits and guidelines exist for many substances. However, for certain chemicals and certain types of environmental media, there simply may not be an existing value. In that situation, the decision-maker can consult with subject matter experts who may consider several options.[62] They can review available toxicity data from animal and human studies to determine if a human exposure value could be estimated using the same modeling procedures and principles used to develop the exposure guidelines described in Appendix A.[63] Another approach would be to use structural modeling, such as Quantitative Structure Activity Relationship (QSAR), or surrogate/relative potency chemical toxicity information to derive an alternative value.[64] These options may have several drawbacks and may not be practical in a large-scale incident. However, while QSAR modeling may be viewed as complex, it may yield useful risk assessment information. How it is managed is what's important.

[62]Army, U.S. Marine Corps, Navy, Air Force (2001). Multiservice Tactics, Techniques, and Procedures for Nuclear, Biological, and Chemical Aspects of Consequence Management. FM3-11.21/MCRP 3-37.2C/NTTP 3-11.24/AFTTP (I) 3-2.37. Washington, DC.

[63]U.S. Department of Health and Human Services (2016, November 3). National Toxicology Program: 14th Report on Carcinogens.

[64]Organisation for Economic Co-operation and Development (2004). Manual for Assessment of Chemicals. Paris, France.

5. Key Elements in Clearance Decision-Making

5.1. Overview

Chemical incident consequence management activities may parallel those of a HAZMAT response; however, the elevated scale of the nationally significant chemical incident and the level of public concern will involve the coordination of many agencies. The decisions related to consequence management phase activities (e.g., clearance decisions for contaminated areas, decontamination technology, final resumed use/re-occupancy) will likely receive high-level technical review and depend greatly on the information gathered throughout the crisis and consequence management operations. Many incident-specific factors (e.g., the types of chemicals released, their degradation byproducts, the amount released, how they were released, and collateral hazards) will have an impact on response decisions. The discussion of multi-agency coordination is provided here to guide decision-makers through the response process, including the identification of risk-based cleanup goals and ultimate clearance criteria.

This section describes the major steps and decisions in the process for defining site-specific clearance criteria. The processes listed below, although presented sequentially, can be performed concurrently during across the various operational phases of chemical incident response and recovery as discussed in Section 2 above. Figure 7 outlines the components for developing clearance criteria (the quantitative or qualitative measures evaluated to determine the attainment of the clearance goal). This process is intended to be flexible; it includes the evaluation of the specific hazardous chemical contaminant, the potentially exposed population, and the analytical realities at the time of the contamination event. A step-by-step-by-step illustration of the decision-making process is provided in Appendix D.

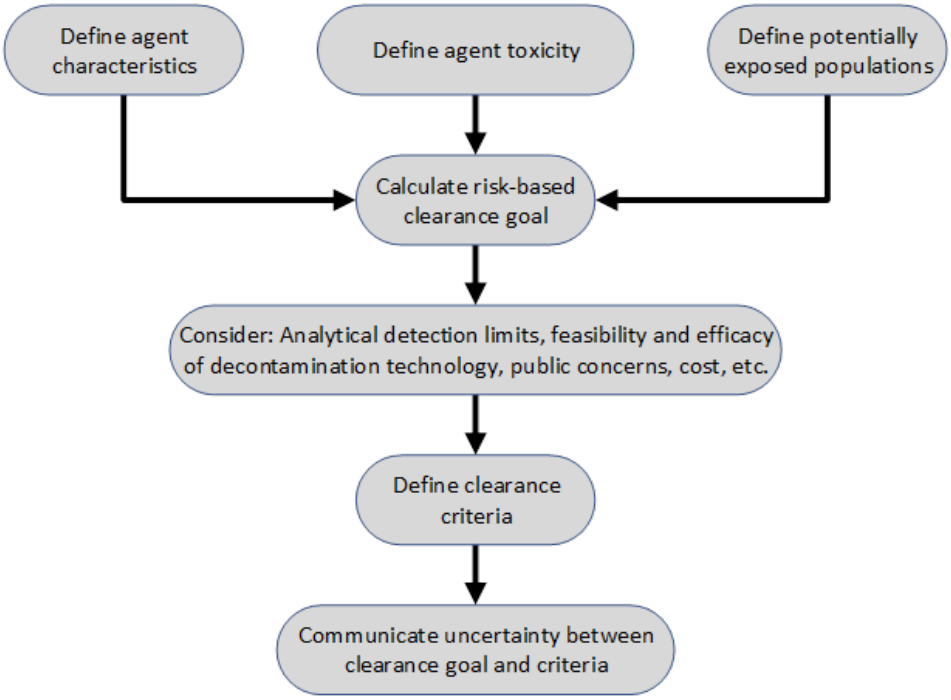

Figure 7: Clearance Criteria Definition Process

1. Estimate Risk-based Clearance Goals

- Using site-specific information on chemical identity, exposure, and health effects, determine appropriate risk-based clearance goals defined by or using method developed by federal or state agencies for appropriate exposure durations.

2. Consideration of Site-specific and Stakeholder Issues

- Provisions should be made to incorporate stakeholders' perspectives into clearance discussions.
- Consider issues that are unique to the site-specific circumstances that may impact the attainment of risk-based clearance goals:
    - Feasibility issues (analytical detection and laboratory capacity)
    - Uncertainties/confidence (availability, confidence in, impact of historical inequities, interpretation and application of exposure guidelines, sampling methods/validation, decontamination approach effectiveness)
    - Time/resource concerns (extent of contamination, critical infrastructure/items, economic impacts of cleanup options, environmental justice)
    - Other confounding factors (the variety of uncertainties involved in the initial; nature and toxicity of breakdown products and collateral hazards; disproportionate impact on communities of color, low-income communities, and other underserved or historically marginalized communities; waste generation; etc.).
- Consider adequacy of verification that clearance criteria have been successfully achieved with appropriate evaluation of clearance sampling and analysis of air, building surfaces, soil, surface water, ground water, drinking water, as needed.
- Consider options for decontamination methods (e.g., monitored natural attenuation; thermal degradation; or solid, liquid, foam, gel, vapor or gas decontamination technologies) to determine which approach(es) will provide adequate cleanup efficacy.

3. Risk Communication

- Determine the potential magnitude of difference between the desired risk-based clearance goal and the clearance criteria.
- Develop a risk communication strategy that adequately describes the clearance criteria and the uncertainties associated with the attainment of clearance goals, such as:
    - Basis for clearance goals
    - Potential for residual contamination

- Institutional controls that may remain
- Long-term monitoring.

5.2. Estimate Risk-Based Clearance Goals

Risk assessment combines both toxicity assessment and exposure assessment to estimate a risk characterization. This risk characterization is then provided to the decision-maker along with the other inputs to determine the extent of the response. Elements of the risk assessment (identification of health effects associated with hazardous chemical contaminant, chemical persistence that may impact exposure duration, etc.) will guide the development of risk-based clearance goals.

See Section 4 for a discussion of the principles of conducting a risk assessment, in the context of hazardous chemicals.

A risk assessment (as described in Section 4) is a process that combines toxicity information, site-specific exposure estimates, and the concentration of the chemical in the environment to estimate the magnitude of cancer risk or noncancer hazard associated with the exposure. Developing risk-based clearance goals is a similar process. Rather than calculating risk or hazard, a target risk/hazard is defined by the IC/UC with appropriate stakeholder input. Information on the chemical toxicity as well as exposure magnitude and duration will guide the estimation of an environmental target concentration (risk-based goal) for the chemical contaminant. The resultant risk-based goal should be established at an environmental concentration that is without adverse health effects for the expected duration of exposure.

This is the process that various governmental and professional organizations use to derive risk-based exposure guidelines. A more detailed discussion of risk-based exposure guidelines is found in Appendix A. Risk-based exposure guidelines can be used during different phases of the response for a variety of purposes. For example, acute exposure guidelines (i.e., action levels) used to evaluate acute effects experienced following short-term exposures can be used during the initial response and can inform public health determinations and help in decision-making for activities such as evacuation/shelter-in-place or can provide information to modify the HASP as needed; for example, informing occupational risk decisions concerning appropriate worker protections. Chronic or long-term exposure guidelines derived for longer-term exposures and chronic health effects may be employed in developing risk-based, chemical-specific, site-specific clearance goals when making decisions concerning decontamination/remediation options. These exposure guidelines based on site- and incident-specific conditions and environmental contaminant concentrations without inequitable adverse health effects for protracted exposure durations can serve as clearance goals.

As discussed below, other factors will likely be needed to ensure a selected remediation/cleanup goal will be both feasible to achieve and acceptable to those affected. For example, given the potential significant extent of contamination or complexity of remediation options, striving for an extremely stringent goal may prove to be technically infeasible or may contribute to other adverse economic problems that will significantly decrease quality of life for the same population. Feasibility and acceptability decisions should be made as much as possible by those affected, taking into consideration all the available information.

However, it is of paramount importance that all potential health effects are evaluated when determining the preliminary clearance goal and the clearance criteria that will be used to make the final decision for ultimate resumed use/re-occupancy. Both acute health risks associated with the short-term exposures and potential chronic health effects associated with low levels of potential residual chemical concentration remaining after cleanup/remediation must be considered.

5.3. Clearance Goals and Options

Selecting clearance goals should be based on a flexible approach where a variety of dose- and/or risk-based exposure guidelines (e.g., advisory levels, clearance goals) from federal, state, or other sources (e.g., national and international advisory organizations) are reviewed in the context of the incident at hand. Exposure guidelines of higher or lower concentration may be appropriate depending on the site-specific circumstances or in order to balance other relevant factors such as technical feasibility.

A flexible process in which numerous factors are considered to achieve an end result that balances local needs and desires, health risks, costs, technical feasibility, and other factors may be warranted. The general process outlined in this document provides decision-makers with input from technical experts and stakeholder representatives, as well as providing an opportunity for public comment. The extent and complexity of the process for an actual incident should be tailored to the characteristics and needs of a given incident.

Activities may include quantitative and qualitative assessments applied at each stage of site restoration decision-making, from evaluating remediation options through implementing the chosen remediation alternative. Evaluating and prioritizing remediation options following an incident should balance relevant factors, including:

- Types of contamination (e.g., CWA or TIC)
- Other hazards present
- Risk-based human health exposure guidelines
- Areas affected (e.g., size, location relative to population)
- Projected land use
- Preservation or destruction of places of historical, national, or regional significance
- Actions already taken and decisions made during crisis management to protect public health and the environment
- Public welfare
- Ecological risks
- Costs and available resources to implement and maintain remedial options
- Potential adverse impacts of remedial options to human health, environment, economy, etc.
- Technical feasibility of remediation options
- Long-term effectiveness
- Wastes generated and disposal options and costs
- Timeliness
- Public acceptability, including local cultural sensitivities
- Economic effects (e.g., tourism, business, and industry)

- Environmental equity and justice

A flexible process provides an opportunity for decision-makers to involve stakeholders and build public confidence in the decision-making process.

5.3.1. STAKEHOLDER CONCERNS

- Early risk communication with stakeholders is essential to establish an understanding of the types of health effects and degree of certainty for those effects.
- Share with stakeholders that if uniquely susceptible populations are at especially high risk, alternative site uses may need to be considered.

Future use of site/population of concern. Appropriate mechanisms to coordinate with stakeholders (such as property owners and SLTT government officials as well as representatives of business and community groups) should be established as part of the consequence management planning process. One of the initial communications with stakeholders should be to determine the types of activities and persons who are anticipated to occupy or use the contaminated area/facilities. Vulnerable populations of concern, to include individuals with disabilities and others with access and function needs, should be identified. Environmental justice considerations should be considered whether there is a disproportionate impact on communities of color, low-income communities, and other underserved or historically marginalized communities. Discussion should include consideration of potential alternative land/facility uses or institutional controls that could be selected to minimize exposure.

Types of health effects. The types of health effects that may be caused by exposure to the chemical of concern may be perceived differently by the various populations at risk. Acute or immediately noticeable symptoms will typically be easier to detect and describe. Those effects that are more pronounced or severe (such as difficulty breathing) will likely be of greater immediate concern. Effects that occur only after long-term exposures and/or that take years to develop (such as cancer) may be less certain but may result in significant fear among those at risk.

5.3.2. FEASABILITY ISSUES

Chemical Detection. Clearance goals should be evaluated in context with the ability to verify residual chemical contamination using one or more analytical methods. In order for chemical analysis to be able to confirm that an area has been sufficiently decontaminated, the detection limit of the analytical method should be lower than or equal to the clearance goal. In addition to the analysis method to detect a chemical at a sufficiently low quantitation level is the issue of sampling efficiency. Sampling efficiency will vary according to chemical, surface type and environmental media. Collected samples require analyses in specialized laboratories. Only select laboratories will have the capability to analyze for all chemicals of concern in various matrix types, limiting the capacity to analyze samples, and wide-area response may overwhelm laboratory resources. The EPA has developed a *Best Practices to Minimize Laboratory Resources for Waste Characterization During a Wide-Area Release of Chemical Warfare Agents.* This

document contains information that may be useful for labs to use during such an incident.[65] Risk management options (e.g., institutional controls) may need to be considered if it is not possible to verify a successful decontamination analytically.

Remediation Options. The remediation options selected should provide an adequate mechanism for cleaning up in an effective, timely, cost effective manner. Factors to consider when selecting remediation options are summarized below:

- **Chemical Parameters.** The first consideration is whether the cleanup approach is feasible and effective for the chemical of concern. This will generally be supported with some data or knowledge of the chemical structure and other parameters. However, the form and amount of the chemical present, temperature/humidity, and other environmental conditions and chemical parameters may have an impact on cleanup effectiveness. For example, monitored natural attenuation may be a desired approach for highly volatile compounds. But if a large amount of liquid agent is present, the temperature is quite low or the chemical contaminant is persistent, other, more aggressive techniques may be desired. Engineering feasibility studies may be needed to ensure remediation options can meet desired results.

- **Materials and Surfaces Characteristics.** Some environmental materials and surfaces, including organic and polymeric materials, are more difficult to address because they act as sinks and require specific remediation approaches.

- **Impacts on Safety and the Environment.** Certain decontamination methods may be extremely dangerous to apply or may cause extreme damage to properties/facilities, thus rendering them inoperable or otherwise requiring additional restorative operations. When possible, less toxic and destructive methods should be evaluated.

5.3.3. UNCERTAINTIES/CONFIDENCE ISSUES

Availability/confidence in clearance goal. Despite the availability of numerous quantitatively derived human toxicity and health-based exposure guidelines for certain chemicals and certain types of environmental materials and surfaces (Appendix A), there may not be an existing exposure guideline appropriate for a given chemical release event. Below are two examples of methods that could be used in such situations:

- Reviewing available toxicity data (animal studies, human studies, anecdotal information) to determine if a human exposure value could be estimated using the same procedures and principles used to develop the exposure guidelines described in Appendix A

[65]U.S. Environmental Protection Agency (EPA) (2018). Best Practices to Minimize Laboratory Resources for Waste Characterization During a Wide-Area Release of Chemical Warfare Agents Office.

- Using structural modeling (e.g., QSAR) or surrogate/relative potency chemical toxicity information to estimate toxicity

The use of approaches such as those mentioned here may increase the uncertainty and decrease confidence in the clearance goal.

- Time and uncertainty constraints may result in provisional toxicity values with little peer review.
- The time required for a full peer review may be outweighed by the need to move forward in cleanup activities.

Interpretation and application of toxicity and exposure for clearance goal derivation. As previously discussed in Section 5.2, many of the acute and short-term exposure guidelines described in Appendix A are prescribed for use only during initial response decisions, such as evacuation/sheltering-in-place or emergency drinking water guidance. These acute and short-term values will likely not be appropriate as final clearance goals. Ideally, the full range of exposure guidelines and the underlying basis/assumption should be evaluated for appropriateness to the phase of the remediation process under consideration (Appendix A).

Decontamination approach effectiveness. Upon evaluation of all factors relevant to the circumstances of the site and scenario at hand, there may be substantial confidence that the decontamination process will be very effective. The remediation approach should be based on a balance of the desired future use of the site and associated cleanup decisions (upper bound as well as any more protective lower-level goals), the feasibility of implementing the cleanup operation, and the resources needed as well as any containment/protective barriers to minimize adverse environmental and/or health effects that might result from the remediation operation itself (e.g., run off of wastewater containing decontamination solutions). A pilot study may be helpful in improving confidence in a selected remediation approach.

When developing a decontamination strategy and sampling plan, always coordinate with stakeholders to prioritize critical areas and determine whether different cleanup decisions will be needed to facilitate rapid clearance.

5.3.4. TIME/RESOURCES ISSUES

Extent of contamination. The magnitude of the affected area may be so large and contamination so vast that uniform site clearance goals may not be feasible. In those instances, risk management decisions that mitigate risk but permit limited access may be warranted.

Critical infrastructures/items. If structures or facilities (such as power plants, water treatment plants, hospitals, or key government operational centers) that provide critical services to the local populations or to state or national operations are shut down due to potential or known contamination, these areas may need expedited cleanup and clearance. Stakeholder and other pressures may also identify other areas, facilities, or items of special importance.

- Clearance goals should be developed with consideration to available decontamination methods/options.
- Consider the overall estimated direct cleanup cost, length of time to final clearance, and indirect economic impacts.

Economic impacts of cleanup options. Similar to the need to clear areas that provide critical infrastructure service, certain business operations (e.g., national and international financial centers) may also need to be considered when choosing the remediation approach and associated objectives. The overall cost of operations versus those associated with other options must be considered. There are often multiple cleanup methods to achieve the same clearance goals. For example, monitored natural attenuation will result in minimal direct costs but may require more time or sampling, which can delay reopening facilities and possibly increase indirect (economic) cost. More aggressive options may incur higher direct costs but are likely to result in shorter time to reoccupy and limited post-decontamination monitoring.

5.3.5. WASTE MANAGEMENT ISSUES

Collecting decontamination solution and removing contaminated material or items destroyed by the decontamination process can be resource and cost intensive. With less well-known chemicals (e.g., CWAs, exotic TICs), it may be difficult to find an appropriately permitted, suitable, and willing disposal facility.[66] In some cases, waivers to established waste management, treatment, and transport requirements may be needed.

The issue of waste management for a large-scale, highly toxic, hazardous chemical release response is a complex issue. One of EPA's principal roles is to provide technical support to FSLTT authorities, industry, and other stakeholders on waste management decisions before, during, and after a large-scale chemical contamination incident occurs. Reponses to large-scale chemical releases involve waste management issues and decisions, which can significantly affect the cost and timeline of the response to and recovery from the incident. For example, terrorist events can result in large amounts of contaminated materials and debris, large-scale natural disasters can generate large quantities of mixed debris, and animal disease outbreaks may result in the need to treat and/or dispose of large volumes of contaminated carcasses. Pre-incident waste management planning is an important aspect of being prepared and can reduce the time and cost of response and recovery from a chemical incident.[67] Therefore, it is important to incorporate planning and stakeholder participation into the waste management decision-making

[66]Assistance with identifying disposal facilities can be obtained from the Department of Defense's Deputy Assistant Secretary of Defense (DASD) for Threat Reduction and Arms Control (TRAC). The DASD TRAC is the principal advisor to the Assistant Secretary of Defense (ASD) for Nuclear Chemical and Biological Defense Programs (NCB) and has responsibility for implementation and compliance with nuclear, biological, and chemical treaties as well as chemical demilitarization programs, including destruction of the U.S. chemical stockpile.

[67]DHS (2012). Key Planning Factors for Recovery from a Chemical Warfare Agent Incident, pp. 24-25.

process in large-scale chemical contamination incidents as early as possible. To address difficult waste management issues, EPA's Incident Management Handbook recommends the use of a waste management specialist, development of a waste management plan, and the use of a technical working group to tackle difficult waste management decisions. Advice and planning tools for chemical contamination incident responses can be found at the EPA waste management website.[68] EPA conducts preparedness planning operations to develop strategies and support documents for waste management when dealing with disposal of debris or other wastes contaminated with CWAs. EPA also develops a number of supporting tools and/or documents that may assist in waste disposal, including the I-WASTE Decision Support Tool (I-WASTE DST). The I-WASTE DST is used to estimate types and amounts of waste streams for certain facilities and provides a national listing of treatment/disposal facilities to assist during the planning and preparedness activities.

- To assist with estimating types and amount of wastes and to identify local waste management facilities, obtain access to the I-WASTE DST.
- Information may be found through EPA's Homeland Security Research Program (HSRP).

5.3.6. OTHER CONFOUNDING FACTORS

Other Factors that Can Confound Decision-Making

- Limited Comprehensive Human Exposure Guidelines
- Residual toxic, persistent products
- Residual chemical byproducts
- Collateral hazards from decontamination and demolition debris

Human Exposure Guidelines. The lack of comprehensive human exposure guidelines and toxicity values for inhalation, dermal, or ingestion routes of exposure that are available for civilian sector clearance may confound the clearance process.

Breakdown products and collateral hazards. Even if the hazardous chemical itself does not persist, persistent/toxic breakdown products may remain as byproducts or other contaminants and may be released by explosions or during decontamination and demolition operations (collateral hazards). Such breakdown products and collateral hazards may be of lesser concern initially, but early consideration of these potential longer-term issues will assist in the process of determining cleanup options and clearance sampling. For example, some breakdown products can be avoided through appropriate selection of decontamination technology.

[68] U.S. EPA. (January 2021). Waste management. https://www.epa.gov/emergency-response-research/waste-management.

5.4. Decontamination

Decontamination reagents for CWAs and TICs may be grouped into the following two broad categories:

- **Surface-applied Reagents.** Surface-applied reagents that utilize various reaction chemistries may be effective on some nonporous surfaces but may corrode or degrade the surface. Surface applied reagents are further broken down into:
    - **Solid and Liquid Reagents.** Decontamination solutions may pool on horizontal surfaces for a longer time than other surfaces.
    - **Foam and Gel Reagents.** Foams and gels use less decontamination reagent and maintain longer contact time with surfaces but may present more cleanup problems. Foams and gels have varying effectiveness on vertical and overhead surfaces
- **Vapor and Gas Reagents.** Vapors and gases have been demonstrated to be effective against biological contamination in enclosed spaces, but there are fewer data available indicating effectiveness in decontamination of chemicals. Both vapors and gasses might be effective in decontamination of residual subsurface CWAs; studies of this application are ongoing.

CWA or TIC permeation into materials may also impact decontamination effectiveness. Permeation varies by material (e.g., porous, nonporous, organic, polymeric) and also by the contamination scenario (e.g., vapor and/or aerosol condensation and minor spill versus heavy splash). Most decontamination reagents are more effective on the surface of contaminated objects and have limited ability to destroy CWAs/TICs that have permeated a material, but vapors near the surface might be destroyed while the decontamination reagent is present. However, after removal of the decontamination reagent, permeated CWAs/TICs will continue to slowly leach out and pose a hazard unless the hazardous chemical is destroyed within the porous material.

No single decontamination reagent or method is applicable in all situations. EPA's HSRP has summarized currently available decontamination products and technologies that have shown various levels of efficacy for TICs and CWAs that may impact a variety of surfaces, large volumetric spaces, and sensitive items such as electronics. No summary is exhaustive and no recommendation of these products by the EPA is implied. Other decontamination products using mechanical/physical or monitored natural attenuation procedures can also be used. A cost versus efficacy assessment should be done in addition to a technical feasibility study to determine if the technology or procedures selected meet the clearance decisions in a timely, cost-effective manner.

5.5. Verify Clearance

After all remediation activities have been completed, clearance environmental sampling and analysis should be performed. This clearance sampling may include activities such as aggressive sampling, using blowers that may potentially aerosolize any residual hazards, and sampling in any area where the agent might possibly remain unaffected by the decontamination activities. Sampling objectives and quality assurance procedures should be established prior to initializing sampling.

Clearance sampling and analysis are carried out to determine whether the cleanup methods were successful. The objective of clearance sampling is not to provide a risk-free environment, but to provide the best available scientific evidence for the potential for any residual risk to human health or the environment. Clearance criteria (based on a *weight-of-evidence* approach using a combination of quantitative measures such as sampling results and other more qualitative factors) are generally determined before cleanup steps are taken; this allows the overall process for judging the success of the cleanup to be clear and unbiased.

The strategy for conducting post-cleanup environmental sampling depends on the nature and extent of the contamination, as determined by characterization sampling that was conducted prior to remediation. For example, if characterization sampling indicates heavy contamination in one area, some contamination in the surrounding area, and none in remaining areas, the strategy can implement **targeted** surface sampling for the first area (i.e., taking clearance samples at exactly the same locations where positive samples occurred), **biased** surface sampling in the second area (i.e., taking samples at locations close to areas found during characterization to be contaminated or expected to have considerable contact by people), and **random** surface sampling in the remaining areas. The plan also must specify what kinds of samples will be taken and in which locations.

5.6. Clear for Resumed Use/Occupancy

Decisions on clearance and resumed use/re-occupancy will be based, in part, on recommendations from the planning team that include evaluation of decontamination efficacy data and clearance sampling. The process for re-entry should be closely coordinated with the Stakeholder Working Group. Decision-makers should be prepared to answer any questions or concerns from the public concerning clearance and resumed use/re-occupancy decisions, including any use restrictions.

Generally, local public health authorities are responsible for the re-occupancy/resumed use determinations, based upon the sampling data, interpretation of the data, and site-specific clearance goals.

Decision-makers should be prepared to provide publicly available information describing cleanup activities and the basis for determining resumed use of a water supply. Documentation should not only be available in layperson summaries or fact sheets but, ideally, should include more detailed information regarding sampling, results, and involved/approving agencies. If possible, materials should include point of contact information to address technical questions about the remediation effort and resumed use/re-occupancy decisions. Effective risk communication should continue to be a priority during this phase and throughout resumed use/re-occupancy of an impacted area or resumed use of a water system.

Glossary

Action level: The existence of a contaminant concentration in the environment high enough to warrant action or trigger a response.

Acute exposure duration: Exposure by the oral, dermal, or inhalation route for 24 hours or less. [69]

Aerosol: A suspension of liquid or solid particles in air.

Agent: Historically, "agent" has referred to weaponized preparations of chemical or biological materials. In this document, agent refers to a causative substance without regard to military use (e.g., a causative source of hazard).

Biased sampling: Biased sampling is used in areas where samples previously tested positive and can be applied during clearance at specific locations that were found to be contaminated during the characterization phase. Biased samples are samples collected adjacent to areas of known contamination, high-traffic areas, or surfaces likely to be encountered by occupants following re-occupancy.[70]

CERCLA: Comprehensive Environmental Response, Compensation, and Liability Act (42 USC 9601 et seq.), as amended by the Superfund Amendments and Reauthorization Act of 1986. Authorizes the President and EPA (by delegation from the President) to respond to releases or substantial threats of releases of pollutants, contaminants, or hazardous substances that may present an imminent and substantial danger to the public health or welfare.

Characterization phase: Process of obtaining specific information about an agent, such as its identity, composition, formulation, physical properties, toxicological properties, ability to aerosolize, and persistence, and about the nature and extent of contamination of the agent, such as locations or items contaminated and the amount of contamination. Characterization of the agent and of the contamination at an affected site generally occurs after First Response and before cleanup.

Characterization sampling: Environmental sampling intended to assess the nature (identity and properties) and extent (location and quantity) of contamination of an area or items. Generally occurs after First Response and before cleanup.

Chemical warfare agent (CWA): Chemicals listed by the Chemical Warfare Convention as chemical warfare agents.

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[69]U.S. Environmental Protection Agency (2002). A Review of the Reference Dose and Reference Concentration Processes. Risk Assessment Forum. EPA/630/P-02/002F, 2002.

[70] Carlsen, T., et al. (2005, September). Restoration Plan for Major International Airports After a Bioterrorist Attack. Lawrence Livermore National Laboratory, Livermore, CA, UCRL-TR-210178.

The Convention defines CWA within these criteria:

1. "Chemical Weapons" means the following, together or separately:

   (a) Toxic chemicals and their precursors, except where intended for purposes not prohibited under this Convention, as long as the types and quantities are consistent with such purposes;

   (b) Munitions and devices, specifically designed to cause death or other harm through the toxic properties of those toxic chemicals specified in subparagraph (a), which would be released as a result of the employment of such munitions and devices;

   (c) Any equipment specifically designed for use directly in connection with the employment of munitions and devices specified in subparagraph (b).

2. "Toxic Chemical" means: Any chemical which through its chemical action on life processes can cause death, temporary incapacitation or permanent harm to humans or animals. This includes all such chemicals, regardless of their origin or of their method of production, and regardless of whether they are produced in facilities, in munitions or elsewhere.
3. "Precursor" means: Any chemical reactant which takes part at any stage in the production by whatever method of a toxic chemical. This includes any key component of a binary or multi-component chemical system.

Chronic exposure duration: Repeated exposure by the oral, dermal, or inhalation route for more than 30 days, up to approximately 10 percent of the life span in humans (approximately 90 days to 2 years in typically used laboratory animal species). [71]

Cleanup: Process of containing, removing, or treating a contaminated site and/or items.

Clearance: Process of determining that clearance criteria have been met for a specific contaminant in or on a specific site or item. Occurs before re-occupancy.

Clearance criteria: Measures that serve as the basis for determining whether a site can be opened for resumed use/re-occupancy either on an unrestricted or limited basis (with site controls). Clearance criteria are based on the clearance goals and the consideration of other issues such as technical feasibility, analytical capability, stakeholder concerns, etc.

Clearance goal: Amount of residual contamination for a specific contaminant in or on an area or item that provides acceptable protection to human health and the environment for protracted exposure durations.

[71] U.S. Environmental Protection Agency (2002). A Review of the Reference Dose and Reference Concentration Processes. Risk Assessment Forum. EPA/630/P-02/002F, 2002.

Clearance phase: The phase of a response when actions are taken following decontamination of a site. This phase involves clearance sampling and analysis and making a determination as to whether the site is cleaned up sufficiently to release for resumed use/re-occupancy.

Clearance sampling: Environmental sampling conducted after decontamination that is intended to provide a basis for determining if clearance criteria have been met.

Concentration level: Estimated or measured level of an agent (e.g., chemical) in materials and surfaces (e.g., air), usually in units of milligrams per cubic meter (mg/m3) for air, micrograms per centimeter squared (µg/cm2) for surfaces, or parts per million (ppm) and milligrams per liter (mg/L) for other media.

Consequence management: An emergency management function of response that includes measures to protect public health and safety, restore essential government services, and provide emergency relief to governments, businesses, and individuals affected by the consequences of a chemical incident.

Containment: Actions taken to prevent the spread of a contaminant from a particular area or movement within the area. Also, an action taken to seal a site prior to fumigation.

Contamination: Deposition and/or absorption of chemicals on and by structures, areas, or materials and surfaces (e.g., soil, air, water) which renders them unfit for human use by the presence of those agents, including chemicals, radioactive elements, bacteria, or organisms.

Course of Action: An overall plan that describes the selected strategies and management actions intended to achieve Incident Objectives, comply with Incident Requirements, and are based on current and expected conditions.

Critical infrastructure: Systems and assets, whether physical or virtual, so vital that the incapacity or destruction of such may have a debilitating impact on the security, economy, public health or safety, environment, or any combination of those sectors, across any FSLTT jurisdiction. As established in the National Infrastructure Protection Plan, this includes the sectors of agriculture and food; drinking water and wastewater treatment systems; dams; public health and healthcare; emergency services; government and commercial facilities; defense industrial base; national monuments and icons; information technology; telecommunications; energy; nuclear reactors materials and waste; transportation systems; banking and finance; chemical; and postal and shipping.

Crisis management: A law enforcement function that includes measures to identify, acquire, and plan the use of resources needed to anticipate, prevent, and/or resolve a chemical incident.

Decision-maker: Person charged with determining and directing appropriate actions in response to a potential or actual incident at a particular site.

Decontamination: Process of inactivating or removing a contaminant from humans, animals, plants, food, water, soil, air, areas, or items through physical, chemical, or other methods to meet a clearance goal. Decontamination applies to both disinfection and sterilization processes. (Generally occurs as part of cleanup.)

Emergency Operations Center (EOC): Physical location at which the coordination of information and resources to support domestic incident management activities normally takes place. An EOC may be a temporary facility or located in a more central or permanently established facility, perhaps at a higher level of organization within a jurisdiction. EOCs may be organized by major functional disciplines (e.g., fire, law enforcement, and medical services), by jurisdiction (e.g., FSLTT), or by some combination thereof.

Environmental justice: The fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income, with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies. This goal will be achieved when everyone enjoys: the same degree of protection from environmental and health hazards, and equal access to the decision-making process to have a healthy environment in which to live, learn, and work.[72]

Environmental sampling: Sampling conducted on inanimate surfaces or in air, water, or soil for the purpose of detecting the presence of a specific agent.

Exposure level: Measured or estimated amount of an agent (e.g., chemical) to which an individual or populations of individuals is exposed, usually expressed as concentration over a defined period (e.g., ppm for one hour).

First responder: Designation for a person who, in the course of their professional duties of responding to emergencies, and in the early stages of an incident, is responsible for the protection and preservation of life, property, evidence, the environment, and for meeting basic human needs. May be a member of a FSTTL emergency public safety, emergency response, emergency medical, law enforcement, fire and rescue, military, or other recognized agency and authority including a volunteer or private organization, as well as other skilled support personnel (such as equipment operators, administrators, security personnel, etc.) who provide immediate support services during response and protection operations.

First response phase: Phase of a response in which actions are taken immediately following notification of a chemical incident or release. In addition to search and rescue, scene control, and law enforcement activities, first response includes initial site containment, environmental sampling and analysis, and public health activities, such as treatment of potentially exposed persons.

Fourth Generation Agents (FGAs): A group of Soviet Union/Russian-developed nerve agents; also known as Novichoks or A-series agents. FGAs were developed after the third generation of chemical warfare agents (V-series nerve agents).

Hazard: Something that is potentially dangerous or harmful, often the root cause of an undesired outcome.

Health and Safety Plan (HASP): Written plan required under the Occupational Health and Safety Administration's (OSHA's) Hazardous Waste Operations and Emergency Response standard (29 CFR

[72] For more information refer to https://www.epa.gov/environmentaljustice

1910.120). This standard requires a written HASP, which identifies site hazards and appropriate controls to protect employee health and safety. [73]

Incident: Occurrence or event, natural or human-caused, which requires an emergency response to protect life or property. Incidents can, for example, include major disasters, emergencies, terrorist attacks, terrorist threats, wild land and urban fires, floods, hazardous materials spills, nuclear accidents, aircraft accidents, earthquakes, hurricanes, tornadoes, tropical storms, war-related disasters, public health and medical emergencies, and other occurrences requiring an emergency response.[74]

Incident Action Plan (IAP): An oral or written plan containing general objectives reflecting the overall strategy for managing an incident. It may include the identification of operational resources and assignments. It may also include attachments that provide direction and important information for management of the incident during one or more operational periods.

Incident Commander (IC): Individual responsible for all incident activities, including the development of strategies and tactics and the ordering and release of resources. The IC has overall authority and responsibility for conducting incident operations and is responsible for managing all incident operations at the incident site.

Incident Command Post: The field location where the primary functions are performed. The Incident Command Post may be co-located with the incident base or other incident facilities.

Incident Command System (ICS): A standardized on-scene emergency management construct specifically designed to provide for the adoption of an integrated organizational structure that reflects the complexity and demands of single or multiple incidents, without being hindered by jurisdictional boundaries. ICS is a management system designed to enable effective incident management by integrating a combination of facilities, equipment, personnel, procedures, and communications operating within a common organizational structure, designed to aid in the management of resources during incidents. It is used for all kinds of emergencies and is applicable to small as well as large and complex incidents. ICS is used by various jurisdictions and functional agencies, both public and private, to organize field-level incident management operations.

Joint Field Office: Central office where the operations of the various federal entities participating in a response at the local level are collocated. This improves the efficiency and effectiveness of federal incident management activities.

Joint Information Center (JIC): Focal point for the coordination and provision of information to the public and news media concerning the federal response to the emergency.

[73] Hazardous Waste Operations and Emergency Response, 29 C.F.R § 1910.120. (2020).
[74] U.S. DHS (2013). National Response Framework.

Long-term duration: Repeated exposure by the oral, dermal, or inhalation route for more than 30 days, up to approximately 10 percent of the life span in humans (more than 30 days up to approximately 90 days in typically used laboratory animal species).[75]

Local government: Public entities responsible for the security and welfare of a designated area as established by law. Includes county, municipality, city, town, township, local public authority, school district, special district, intrastate district, council of governments, regional or interstate government entity, or agency or instrumentality of a local government; an Indian tribe or authorized tribal organization, a native village or native cooperation; or a rural community, unincorporated town or village, or other public entity; state governments are separate entities and are not included in the definition of local government.

Media: Refers to the air, water, soil, or surface that has been or is potentially contaminated by an agent (e.g., chemical).

Mitigation: The capabilities necessary to reduce the loss of life and property from natural and/or man-made disasters by lessening the impacts of disasters.

Mode of release: Method of dispersal that could include explosion, aerosolization, injection, ingestion, or vector diffusion. Releases may also be covert leading to unintentional cross-contamination.

Monitored natural attenuation: Destruction or inactivation of agents via natural, environmental mechanisms such as heat, light, biochemical, or chemical reactions. The dilution, dispersion, (bio)degradation, irreversible sorption, and/or natural decay of contaminants causing a net reduction of contaminant mass, toxicity and human and ecological risk.

National Incident Management System (NIMS): System mandated by HSPD-5 that provides a consistent, nationwide approach for FSLTT governments; private-sector; and NGOs to work effectively and efficiently together to prepare for, respond to, and recover from domestic incidents, regardless of cause, size, or complexity. To provide for interoperability and compatibility among FSLTT capabilities, the NIMS includes a core set of concepts, principles, and terminology. HSPD-5 identifies these as the ICS; multiagency coordination systems; training; identification and management of resources (including systems for classifying types of resources); qualification and certification; and the collection, tracking, and reporting of incident information and incident resources.

National Response Framework (NRF): Homeland Security Act of 2002 and the HPSD-5 directed the DHS to develop an NRF. The NRF is a guide to how the nation responds to all types of disasters and emergencies. It is built on scalable, flexible, and adaptable concepts identified in the NIMS to align key roles and responsibilities across the nation.

[75] U.S. Environmental Protection Agency (2002). A Review of the Reference Dose and Reference Concentration Processes. Risk Assessment Forum. EPA/630/P-02/002F, 2002.

Nationally significant or large-scale incident: A designation to distinguish events from day-to-day responses. This is generally an incident that because of the magnitude, complexity, toxic potency or deliberate nature requires federal assets and exceeds the capability of state, tribal, territorial, or local agencies.

Non-persistent: Agent that is readily dispersed, de-activated, and poses no long-term hazard.

Non-Traditional Agent (NTA): NTAs are a broad group of chemicals that fall outside the traditional chemical agent categories.

Normalcy: Pre-event condition and/or operation status.

Notification phase: The first set of actions to take place after the release of a hazardous chemical. This includes such activities as receiving and assessing information, identifying potential release sites, and relaying key information to appropriate agencies.

Novichok : A group of nerve agents developed by the Soviet Union/Russia; also known as Fourth Generation Agents, FGAs, or A-series agents. These agents are lesser characterized, weaponized organophosphate agents. The use of known Novichok agents in warfare is banned under the Chemical Weapons Convention of 1997. Novichok agents are considered more potent than VX gas and can be applied in unitary and binary forms. Like other nerve agents, Novichok agents irreversibly bind acetylcholinesterase and produce a cholinergic toxidrome. Uniquely, these agents are thought to also target neurons in the peripheral nervous system. Delayed treatment or massive exposure may therefore cause a debilitating neuropathy. The recent 2018 assassination attempt of a Russian dissident and his daughter in the United Kingdom highlights the importance of recognizing the potential lethal effects of these nerve agents. Treatment of Novichok agent poisoning is similar to management of other nerve agent.[76]

Persistent: Agent that remains active in the environment or resists decontamination efforts. These agents are likely to pose long-term hazards.

Prevention: The capabilities necessary to avoid, prevent, or stop a threatened or actual act of terrorism. In national preparedness guidance, the term "prevention" refers to preventing imminent threats.

Recovery: The capabilities necessary to assist communities affected by an incident to recover effectively.[77]

Remediation phase: The phase of response where actions are taken between the Characterization Phase and the Clearance Phase. This includes selecting and implementing decontamination technologies and

[76] Chai, P. R., Hayes, B. D., Erickson, T. B., & Boyer, E. W. (2018). Novichok agents: a historical, current, and toxicological perspective. Toxicology Communications, 2(1), 45–48. https://doi.org/10.1080/24734306.2018.1475151.
[77] U.S. DHS (2017, October). National Incident Management System.

procedures, formation of a remedial action plan, waste disposal, source reduction, and verification of decontamination parameters.

Removal action: Short-term response actions taken to address releases or threatened releases of hazardous substances, pollutants, or contaminants that require a prompt response. Performed in accordance with the National Oil and Hazardous Substances Pollution Contingency Plan and under the authority of CERCLA.[78]

Resumed Use/Re-occupancy: Process of renovating a facility, monitoring the workers performing the renovation, and deciding when to permit reoccupation. Generally occurs after a facility has been cleared but before occupants are permitted to return.

Residual contamination: Amount of contaminant remaining after an area has been decontaminated. Residual contamination may be below the ability to detect its presence.

Resources: Personnel and major items of equipment, supplies, and facilities available or potentially available for assignment to incident operations and for which status is maintained. Resources are described by kind and type and may be used in operational support or supervisory capacities at an incident or at an EOC.

Response: The capabilities necessary to save lives, protect property and the environment, and meet basic human needs after an incident has occurred.

Restoration: The process of renovating or refurbishing a facility, bringing it back to an unimpaired or improved condition after decontamination, and making a decision to permit occupants to return. Restoration generally occurs after a facility has been cleared but before occupants are permitted to return.

Risk: Probability that a substance or situation will produce harm under specified conditions. Risk is a combination of two factors: (1) the probability that an adverse incident will occur (such as a specific disease or type of injury) and, (2) the consequences of the adverse incident.

Risk assessment: Gathering and analyzing information on what potential harm a situation poses and the likelihood that people or the environment will be harmed. A methodological approach to estimate the potential human or environmental risk of a substance that uses hazard identification, dose–response, exposure assessment, and risk characterization.

Risk communication: Interactive process of exchange of information and opinion among individuals, groups, and institutions. It often involves multiple messages about the nature of risk or expressing concerns, uncertainties, opinions, or reactions to risk messages or to legal and institutional arrangements for risk management.

[78] Removal action, 40 CFR § 300.415. (2015).

Risk management: Process of identifying, evaluating, selecting, and implementing actions to reduce risk to human health and to ecosystems. The goal of risk management is scientifically sound, cost-effective, integrated actions that reduce or prevent risk while taking into account social, cultural, ethical, political, and legal considerations.[79]

Sampling: Act of collecting representative portions of an environmental materials and surfaces that help to specify the number, type, and location (spatial or temporal) of contamination. Samples are selected to determine if contamination is present, and if so, to determine the approximate locations of contamination and estimation of the contaminant levels.[80]

Sampling and Analysis Plan (SAP): Plan that describes the methods, strategies, and analyses for characterization sampling, verification sampling (if applicable), and clearance sampling for a contaminated site.

Screening: Systematic examination or assessment done specially to detect an unwanted substance, attribute, person, or undesirable materiel

Short-term exposure duration: Repeated exposure by the oral, dermal, or inhalation route for more than 24 hours, up to 30 days.[81]

Site characterization: Process of gathering site-specific data, including overall descriptions of the site, material types present at the site, potential human exposure pathways, and environmental conditions in order to estimate the extent of contamination. Site characterization occurs as an early step in consequence management.

Targeted sampling: Sampling in which sites are allocated to specific locations of concern for the purpose of trying to answer site-specific questions.[82]

Technical Working Group: Group of technical experts assembled by the Incident/Unified Command to provide guidance during the planning and implementation of cleanup operations.[83]

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[79] Presidential/Congressional Commission on Risk Assessment and Risk Management (1997). Final Report, Vol 1.

[80] U.S. Environmental Protection Agency (2002). A Review of the Reference Dose and Reference Concentration Processes. Risk Assessment Forum. EPA/630/P-02/002F, 2002.

[81] U.S. Environmental Protection Agency (2002). A Review of the Reference Dose and Reference Concentration Processes. Risk Assessment Forum. EPA/630/P-02/002F, 2002.

[82] EPA (2008). Handbook for Developing Watershed Plans to Restore and Protect Our Waters.

[83] Carlsen, T. et al. (2005, September). Restoration Plan for Major International Airports After a Bioterrorist Attack. Lawrence Livermore National Laboratory, Livermore, CA, UCRL-TR-210178.

Toxicity: Degree to which some agent is poisonous or harmful, often inversely related to the amount of the agent that causes the harmful or fatal effect(s).

Toxic industrial chemical (TIC)/toxic industrial material (TIM): Any industrial chemical hazard that is toxic and/or lethal and not designed specifically for military purposes; however, a TIC/TIM may be employed as a chemical warfare agent.

Uncertainty: Imperfect knowledge concerning the present or future state of the system under consideration; a component of risk resulting from imperfect knowledge of the degree of hazard or of its spatial and temporal distribution.

Unified Command (UC): Application of ICS used when there is more than one agency with incident jurisdiction or when incidents cross political jurisdictions. Agencies work together through the designated members of the UC to establish their designated IC at a single Incident Command Post and to establish a common set of objectives and strategies and a single IAP.[84]

[84] U.S. DHS (2017, October). National Incident Management System.

Acronyms and Abbreviations

AAMP	Ambient Air Modeling Plan
AC	Hydrogen cyanide
AChE	Acetylcholinesterase
ACGIH	American Conference of Governmental Industrial Hygienists
AEGL	Acute Exposure Guideline Level
ATSDR	Agency for Toxic Substances and Disease Registry (of HHS)
AUES	American University Experimental Station
BMD	Benchmark Dose
BZ	3-Quinuclidinyl benzilate
CA-REL	California EPA's Reference Exposure Level
CAFS	Chemical Agent Filtration System
CalEPA	California Environmental Protection Agency
CAMEO	Computer-Aided Management of Emergency Operations
CDC	Centers for Disease Control and Prevention
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CG	Carbonyl chloride (phosgene)
CIR	Critical Information Requirements
CK	Cyanogen chloride
COA	Course of Action
CONOPs	Concept of Operations
CSF	Oral/Cancer Slope Factor
CSM	Conceptual Site Model
CWA	Chemical Warfare Agent

CX	Phosgene oxime
DDOE	District of Columbia Department of the Environment
DEP	Department of Environmental Protection (local)
DHEC	Department of Health and Environmental Control (local)
DHS	Department of Homeland Security
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of Interior
DOT	Department of Transportation
DP	Diphosgene
DU	Decontamination Unit
ECS	Engineering Control System
EOC	Emergency Operations Center
EPA	Environmental Protection Agency
ERPG	Emergency Response Planning Guideline
ES&H	Environmental Safety and Health
EU	Environmental Unit
FBI	Federal Bureau of Investigation
FEMA	Federal Emergency Management Agency
FGA	Fourth Generation Agent
FSLTT	Federal, state, local, tribal and territorial
FUDS	Formerly Used Defense Site
GA	Tabun
GB	Sarin

GD	Soman
GF	Cyclosarin
GPL	General Population Limit
HASP	Health and Safety Plan
HAZMAT	Hazardous material
HAZWOPER	Hazardous Waste Operations and Emergency Response Standard (29 CFR 1910.120)
HBESL	Health-Based Environmental Screening Level
HD	Sulfur mustard
HEAST	Health Effects Assessment Summary Table
HHS	Department of Health and Human Services
HI	Hazard Index
HN	Nitrogen mustard
HSPD	Homeland Security Presidential Directive
HSRP	Homeland Security Research Program
HVAC	Heating, Ventilation, and Air Conditioning System
IAB	Information Analysis Brief
IAP	Incident Action Plan
IC	Incident Commander
ICS	Incident Command System
IC/UC	Incident Command/Unified Command
IDLH	Immediately dangerous to life or health
IMAAC	Interagency Modeling and Atmospheric Assessment Center
IRIS	Integrated Risk Information System
IUPAC	International Union of Pure and Applied Chemistry

IUR	Inhalation Unit Risk
JFO	Joint Field Office
JIC	Joint Information Center
K_{ow}	Octanol-water partition coefficient
L	Lewisite
LOAEL	Lowest observed adverse effect level
LOC	Level of Concern
µg/cm^2	Micrograms per square centimeter
µg/m^3	Micrograms per cubic meter
mg/kg-day	Milligrams per kilograms of body weight per day
mg/L	Milligrams per liter
mg/m^3	Milligrams per cubic meter
MCL	Maximum Contaminant Level
MRL	Minimum Risk Level
NAS	National Academy of Science
NIMS	National Incident Management System
NIOSH	National Institute for Occupational Safety and Health
NOAEL	No observed adverse effect level
NRC	National Research Council
NRF	National Response Framework
NRT	U.S. National Response Team
NSF	National Strike Force
NSTC	National Science and Technology Council
NTA	Non-Traditional Agent

OSHA	Occupational Safety and Health Administration
OSTP	Office of Science and Technology Policy
PAL	Provisional Advisory Level
PEL	Permissible Exposure Limits
PIO	Public Information Officer
POD	Point of Departure
POI	Point of Interest
PPB	Parts per billion
PPE	Personal protective equipment
PPM	Parts per million
PPRTV	Provisional Peer-Reviewed Toxicity Value
PS	Chloropicrin
QAPP	Quality Assurance Project Plan
QSAR	Quantitative Structure Activity Relationship
RAGS	Risk Assessment Guidance for Superfund
RAP	Remedial Action Plan
RBC	Risk Based Concentration
REL	Recommended Exposure Limit
RfC	Inhalation reference concentration
RfD	Oral reference dose
RI/FS	Remedial investigation/feasibility study
SAP	Sampling and Analysis Plan
SCBA	Self-contained breathing apparatus
SLTT	State, local, tribal and territorial

SSC	Science Support Coordinator
START	Superfund Technical Assessment and Response Team
STEL	Short-term Exposure Limit
STSC	Superfund Health Risk Technical Support Center
TEEL	Temporary Emergency Exposure Level
TIC	Toxic Industrial Chemical
TIM	Toxic Industrial Material
TLV	Threshold Limit Values
TSD	Technical Support Document
TWA	Time Weighted Average
UC	Unified Command
USACE	United States Army Corps of Engineers
USCG	United States Coast Guard
USDA	United States Department of Agriculture
USGS	United States Geological Survey
VX	*O*-Ethyl *S*-(2-diisopropylaminoethyl) methylphosphonothiolate
WMP	Waste Management Plan
WPL	Worker Population Limit
2-PAM Cl	2-pyridine aldoxime methyl chloride

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Appendix A: Chemical-Specific Exposure Guidelines

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1. Introduction

1.1. Purpose

The purpose of this appendix is to provide an overview of the range of health-based exposure guidelines that may be used by risk managers during the operational phases of response and recovery to a nationally significant or large-scale chemical incident. This appendix provides descriptions of a number of health-based exposure guidelines based on short-term and long-term exposure durations. As many health-based exposure guidelines have been developed by governmental and professional organizations for different purposes, this appendix provides background information to assist in selecting the appropriate type of value for addressing contamination of air, soil, surfaces, and drinking water, and in understanding how those exposure guidelines may be best used. The information provided in this appendix is intended to facilitate the selection of the most appropriate values for planning and response decisions in the context of a nationally significant or large-scale release of a hazardous chemical.

The values described in this appendix may change in the future. Therefore, users should confirm the validity of the values prior to use in an incident.

1.2. Organization

The information presented in this appendix is organized into three areas: (1) an overview of available exposure guidelines, (2) an overview and list of health-based exposure guidelines for workers and the general population,[85] and, (3) considerations for selecting and implementing health-based exposure guidelines.

[85]Because of the potential use of PPE and other issues, emergency response and remediation workers will require different exposure guidelines selection logic as compared to the general population. Therefore, separate discussions are presented for workers and the general population.

2. Health-Based Exposure Guidelines

2.1. Overview

The goal for risk managers is to select an appropriate basis (criteria) for deciding if clearance goals have been met for different materials and surfaces (e.g., air, water). The preference is to have criteria that are expressed in concentration units (e.g., milligram chemical per cubic meter of air, milligram chemical per square meter surface area, milligram chemical per liter of drinking water). In general, two types of health-based (aka risk-based) exposure guidelines may be available to provide a basis for these decisions. In some cases, exposure guidelines are already reported in units of **"concentration"** and may be used as is – this is usually the case for inhalation exposure guidelines. In other cases, guidelines are expressed in terms of **"dose"** (e.g., milligrams per kilograms of body weight per day [mg/kg-day], such with EPA's Reference Dose [RfD]). This estimate of dose is often expressed as a dose associated with absence of adverse health effects (e.g., RfD) or some target risk. These kinds of values are often referred to as toxicity values. These toxicity values can then be combined with exposure targets to derive target material and surface concentrations using risk-based calculations. The decisions on final disposition of the affected site by the IC/UC (e.g., return to full original use or use with some limitations) may have an effect on some of the assumptions applied in determining reasonable clearance criteria, especially if they are derived from the dose-based exposure guidelines.

Some of the values discussed in this appendix are regulatory (e.g., the OSHA PELs and the EPA Maximum 18 Contaminant Levels [MCLs]) and enforceable by law. Others are not. However, all are intended for informational purposes to assist in decision-making during a contamination incident. For simplicity's sake, this document will generalize all values with the term "exposure guideline." However, it should not be implied that the use of the word "guideline" denotes, in this case, the existence of or lack of any regulatory significance. Additional information regarding each exposure guideline discussed in this appendix may be found in the EPA's Graphical Arrays of Chemical-Specific Health Effect Reference Values for Inhalation Exposures, Table 1.1.[86]

Health-based exposure guidelines are one of the key inputs in the common approach to deriving clearance goals and clearance criteria. These exposure guidelines are derived from equations that combine a level of exposure (dose or concentration in air), a level of acceptable risk, and a set of exposure assumptions for a particular chemical, medium, and exposure scenario. Thus, the resulting health-based exposure guideline will be specific to a particular population and exposure scenario. For example, there are health-based exposure guidelines developed for healthy workers that assume exposures lasting only 15 minutes and other exposure guidelines for exposures up to 8 or 10 hours per day, 40 hours per week for a working lifetime. Conversely, there are exposure guidelines that are based on long-term, or even lifetime exposures to the general population that are meant to be protective of sensitive members of the population such as children and the elderly. Although it is preferred that

[86] EPA's Graphical Arrays of Chemical-Specific Health Effect Reference Values for Inhalation Exposures (2009) may be found at: https://ofmpub.epa.gov/eims/eimscomm.getfile?p_download_id=495646

planners develop scenario-specific cleanup goals and clearance criteria, in the absence of resources and scenario-specific information, pre-calculated, health-based exposure guidelines can provide a useful tool for assessors and decision-makers. However, it is important to clearly understand the basis for any pre-calculated exposure guidelines used so that they are applied appropriately in the response action.

Exposure guidelines have been developed by many different sources and for many purposes. To assist planners, this appendix provides a list of available sources. In general, it is recommended that planners select peer-reviewed exposure guidelines, used in combination with appropriate exposure factors, to arrive at relevant cleanup goals and clearance criteria for the situation of concern.

Inhalation exposure guidelines are often presented as a concentration of a particular chemical in the air and may be directly compared to environmental concentrations. Oral exposure guidelines, however, are presented as applied or administered doses (e.g., mg/kg-day). which are subsequently used in equations to derive acceptable concentrations for drinking water, soil, and surfaces. Due to a lack of dermal toxicity values, oral values are generally used to assess risks from dermal exposure. Depending on the studies from which a value for a chemical was derived, one may need to adjust the oral value to account for the difference between an administered dose and an absorbed dose.[87]

Some chemicals exhibit both carcinogenic and noncarcinogenic toxicity. For such chemicals, clearance goals and clearance criteria generally are based on the more protective of the cancer- or noncancer-based exposure guidelines. Noncancer values are used primarily to determine a concentration below which no adverse effect is anticipated (threshold), while cancer-based values reflect a degree of increased risk of developing cancer (non-threshold effect).

2.2. Development of Health-Based Exposure Guidelines

Exposure guidelines developed by various federal, state, or professional organizations are derived from data drawn from the epidemiologic and toxicological literature. Default uncertainty factors are often used in the derivation of these exposure guidelines to ensure that they are protective of the population for which they were intended and to account for unknown differences between the population studied and the population to be protected. Other adjustments may also be applied to account for differences in duration of exposure or other variables or to account for unknown information.

There is considerable variation in how organizations define the length of time associated with different exposure durations. One example is the following set of definitions from the EPA's Risk Assessment Forum,[88] which have been adopted for use in this document:

[87]See Chapter 4 of the EPA (2004) Risk Assessment Guidance for Superfund (RAGS), Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment. Available at: https://www.epa.gov/risk/risk-assessment-guidance-superfund-rags-part-e, last accessed 2/5/2021.

[88]U.S. EPA. (2002). A Review of the Reference Dose and Reference Concentration Processes. U.S. Environmental Protection Agency, Risk Assessment Forum, EPA/630/P-02/002F. Washington, DC

- **Acute exposure duration:** Exposure by the oral, dermal, or inhalation route for 24 hours or less
- **Short-term exposure duration:** Repeated exposure by the oral, dermal, or inhalation route for more than 24 hours, up to 30 days
- **Long-term (or Chronic) exposure duration:** Repeated exposure by the oral, dermal, or inhalation route for more than 30 days, up to approximately 10 percent of the life span in humans (**approximately 90 days to 2 years in typically used laboratory animal species**)

2.3. Exposure Guideline Derivation – Consideration of Uncertainty and Variability

Generally, scientifically sound, peer-reviewed assessment-specific data are preferred when deriving exposure guidelines. However, if such data are not available, default values are applied when deriving both cancer and noncancer exposure guidelines (see Sections 2.3.1 and 2.3.3). These default values are designed to err on the side of being health protective. Any effort to reconsider these values during the process of developing clearance goals should involve an experienced toxicologist and should ensure that both cancer and noncancer protection is maintained for the site-specific exposure considerations.

2.3.1. NONCANCER EXPOSURE GUIDELINES

Agencies that develop noncancer exposure guidelines, such as EPA and the Agency for Toxic Substances and Disease Registry (ATSDR), utilize an approach that is intended not to underestimate risk in the face of uncertainty and variability. When there are gaps in the available information, uncertainty factors are applied to derive exposure guidelines that are intended to be protective against appreciable risk of deleterious effects. Uncertainty factors are commonly default values[89] (e.g., factors of 10 or 3), used in the absence of compound-specific data. However, when data are available, uncertainty factors may also be developed using compound-specific information.

EPA begins the development of a toxicity value (dose-based exposure guideline) by evaluating all of the available peer-reviewed literature to determine noncancer endpoints of concern, evaluating the quality, strengths, and limitations of the available studies. EPA typically chooses the relevant endpoint that occurs at the lowest dose, often using statistical modeling of the available data, and then determines the appropriate point of departure (POD) for derivation of the toxicity value. A POD is determined by: (1) a statistical estimation using the benchmark dose (BMD) approach [preferred method]; and (2) use of the

[89]According to the NRC report Science and Judgment in Risk Assessment (NRC, 1994), "[Standard] options are generic approaches, based on general scientific knowledge and policy judgment, that are applied to various elements of the risk-assessment process when the correct scientific model is unknown or uncertain." The 1983 NRC report *Risk Assessment in the Federal Government: Managing the Process* defined the standard option as "the option chosen on the basis of risk assessment policy that appears to be the best choice in the absence of data to the contrary." (NRC, 1983a, p. 63).

dose or concentration at which the toxic response was not significantly elevated (no observed adverse effect level [NOAEL]); or by (3) use of the lowest observed adverse effect level (LOAEL).[90]

A series of downward adjustments using uncertainty factors is then applied to the POD to estimate the toxicity value.90 While collectively termed "uncertainty factors," these factors account for a number of different quantitative considerations when utilizing observed animal (usually rodent) or human toxicity data in a risk assessment. The uncertainty factors are intended to account for: (1) variation in susceptibility among the members of the human population (i.e., inter-individual variability such as the elderly and children); (2) uncertainty in extrapolating from experimental animal data to humans (i.e., interspecies differences); (3) uncertainty in extrapolating from data obtained in a study with less-than-lifetime exposure (i.e., extrapolating from subchronic to chronic exposure); (4) uncertainty in extrapolating from a LOAEL in the absence of a NOAEL; and (5) uncertainty when the database is incomplete or there are problems with applicability of available studies. When scientifically sound, peer-reviewed assessment-specific data are not available, default adjustment values are selected for the individual uncertainty factors. For each type of uncertainty (when relevant to the assessment), EPA typically applies an uncertainty factor value of 10 or 3 with the cumulative uncertainty factor value leading to a downward adjustment of 10-3,000-fold from the selected POD. If an extrapolation step or adjustment is not relevant to an assessment (e.g., if applying human toxicity data and an interspecies extrapolation is not required) the associated uncertainty factor is not used. The major adjustment steps are described more fully below.

1. Heterogeneity among humans is a key source of variability as well as uncertainty. Uncertainty related to human variation is considered in extrapolating doses from a subset or smaller-sized population, often of one sex or of a narrow range of life stages (typical of occupational epidemiologic studies), to a larger, more diverse population. In the absence of pollutant-specific data on human variability, a 10-fold uncertainty factor is used. The actual degree of human variability may be larger or smaller; however, data to examine the potential magnitude of human variability are often unavailable. In some situations, a smaller uncertainty factor of 3 may be applied to reflect a known lack of significant variability among humans.
2. Extrapolation from results of studies in experimental animals to humans is a necessary step for the majority of chemical risk assessments. When interpreting animal data, the concentration at the POD (e.g., NOAEL) in an animal model (e.g., rodents) is extrapolated to estimate the equivalent human dose. While there is long-standing scientific support for the use of animal studies as indicators of potential toxicity to humans, there are uncertainties in such extrapolations. In the absence of data to the contrary, the typical approach is to use the relevant endpoint from the most sensitive species, strain, and sex in assessing risks to the average human. However, because the most commonly available data for an assessed compound are usually from rodent species, the extent of interspecies variability is often unclear.

[90]U.S. EPA. (2002). A Review of the Reference Dose and Reference Concentration Processes. U.S. Environmental Protection Agency, Risk Assessment Forum, EPA/630/P-02/002F. Washington, DC

3. Pharmacokinetic models are useful to examine species differences in pharmacokinetic processing and associated uncertainties; however, such dosimetric adjustments are not always possible. Information may not be available to quantitatively assess toxicokinetic or toxicodynamic differences between animals and humans, and in many cases a 10-fold uncertainty factor (with separate factors of 3 for toxicokinetic and toxicodynamic components) is used to account for expected species differences and associated uncertainty in extrapolating from laboratory animals to humans in the derivation of an exposure guideline. If information on one or the other of these components is available and accounted for in the cross-species extrapolation, an uncertainty factor of 3 may be used for the remaining component.
4. In the case of developing toxicity values for chronic exposures when data from only shorter duration studies are available (e.g., 90-day subchronic studies in rodents), or when such data are judged to be the most appropriate for development of an inhalation reference concentration (RfC), an additional uncertainty factor of 3 or 10 is typically applied unless the available scientific information supports use of a different value.
5. Toxicity data are typically limited as to the dose or exposure levels that have been tested in individual studies; in an animal study, for example, treatment groups may differ in exposure by up to an order of magnitude. The preferred approach to arrive at a POD is to use BMD analysis; however, this approach requires adequate quantitative results for a meaningful analysis, which is not always possible. Use of a NOAEL is the next preferred approach in determining a POD for deriving a health-based exposure guideline. However, many studies lack a dose or exposure level at which an adverse effect is not observed (i.e., a NOAEL is not identified). When using data limited to a LOAEL, an uncertainty factor of 10 or 3 is often applied.
6. The database uncertainty factor is intended to account for the potential for deriving an underprotective value due to an incomplete characterization of the chemical's toxicity. In the absence of studies for a known or suspected endpoint of concern, an uncertainty factor of 10 or 3-fold is typically applied.

2.3.2. ACUTE NONCANCER EXPOSURE GUIDELINES

Many of the uncertainty factors used to account for variability and uncertainty in the development of acute exposure guidelines are quite similar to those developed for chronic durations, but more often using individual uncertainty factor values that may be less than 10. Uncertainty factors are applied based on chemical-specific or health effect-specific information (e.g., simple irritation effects do not vary appreciably between individuals, hence a value of 3 is typically used). The uncertainty factors generally applied in the derivation of acute toxicity values include: (1) heterogeneity among humans, (2) uncertainty in extrapolating from animals to humans, (3) uncertainty in LOAEL to NOAEL adjustments, and (4) uncertainty in accounting for an incomplete database on toxic effects of potential concern. Additional adjustments are often applied to account for uncertainty in extrapolation from observations at one exposure duration (e.g., 4 hours) to arrive at a POD for derivation of an acute toxicity value at another exposure duration (e.g., 1 hour).

2.3.3. CANCER EXPOSURE GUIDELINES

For cancer endpoints EPA usually derives an oral slope factor for ingestion and a unit risk value for inhalation exposures. These values allow estimation of an upper bound lifetime probability of developing cancer given long-term exposures to a pollutant. Depending on the pollutant being evaluated, EPA relies on both animal bioassays and epidemiological studies to characterize cancer risk. There is long-standing scientific support for the use of animal cancer bioassays as indicators of potential human risk when other human cancer risk data are unavailable. Extrapolation of study data to estimate potential risks to human populations is based upon EPA's assessment of the scientific database for a pollutant using EPA's guidance documents and other peer-reviewed methodologies. The EPA "Guidelines for Carcinogen Risk Assessment" describes the Agency's recommendations for methodologies for cancer risk assessment.[91] EPA believes that cancer risk estimates developed following the procedures described in the Cancer Guidelines and outlined below generally provide an upper bound estimate of risk. That is, EPA's upper bound estimates represent a "plausible upper limit to the true value of a quantity" (although this is usually not a true statistical confidence limit).[92] In some circumstances, the true risk could be as low as zero; however, in other circumstances the risk could also be greater. When developing an upper bound estimate of risk and to provide risk values that do not underestimate risk, EPA generally relies on conservative default approaches.[93] EPA also uses the upper bound (rather than lower bound or central) estimates in its assessments, although it is noted that this approach can have limitations for some uses (e.g., priority setting, expected benefits analysis).

[91]EPA. *Guidelines for Carcinogen Risk Assessment* (2005). U.S. Environmental Protection Agency, Washington, DC, EPA/630/P-03/001F. https://www.epa.gov/risk/guidelines-carcinogen-risk-assessment, (website), 12/1/2014.

[92]EPA's Integrated Risk Information System Glossary. http://ofmpub.epa.gov/sor_internet/registry/termreg/searchandretrieve/glossariesandkeywordlists/search.do?details=&glossaryName=IRIS%20Glossary (website), last accessed 12/1/2014.

[93]According to the NRC report *Science and Judgment in Risk Assessment* (NRC, 1994) "[Default] options are generic approaches, based on general scientific knowledge and policy judgment, that are applied to various elements of the risk-assessment process when the correct scientific model is unknown or uncertain." The 1983 NRC report *Risk Assessment in the Federal Government: Managing the Process* defined *default option* as "the option chosen on the basis of risk assessment policy that appears to be the best choice in the absence of data to the contrary" (NRC, 1983a, p. 63). Therefore, default options are not rules that bind the agency; rather, the agency may depart from them in evaluating the risks posed by a specific substance when it believes this to be appropriate. In keeping with EPA's goal of protecting public health and the environment, default assumptions are used to ensure that risk to chemicals is not underestimated. See U.S. EPA. (2002). A Review of the Reference Dose and Reference Concentration Processes. U.S. Environmental Protection Agency, Risk Assessment Forum, EPA/630/P-02/002F. Washington, DC.

3. Summary of Available Exposure Guidelines

3.1. Overview

The following is a descriptive list of health-based exposure guidelines that may be useful to risk assessors and decision-makers responding to a nationally significant or large-scale chemical incident. This list is organized by three general categories of exposure guidelines: (1) Occupational Values, (2) Emergency Response Values, and (3) General Public Health Protection Values.

3.2. Occupation Exposure Guidelines

3.2.1. OCCUPATIONAL EXPOSURE LIMITS — VARIOUS SOURCES AND ORGANIZATIONS

Several considerations apply to the selection of appropriate occupational exposure limits; they include both a maximum concentration of chemical in air and a defined exposure duration. The range of available limits include: (1) 8- to 10-hour time-weighted average (TWA) limits, (2) ceiling values, which are concentrations that should not be exceeded at any time during an 8-hour workday, and (3) short-term exposure limits (STELs), which are generally 15-minute exposure limits that should not be exceeded during the course of a workday. The ceiling and STEL values are assigned to substances that exert toxic effects over a short period of time.

Chemicals may have one or more of these values. For example, OSHA has assigned carbon disulfide both a ceiling value and a TWA. In this case, neither the ceiling value nor the TWA should be exceeded. A worker may experience multiple peak exposures during the work shift; however, none of these peaks may exceed the ceiling value. In addition, the average of these peaks and other total exposures over the entire work shift may not exceed the TWA value.

The STEL, ceiling, and TWA values are concentrations to which workers may be safely exposed daily, throughout their entire working life (up to 40 years). They are designed to protect healthy adults. It is, however, important to note that not all workers will be protected from adverse health effects even though their exposures are maintained below these levels. Some may experience adverse health effects because of personal susceptibility, a preexisting medical condition, and/or hypersensitivity (allergy). The occupational criteria are not intended for application to community exposure or the general public.

The primary sources of occupational exposure criteria for the workplace are: (1) NIOSH Recommended Exposure Limits (RELs); (2) the American Conference of Governmental Industrial Hygienists' (ACGIH)

Threshold Limit Values (TLVs); and, (3) OSHA's PELs, which include TWA, ceiling and STEL values.[94, 95, 96] The OSHA PELs are legally enforceable exposure limits, whereas the NIOSH RELs and ACGIH TLVs and BEIs are recommended guidelines.

Within an occupational setting, Occupational Exposure Banding (OEB) may be useful when other occupational exposure limits are not available or applicable. Additional information is available at the NIOSH Occupational Exposure Banding website.[97]

Additionally, the CDC has recommended exposure limits for workers to protect against potential exposure to the chemical warfare agents GA, GB, VX, H, and HD.[98, 99] These exposure limits are intended for use among workers involved in chemical weapons disposal. Similar to other occupational exposure guidelines, these worker population limits for chemical warfare agents are described in terms of 8-hour TWAs and STEL values and are applicable to long-term, routine work in dismantling chemical weapons.

3.2.2. IMMEDIATELY DANGEROUS TO LIFE OR HEALTH (IDLH) VALUES – NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH (NIOSH)[100]

IDLH values are published by NIOSH,[101] which defines an IDLH condition as a situation "that poses a threat of exposure to airborne contaminants when that exposure is likely to cause death or immediate or delayed permanent adverse health effects or prevent escape from such an environment." Furthermore, the stated purpose of establishing an IDLH values is to "ensure that the worker can escape from a given

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[94]NIOSH. 2004. *NIOSH Pocket Guide to Chemical Hazards*, DHHS (NIOSH) Publication No. 97-140. Cincinnati, OH. www.cdc.gov/niosh/npg/npg.html (website) last accessed 12/1/2014.

[95]ACGIH. 2021. *TLVs® and BEIs®.* Cincinnati, OH: ACGIH. https://www.acgih.org/tlv-bei-guidelines/policies-procedures-presentations/overview.

[96]OSHA Permissible Exposure Limits are available at: https://www.osha.gov/annotated-pels/, last accessed 2/7/2021.

[97] Occupational Exposure Banding information is available at https://www.cdc.gov/niosh/topics/oeb/default.html, last accessed 1/10/222.

[98]Centers for Disease Control and Prevention. *Final recommendations for protecting human health from potential adverse effects of exposure to agents GA (tabun), GB (sarin), and VX*, (website), https://www.govinfo.gov/app/details/FR-2003-10-09/03-25583. Fed Reg. 2003;68(196):58348-51.Accessed 2/7/2021.

[99] Centers for Disease Control and Prevention. *Interim recommendations for airborne exposure limits for chemical warfare agents H and HD (sulfur mustard)*, (website), https://www.govinfo.gov/app/details/FR-2004-05-03/04-9946. Fed Reg. 2004; 69(85):24164-8, last accessed 2/7/2021.

[100] See https://www.cdc.gov/niosh/docs/2014-100/

[101]NIOSH (2013). *Current Intelligence Bulletin 66: Derivation of Immediately Dangerous to Life or Health (IDLH) Values.* Cincinnati, OH: US HHS, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication 2014–100. http://www.cdc.gov/niosh/docs/2014-100/ (website) last accessed 12/1/2014. The actual published IDLH values can be found at: http://www.cdc.gov/niosh/idlh/intridl4.html, last accessed 12/1/2014.

contaminated environment in the event of failure of the respiratory protection equipment." A situation resulting in airborne concentrations at or near the IDLH value should be considered a non-routine event, and exposure duration should not exceed 30 minutes. However, the 30-minute period was not meant to imply that workers should stay in the work environment any longer than necessary following the failure of respiratory protection equipment. All available precautions should be taken to ensure that workers exit the environment immediately if exposures are at or near concentrations equivalent to IDLH values. NIOSH recently updated their methodology for deriving IDLH values and is in the process of establishing new values for hundreds of chemical agents.

The NIOSH respirator selection logic uses an IDLH value as one of several respirator selection criteria. Under the NIOSH respirator decision logic, respirators with the highest protection factor would be selected for emergency situations, firefighting, exposure to carcinogens, entry into oxygen-deficient atmospheres, entry into atmospheres that contain a substance at a concentration greater than 2,000 times the NIOSH REL or OSHA PEL, and for entry into potential IDLH conditions. These respirators with the highest protection factor include either a self-contained breathing apparatus (SCBA) that has a full face piece and is operated in a pressure-demand or other positive-pressure mode, or a supplied-air respirator that has a full face piece in combination with an auxiliary SCBA, both operated in a pressure-demand or other positive-pressure mode.

3.3. Emergency Response Exposure Guidelines

3.3.1. ACUTE EXPOSURE GUIDELINE LEVELS (AEGLS) – U.S. ENVIRONMENTAL PROTECTION AGENCY

The AEGLs are developed through an EPA Federal Advisory Committee and reviewed and published by the NRC, as specified in the Standard Operating Procedures (SOP) document.[102, 103] The development process includes one of the highest levels of peer-review and public participation.

The SOP document states that AEGLs "represent threshold exposure limits for the general public and are applicable to emergency exposures ranging from 10 min to 8 h."[104] The intended application of AEGL values is "for conducting various risk assessments to aid in the development of emergency preparedness and prevention plans, as well as real-time emergency response actions, for accidental chemical releases

[102]NRC. 2000. *Standing operating procedures for developing acute exposure guideline levels for hazardous chemicals*. Washington, DC: National Academy Press. Available at https://www.epa.gov/aegl/standing-operating-procedures-developing-acute-exposure-guideline-levels-aegls-hazardous, (website), last accessed 2/5/2021.

[103]EPA. (2020). *Acute Exposure Guideline Levels for Airborne Chemicals*, available at: https://www.epa.gov/aegl, (website), last accessed 2/5/2021.

[104]NRC (2000). *Standing operating procedures for developing acute exposure guideline levels for hazardous chemicals*. Washington, DC: National Academy Press.

at fixed facilities and from transport carriers."[105] The SOP document lays out the purpose and objectives of AEGLs by stating that "the primary purpose of the AEGL program and the AEGL Committee is to develop guideline levels for once-in-a-lifetime, short-term exposures to airborne concentrations of acutely toxic, high-priority chemicals."[106] Three health effect levels are developed for 10- and 30-minute and 1-, 4-, and 8-hour exposures, resulting in as many as 15 different AEGL concentration values for a specific chemical. These values are intended to protect the general public and include consideration of sensitive and susceptible persons, including sensitive subpopulations, but not hyper-sensitive or hyper-susceptible persons. The three AEGL health effect levels are defined below.

AEGL-1: The airborne concentration of a substance above which it is predicted that the general population, including susceptible persons, could experience notable discomfort, irritation, or certain asymptomatic, non-sensory effects. However, the effects are non-disabling and are transient and reversible upon cessation of exposure.

AEGL-2: The airborne concentration of a substance above which it is predicted that the general population, including susceptible persons, could experience irreversible or other serious, long-lasting health effects or impaired ability to escape.

AEGL-3: The airborne concentration of a substance above which it is predicted that the general population, including susceptible persons could experience life-threatening health effects or death.

The AEGLs are based primarily on acute toxicology data for vapor exposures, not subchronic or chronic exposure data. The AEGL values include uncertainty factors to account for variability in biological response in the human population. For carcinogens, the chemical-specific Technical Support Document (TSD) includes an evaluation of the degree of excess cancer risks anticipated for one-time exposure at the various AEGL levels (typically less than 1 in 1,000). The guidance does not consider or evaluate the effects that could result from repeated exposures.

AEGLs are not regulatory values, and the AEGL Committee does not provide specific guidance on their implementation or use. Instead, choices made on how and/or which AEGL value to use for various response decisions, such as evacuating or sheltering-in-place, are typically left up to the FSLTT officials responding to the incident. However, it is highly recommended that the expert scientific judgment of qualified toxicologists and/or hazard assessors be sought to help inform chemical- and site-specific decisions.

For each set of AEGLs for a chemical, an associated TSD describes the toxicological derivation of the values. Because the AEGL TSD contains a comprehensive review of all identified acute toxicology data on

[105]NRC (2000). Standing operating procedures for developing acute exposure guideline levels for hazardous chemicals. Page 31. Washington, DC: National Academy Press.

[106]NRC (2000). Standing operating procedures for developing acute exposure guideline levels for hazardous chemicals. Page 21. Washington, DC: National Academy Press.

the subject chemical and the basis for the development of the AEGL values, these documents may also have general use as toxicological references in situations involving an acute exposure scenario that goes beyond the intended purpose of the AEGLs. Planners and risk managers should seek the advice of qualified scientific expertise (toxicologists and/or risk assessors) who are familiar with the TSDs for specific chemicals in order to understand the basis for the AEGL values prior to using these values outside of their stated purpose.

3.3.2. EMERGENCY RESPONSE PLANNING GUIDELINES (ERPGS)—AMERICAN INDUSTRIAL HYGIENE ASSOCIATION

The ERPGs are developed by the American Industrial Hygiene Association and are intended for emergency planning and response operations (similar to AEGLs), but ERPGs are only based on a 1-hour exposure duration.[107] ERPGs are intended to protect most persons in the general population, but not particularly sensitive persons. They are reviewed at regular intervals as new information becomes available.

Definitions of the three levels of ERPG values are as follows:

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

ERPG-2: The maximum airborne concentration below which it is believed nearly all persons could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair a person's ability to take protective action.

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

3.3.3. PROVISIONAL ADVISORY LEVELS (PALS) – ENVIRONMENTAL PROTECTION AGENCY

The EPA Office of Research and Development's HSRP developed health-based provisional advisory levels (PALs) for priority toxic industrial chemicals, chemical warfare agents, and biotoxins in air and drinking water.[108] It is the intent of the PALs Program to provide exposure values for these agents as a means of assisting emergency response and decision-making, and to serve as criteria for determining reuse and temporary re-entry into affected areas. Situations that may necessitate the use of PALs include, but are not limited to, transport/storage accidents, natural disasters, and subversive activities. In the case of a

[107]American Industrial Hygiene Association. (2005). *2005 Emergency response planning guidelines (ERPGs)*. Fairfax, VA: AIHA. ERPGs for some chemicals available at: https://www.aiha.org/get-involved/aiha-guideline-foundation/erpgs, (website).

[108]Lipscomb, J. *Standing Operating Procedures (SOP) for the Development of Provisional Advisory Levels (PALs) for Hazardous Chemicals.* U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-18/224, 2018. https://cfpub.epa.gov/si/si_public_record_report.cfm?Lab=NHSRC&dirEntryId=342162 (website), last accessed 7/7/2020.

nationally significant or large-scale chemical release, EPA can provide PALs to appropriate end-users and stakeholders to evaluate the severity of the situation, identify potential human health outcomes, and determine the most appropriate course of action.

PALs represent a tiered risk system that predicts the likelihood of harm with increasing dose and duration of exposure. PALs provide additional context for risk characterization by extending the AEGL construct to include longer durations of inhalation exposure and the oral exposure route. PALs are developed for 24-hour, 30-day, and 90-day durations, with risk tiers (PAL 1, PAL 2, PAL 3) identified for each based on the severity of expected health outcomes. The health effect for a specific PAL is the biological response identified by a specific study or data set for which an exposure concentration-response or dose-effect relationship has been defined. Although PALs are developed with considerable attention to sensitive populations (e.g., asthmatics, persons with age-dependent sensitivities), PALs are not intended to protect hypersensitive populations.

PAL 1: Represents the assumed continuous exposure concentration of a chemical in air or water above which changes from baseline of specific biomarkers or mild physiological responses may occur in the general population. Concentrations at or below the PAL 1 values are not expected to be associated with adverse health effects. Increasingly greater concentrations above the PAL 1 value could cause progressively harmful effects in the general population, including all ages and sensitive subpopulations.

PAL 2: Represents the assumed continuous exposure concentration of a chemical in air or water above which serious, irreversible, or escape-impairing effects could result. Increasingly greater concentrations above the PAL 2 value could cause progressively harmful effects in the general population, including all ages and sensitive subpopulations.

PAL 3: Represents the assumed continuous exposure concentration of a chemical in air or water above which lethality in the general population, including all ages and sensitive subpopulations, could occur.

It is important to take the exposure duration into account when selecting an appropriate PAL. Since the shortest exposure duration for PALs is 24 hours, EPA recommends use of AEGLs for inhalation exposures to chemicals of less than 24 hours (See Section 3.3.1 above). The 30-day PAL is applicable to exposure durations of greater than 1 day, up to 30 days. The 90-day PAL is applicable to durations of greater than 30 days, up to 90 days.

3.3.4. TEMPORARY EMERGENCY EXPOSURE LIMITS (TEELS) – DEPARTMENT OF ENERGY

The Department of Energy (DOE) has published TEELs for about 1,200 chemicals.[109] TEELs adopt AEGLs and then ERPGs as their primary hierarchy for publication of values, but they also present values

[109]Craig, D. K., Davis, J. S., Hansen, D. J., Petrocchi, A. J., Powell, T. J., & Tuccinardi, T. E. (2000). *Derivation of temporary emergency exposure limits (TEELs).* Journal of Applied Toxicology, 20(1), 11-20.

obtained by other methods for use when AEGLs or ERPGs are not available. Values derived by these other methods are not peer reviewed. In the absence of AEGL and ERPG values, TEELs are based on the correlation between acute data (e.g., lethal concentration, lowest lethal concentration, median lethal concentration) and existing values (e.g., IDLH, STEL, TLVs, and various levels of existing ERPGs). DOE thus provides a methodology for combining hierarchy- and toxicity-based TEELs into procedure-derived TEELs to facilitate its use by anyone requiring concentration limits for chemicals. TEEL values, like the ERPGs, are based on a 1-hour exposure duration. The various TEEL definitions are as follows.

TEEL-0: The threshold concentration below which most persons will experience no appreciable risk of health effects.

TEEL-1: The maximum concentration in air below which it is believed nearly all persons could be exposed without experiencing other than mild transient adverse health effects or perceiving a clearly defined objectionable odor.

TEEL-2: The maximum concentration in air below which it is believed nearly all persons could be exposed without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action.

TEEL-3: The maximum concentration in air below which it is believed nearly all persons could be exposed without experiencing or developing life-threatening health effects.

3.4. General Public Health Protective Exposure Guidelines

3.4.1. INTEGRATED RISK INFORMATION SYSTEM (IRIS) – ENVIRONMENTAL PROTECTION AGENCY

The IRIS, prepared and maintained by EPA, is an electronic database containing information on human health effects that may result from exposure to various chemicals in the environment. IRIS contains descriptive and quantitative information and includes oral reference doses (RfDs) and inhalation reference concentrations (RfCs) for chronic noncarcinogenic health effects and oral slope factors and inhalation unit risks for carcinogenic effects. RfDs are usually provided in units of mg/kg-day, and RfCs in units of mg/m^3. Oral/Cancer Slope Factors (CSF) are usually provided in units of $(mg/kg\text{-}day)^{-1}$, and Inhalation Unit Risk values (IUR) are provided in (microgram per cubic meter [$\mu g/m^3$])$^{-1}$. RfDs, CSFs, and IURs are not directly comparable to environmental concentrations. However, they can be used in equations, along with exposure assumptions, to derive health-based exposure guidelines that can be compared directly to environmental concentrations.

EPA IRIS values represent the Agency's consensus for chronic toxicity values. Many other federal and state agencies also make IRIS their preferred source of toxicity values. IRIS assessments are externally peer-reviewed before they are released as final assessments.

Reference Doses and Reference Concentrations

RfDs and RfCs are generally defined as an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. It can be derived from a NOAEL, a LOAEL, or a benchmark dose, with default or data-derived uncertainty factors generally applied to reflect limitations of the data used.[110]

Oral/Cancer Slope Factors

The CSF is defined as a plausible upper bound on the increased cancer risk from a lifetime exposure to an agent. This estimate is usually expressed as a dose in units of proportion (of a population) affected per mg/kg-day.

Inhalation Unit Risk Values

The upper bound excess lifetime cancer risk estimated to result from repeated exposure to an agent at a concentration of 1 µg/m^3 in air. The interpretation of IUR would be as follows: if unit risk = 2 x 10^{-6} per µg/m^3, 2 excess cancer cases (upper bound estimate) are expected to develop per 1,000,000 people if exposed daily for a lifetime to 1 microgram of the chemical in 1 cubic meter of air.

3.4.2. PROVISIONAL PEER-REVIEWED TOXICITY VALUES (PPRTVS) – ENVIRONMENTAL PROTECTION AGENCY

EPA's Office of Research and Development/National Center for Environmental Assessment/Superfund Health Risk Technical Support Center (STSC) develops PPRTVs on a chemical-specific basis when requested by EPA's Superfund program.[111] The PPRTVs are developed specifically for, and used by, the Superfund Program. Although subject to review and public comment on a site-specific basis as part of the site decision-making process, the PPRTVs are provisional values, and are not widely disseminated.

IRIS normally represents the official EPA scientific position regarding the toxicity of a chemical based on the data available at the time of the review. When no IRIS values are available, the second tier is EPA's PPRTVs. Generally, PPRTVs are derived for one of two reasons. First, the STSC is conducting a batch-wise review of the toxicity values previously published in the Health Effects Assessment Summary Tables (HEAST). As such reviews are completed, those toxicity values are removed from HEAST, and any new toxicity value developed in such a review will be placed in the PPRTV database. Second, Regional Superfund Offices may request a PPRTV for contaminants lacking a relevant IRIS value. The STSC uses the same methodologies to derive PPRTVs in either case.

Where an appropriate toxicity value is not available, a PPRTV may be developed by EPA for a chemical of concern following a nationally significant or large-scale release. SMEs and decision-makers could then

[110]EPA's Integrated Risk Information System information available at: http://www.epa.gov/iris/, (website), last accessed 12/1/2014.

[111]Information on Permissible Exposure Limits at: https://hhpprtv.ornl.gov/, (website), last accessed on 2/7/2021.

review the supporting documents and derivation of the PPRTV to determine its appropriateness in developing a site- or situation-specific decision.

3.4.3. ACUTE INTERMEDIATE AND CHRONIC MINIMUM RISK LEVELS (MRLS) – AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

The ATSDR has developed MRLs in response to mandates under the CERCLA, as amended by the Superfund Amendments and Reauthorization Act.[112]

An MRL is an estimate of the daily human exposure to a hazardous substance that is likely to be without appreciable risk of adverse noncarcinogenic health effects over a specified duration of exposure. These values are not regulatory numbers but are used by ATSDR health assessors and others to identify contaminants and potential health effects that may be of concern at hazardous waste sites.

MRLs are set below levels that, based on current information, might cause adverse health effects in the persons most sensitive to such substance-induced effects. Most MRLs contain some degree of uncertainty because of the lack of precise toxicological information on persons who might be most sensitive (e.g., infants, elderly, and the nutritionally or immunologically compromised) to effects of hazardous substances. In deriving MRLs, ATSDR uses a health-protective approach to address these uncertainties by applying uncertainty factors and modifying factors to the toxicity data. ATSDR states that exposure to a level above the MRL does not necessarily mean that adverse health effects will occur.

MRLs are derived for exposure durations of 1 to 14 days via the oral and inhalation routes of exposure. While ATSDR refers to this duration as acute, it corresponds to the EPA/IRIS short-term exposure scenario (see Section 2.2). In addition, ATSDR derives oral and inhalation MRLs for longer-term exposure durations: intermediate (>14 to 364 days) and chronic (365 days and longer).

MRLs receive extensive internal and external peer-review.

3.4.4. ACUTE AND CHRONIC REFERENCE EXPOSURE LEVELS (CA-RELS) – STATE OF CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY

The California EPA (CalEPA) Office of Environmental Health Hazard Assessment has published reviews of the acute health effects for 51 chemical contaminants and recommends acute CA-RELs for each chemical based on the appropriate and sensitive adverse health effect.[113] The CA-RELs are distinct from the NIOSH occupational RELs. The CA-RELs have a heavy emphasis on the utilization of available human data, with two-thirds of the acute CA-RELs based on observed human health outcomes. The final values

[112] U.S. HHS ATSDR. (2020, October). *Minimal Risk Levels (MRLs) for Hazardous Substances*. Retrieved February 7, 2021, from https://www.atsdr.cdc.gov/mrls/mrllist.asp. (website).

[113]State of California Office of Environmental Health Hazard Assessment (June 2008). *Air Toxics Hot Spots Program Technical Support Document for the Derivation of Noncancer Reference Exposure Levels*. https://oehha.ca.gov/air/crnr/notice-adoption-air-toxics-hot-spots-program-technical-support-document-derivation, (website), last accessed 2/6/2021.

incorporate uncertainty factors similar to those used in deriving RfCs for chronic exposures. CalEPA derives acute (1-hour) inhalation CA-RELs for hazardous airborne substances. The acute CA-REL represents an exposure that is not likely to cause adverse effects in a human population, including sensitive subgroups, exposed to that concentration for 1 hour on an intermittent basis.[114]

Cal-EPA also publishes chronic CA-RELs for 80 substances.[115] Chronic CA-RELs are concentrations or doses at or below which adverse health effects are not likely to occur. A central assumption is that a population threshold exists below which adverse effects will not occur in a population; however, such a threshold is not observable and can only be estimated. Areas of uncertainty in estimating effects among a diverse human population exposed continuously over a lifetime are addressed using extrapolation and uncertainty factors. Protection against carcinogenicity and against adverse health effects of short-term exposures are not considered in these guidelines. For this reason, chemicals should be evaluated separately for their carcinogenic potential and additional acute health effects that may occur.

Cal EPA's Toxicity Criteria Database provides peer-reviewed toxicity values that address both cancer and noncancer effects.[116]

3.4.5. GENERAL POPULATION LIMITS (GPLS) FOR CHEMICAL WARFARE AGENTS – CENTERS FOR DISEASE CONTROL AND PREVENTION

CDC recommends GPLs, which are long-term (lifetime) exposure limits for several chemical warfare agents in air, applicable to populations surrounding chemical weapons disposal sites. GPLs have been developed for GA, GB, VX, HD, and L.[117, 118]

[114]Air Toxics Hot Spots Program (March 1999). *Risk Assessment Guidelines, Part I: Determination of Acute Reference Exposure Levels for Airborne Toxicants*, CalEPA, Office of Environmental Health Hazard Assessment, Air Toxicology and Epidemiology Section.

[115]State of California Office of Environmental Health Hazard Assessment (November 2019). *OEHHA Acute, 8-hour and Chronic Reference Exposure Level (REL) Summary*. http://www.oehha.ca.gov/air/allrels.html. (website), last accessed 2/5/2021.

[116]California OEHHA, Available at http://www.oehha.ca.gov/risk/ChemicalDB/index.asp, last accessed 12/1/2014.

[117]HHS CDC (2003). *Final Recommendations for Protecting Human Health From Potential Adverse Effects of Exposure to Agents GA (Tabun), GB (Sarin), and VX.* Federal Register / Vol. 68, No. 196. Information available at http://www.cdc.gov/nceh/demil/files/Federal%20Register%20Reprint%20-%20October%209.pdf, (website), last accessed 12/1/2014.

[118]HHS CDC (2004). *Interim Recommendations for Airborne Exposure Limits for Chemical Warfare Agents H and HD (Sulfur Mustard).* Federal Register / Vol. 69, No. 85. http://www.cdc.gov/nceh/demil/files/Federal%20Register%20Mustard%20AEL%205_2004.pdf, (website), last accessed 12/1/2014.

3.4.6. OTHER PEER-REVIEWED VALUES OR CONCENTRATION LEVELS

In the absence of chemical-specific toxicity values from one of the above sources (EPA, ATSDR or Cal-EPA), one should consider other peer-reviewed published values. For example, the NRC/NAS has reviewed and published the RfDs for six chemical warfare agents (GA, GB, GD, VX, HD, and L) and a CSF for sulfur mustard.[119] Additionally, a set of peer-reviewed studies developed site and situation-specific clearance goals for an airport CWA attack scenario.[120, 121]

[119]NRC (1999). *Review of the U.S. Army's Health Risk Assessments for Oral Exposure to Six Chemical-Warfare Agents.* Washington, DC: National Academy Press.

[120]Watson A, Hall L, Raber E, et al. 2011a. "*Developing Health-Based Pre-Planning Clearance Goals for Airport Remediation Following a Chemical Terrorist Attack: Introduction and Key Assessment Considerations*." Human and Ecological Risk Assessment, 17:2–56.

[121]Watson A, Dolislager F, Hall L, et al. 2011b. "Developing Health-Based Pre-Planning Clearance Goals for Airport Remediation Following a Chemical Terrorist Attack: Decision Criteria for Multipathway Exposure Routes." Human and Ecological Risk Assessment, 17:57–121.

4. Application of Health-Based Exposure Guidelines in Decision-Making

4.1. Overview

As stated previously, inhalation toxicity values are often presented as a concentration of a particular chemical in air and may be directly compared to environmental concentrations and can, therefore, be considered exposure guidelines. Conversely, oral toxicity values are often presented as an applied or administered dose (e.g., mg/kg-day), which are subsequently used in equations to derive values that may be useful for establishing exposure guidelines or clearance goals for drinking water, soil, and surfaces.

4.2. Importance of Understanding the Basis for an Exposure Guideline

During planning activities or in response to an actual chemical incident, selection of an appropriate exposure guideline on which to make protective action decisions may greatly affect the choice and/or level of response activity. For example, for many people evacuation from their homes can be a very traumatic and disruptive event, with a set of risks associated with their evacuation. Decisions regarding re-use of critical infrastructure facilities such as water treatment, power, and government facilities, as well as hospitals, schools, day care facilities, and prisons can pose difficult risk management questions. Selection of health-based exposure guidelines that are very stringent could result in an unneeded evacuation or inappropriately focused response. Conversely, selection of values that are not stringent enough for final clearance goals may lead to long-term health effects in an exposed population.

Familiarity with the various human health-based exposure guidelines and development of emergency plans and how they might be implemented will help facilitate these decisions in an actual chemical event. Fully understanding the derivation, uncertainties, and possible limitations of an exposure guideline is critical to determining its appropriateness for use in a specific situation.

4.3. Factors to Consider When Selecting an Appropriate Exposure Guideline

Target population, exposure duration, intended application, and level of peer-review are some of the factors that should be considered in choosing an appropriate exposure guideline. No single set of exposure guidelines 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. Also, if an available exposure guideline does not adequately reflect the site- and situation-specific nature of the scenario, a toxicologist should be consulted to derive a *de novo* site-specific exposure guideline.

It is important to differentiate the concepts of short-term or long-term exposures from the resulting *acute* health effects (effects represented by a short and often relatively severe course) or *chronic* health effects (effects persisting over a long period of time). A short-term exposure, for example, could result in either an acute or chronic health effect. Acute or chronic exposure guidelines, however, are derived assuming a specific duration of exposure.

In this document, the choice of appropriate exposure guidelines includes the question of whether a long-term exposure could feasibly exist (e.g., due to persistence of chemical hazards). One must, at a minimum, mitigate the potential for any acute effects that might arise from short-term exposures. However, one should also evaluate whether there is the potential for long-term health effects that might not be addressed by mitigating acute/short-term exposures.

Not all acute exposure guidelines are developed for the same purpose and care must be taken when interpreting the results of an acute impact assessment relative to the exposure guideline exceeded. In particular, the emergency response exposure guidelines (e.g., AEGLs or ERPGs) are derived to address rare, short-term exposure situations and often use lower uncertainty factor values for that purpose. In contrast, the acute CA-RELs developed by the State of California address continuous or short-term emissions of airborne toxicants to which the public living or working in communities surrounding industrial facilities is at risk of being exposed. Acute CA-RELs are based on the most sensitive, relevant, adverse health effect reported in the medical and toxicological literature. These values are designed to protect the most sensitive persons in the population by incorporating relatively protective uncertainty factors. The uncertainty factors incorporated to address data gaps and other factors are similar to those used in developing chronic toxicity values. Other considerations regarding the definition of a particular exposure guideline and the basis for its derivation (i.e., whether it is intended to account for single exposure events [AEGLs] or protect against the possibility of repeating exposures [Acute CA-RELs]), and the health effect severity level (e.g., cases where an AEGL-1 or ERPG-1 are unavailable) should be factored into the risk characterization as potential uncertainties.

4.4. Overview and Description of Health-Based Exposure Guidelines

In the context of a chemical incident, human exposures may occur to chemicals via contaminated air, drinking water, soils or surfaces.[122] For any of these materials and surfaces, human exposures to chemicals may occur through inhalation, ingestion and/or dermal contact. Generally, the primary exposure pathways of concern are inhalation of contaminated air, ingestion of contaminated drinking water, incidental ingestion of contaminated soil, and/or dermal contact with contaminated surfaces.

Some chemical contaminants may contribute exposure via other pathways (i.e., inhalation of a volatile chemical from soil, surface or water; dermal absorption from surface water). In such cases, a multi-pathway risk assessment approach should be used.

Health-based exposure guidelines for workers and the general population are needed to appropriately plan for potential risks resulting from chemical incidents. A number of organizations have developed short-term and long-term exposure guidelines, each with a specific purpose, target population(s) to

[122]The criteria described in this document are for addressing human health issues and do not specifically address potential ecological impacts.

protect, exposure scenarios (e.g., accidental releases, workplace, environmental screening), and severity of adverse health effects considered in their development.[123]

Selection of appropriate health-based exposure guidelines is complicated by several factors, including the following:

- Multiple sources of available exposure guidelines for the same substance
- Differences in exposure guidelines with respect to exposure duration
- Differences in the target population (occupational verses general population)
- Differences in the intended uses of the exposure guidelines
- Variations in the applicable averaging exposure times among exposure guideline
- Differences in the severity of potential health effects associated with the various exposure guidelines
- Gaps in available exposure guidelines.

4.5. Selecting and Applying Health-Based Exposure Guidelines for the General Population

The purpose of this discussion is to examine the suitability, selection, and application of health-based exposure guidelines for the *general population,* which includes a variety of potentially susceptible subpopulations such as children, the elderly, those with genetic or existing disease traits (e.g., asthmatic or immuno-compromised persons), or populations experiencing high and adverse human effects or environmental events, practices or programs.

The exposure guidelines appropriate to each phase of an incident involving hazardous chemicals should reflect the nature of the activity and population to protect, with the objective being the eventual return to normal operations and permanent resumed use/re-occupancy of the affected facilities. Some values will reflect clearance goals, whereas others will be useful in determining acceptable exposure levels during the response effort (i.e., characterization, decontamination and cleanup operations).

For *carcinogens*, an effect level may be based on a toxicity value, such as a "unit risk" level or a "cancer slope factor" (CSF). Since cancer effects are considered non-threshold (any exposure will increase risk), a risk management determination would be necessary to establish a concentration criteria.[124] When both cancer and noncancer effects are caused by a chemical, a risk management decision must be

[123]Woodall, George M., *Acute Health Reference Values: Overview, Perspective, and Current Forecast of Needs.* Journal of Toxicology and Environmental Health, Part A. 68:901-926, 2005.

[124]For further discussion on how the CERCLA applies the risk range: U.S. EPA (1991). *Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions*, Office of Emergency and Remedial Response, Washington, DC. OSWER 9355.0-30.

made as to which effect will drive the decision on a cleanup goal or clearance decision. Often, both are mitigated to a large extent by addressing noncarcinogenic effects, but depending on the level of risk the stakeholders consider acceptable, the cancer endpoint could be a much-lower value.

The following sections discuss specific considerations in selecting health-based exposure guidelines for different media: air, water and soil, and surfaces.

4.5.1. HEALTH-BASED EXPOSURE GUIDELINES FOR AIR

Table A-1 provides a list (should not be interpreted as an exhaustive list) of available inhalation exposure guidelines for the general population matched to each phase of a incident response and recovery.

Table A-1: Existing Inhalation Exposure Guidelines Applicable to the General Public

Duration of exposure	Is exposure expected to be repeated?[a]	Exposure guidelines to be considered
< 8 hours	No	AEGL[b], ERPG[b]
	Yes	24-h PAL, Acute CA-REL, Occupational TWA values[c]
< 24 hour (repeated)	N/A	
1–30 days (repeated)	N/A	30-day PAL, Acute MRL, Occupational TWA values[b, c]
30–90 days (repeated)	N/A	90-day, Intermediate MRL, RfC, IURd
Chronic exposure	N/A	RfC, IURd, Chronic MRL, Chronic CA-REL c

[a]In the early phase of an incident (i.e., in the first few days), there may be a potential for a repetition of exposure to a toxic airborne chemical. When a single exposure event occurs, but the potential for a subsequent exposure event to occur in the next few days due to recurrence or remediation activities exists, a different hierarchy needs to be applied.

[b] Emergency response exposure guidelines such as AEGLs and ERPGs are derived using an assumption of a "once-in-a-lifetime" exposure event. As such, the chemical-specific and incident-specific details should be considered by qualified toxicologists and/or risk assessors prior to using these types of values in instances other than the immediate response to a chemical release (e.g., a single, non-repeated release of duration less than 8 hours).

[c]Occupational values should be used cautiously and only if no, more appropriate values for the general public are available. Expert scientific judgment should be consulted before using these values outside the occupational setting.

[d]The RfC and health-based exposure guidelines derived from an IUR for cancer from IRIS are essentially equivalent in ranking, and the use of the value with a lower concentration should be the first consideration.

4.5.2. HEALTH-BASED EXPOSURE GUIDELINES FOR WATER AND SOIL

Pre-calculated, health-based exposure guidelines for materials and surfaces other than air are not as prevalent and primarily address long-term, chronic exposures. ATSDR MRLs are available for acute, intermediate, and chronic exposure durations, but for materials and surfaces other than air, MRLs are not presented as concentrations that can be directly compared to environmental data. Instead, they are presented as doses (e.g., mg/kg-day), which may be used in the derivation of health-based exposure guidelines. Similarly, EPA RfDs and CSFs are not directly comparable to environmental concentrations but may be used in equations to derive health-based exposure guidelines expressed as environmental concentrations.

For drinking water, a list of drinking water exposure guidelines is available from EPA's "2018 Edition of the Drinking Water Standards and Health Advisories."[125] Examples of drinking water exposure guidelines include Maximum Concentration Levels, Health Advisories (1-day, 10-day and Lifetime values), and Drinking Water Equivalent Levels. For other materials and surfaces and for those chemicals without Maximum Concentration Levels or other drinking water exposure guidelines, EPA's Superfund program has developed tools for calculating risk-based screening levels using chronic toxicity values and a set of default exposure assumptions for residential and nonresidential land uses. EPA has developed screening levels for chronic exposure to soil, water, and air for both residential and occupational exposures. These values are available to risk assessors for use in site-specific decision-making.

State-adopted and EPA-approved water quality standards are Applicable or Relevant and Appropriate Requirements for remedial cleanup. Most states have more than 100 water quality standards for toxins and conventional pollutants. They may include, depending on the state, chemicals that could be involved in a large-scale, nationally significant chemical incident.

In addition, DOD has developed screening levels specifically for chemical warfare agents. The U.S. Army Public Health Center has developed a list of environmental screening levels for CWAs including in water, soil, and waste.[126]

Table A-2 provides a list of available soil, surfaces, and drinking water exposure guidelines for the general population matched to each phase of an incident response.

[125]U.S. EPA (2018). *2018 Edition of the Drinking Water Standards and Health Advisories*. EPA 822-F-18-001. https://www.epa.gov/sites/default/files/2018-03/documents/dwtable2018.pdf (website), last accessed 11/24/2021.

[126]U.S. Army Public Health Command. (2011). *Chemical Agent Health-Based Standards and Guidelines Summary* Table 2: Criteria for Water, Soil, Waste. PHN No: 0711-03. https://phc.amedd.army.mil/PHC%20Resource%20Library/envmed-chemagent-health-guide-table2.pdf (website), last accessed 11/24/2021.

Table A-2: Existing Exposure Guidelines Applicable to the General Public for Soil, Surfaces, and Drinking Water

Duration of exposure	Media	Exposure guidelines to be considered
Acute	All	24-h Oral PAL, Acute CA-REL, Occupational TWA values[a]
1–30 days (repeated)	All	30-day Oral PAL, Acute Oral MRL
30s–90-days (repeated)	All	90-day, Intermediate Oral MRL, RfD, CSF[b]
Chronic exposure	All	RfD, CSF[b], Chronic Oral MRL
	Drinking Water	EPA Maximum Concentration Levels, EPA Lifetime Health Advisory

[a]Occupational values should be used cautiously and only if no, more appropriate values for the general public are available. Expert scientific judgment should be consulted before using these values outside the occupational setting.

[b]The RfC and health-based exposure guidelines derived from an IUR for cancer from IRIS are essentially equivalent in ranking, and the use of the value with a lower concentration should be the first consideration.

4.5.3. CONTAMINATED SURFACES

There are few peer-reviewed, published values for short- or long-term dermal toxicities. 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 were 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)."[127]

The RAGS Part B provides methodologies to calculate cleanup goals for environmental materials and surfaces such as soil and water.[128] More recently, the Agency recognized the need to expand its efforts to include building surfaces. Subsequent to the attack on the World Trade Center, EPA became involved in efforts to develop risk-based surface cleanup goals using methodology similar to that provided by RAGS

[127]See Chapter 4 of the EPA. (2004). Risk Assessment Guidance for Superfund (RAGS), Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment. Available at: https://www.epa.gov/risk/risk-assessment-guidance-superfund-rags-part-e, (website), last accessed 2/5/2021.

[128]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.

Part B.[129] Other available methods for the derivation of surface cleanup goals have been developed by CalEPA that incorporate EPA's Stochastic Human Exposure and Dose Simulation Model[130] and the U.S. Army Public Health Center.[131]

[129]U.S. EPA (2003). World Trade Center Indoor Environment Assessment: Selecting Contaminants of Potential Concern and Setting Health-Based Benchmarks. Prepared by the Contaminants of Potential Concern Committee of the World Trade Center Indoor Air Task Force Working Group.

[130]U.S. EPA. (2020). *Stochastic Human Exposure and Dose Simulation (SHEDS) to estimate human exposure to chemicals,* (website), https://www.epa.gov/chemical-research/stochastic-human-exposure-and-dose-simulation-sheds-estimate-human-exposure, last accessed 2/5/2021.

[131] U.S. Army Public Health Center. (2018). Health Risk Assessment & Occupational and Environmental Health Surveillance. (website). https://phc.amedd.army.mil/topics/envirohealth/hrasm/Pages/default.aspx.

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Appendix B: Example Phases of Chemical Incident Consequence Management and Risk Assessment/Risk Management Decisions

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Introduction

This appendix contains three examples of chemical incidents requiring decisions during various operational phases of chemical incident consequence management phases. The first scenario provides an example involving a chlorine release (based on an actual incident). The second example is a case study of an actual chemical warfare agent (CWA) remediation project. The third scenario describes an example of responses that may be taken following a release of the blister agent HD. This information is provided as a template and provides general information to be used along with the information in this framework document. Table B-1 includes information on the activities that occur during each of the response phases and can be used as a guide for both examples.

Table B-1: Generic Scenario Response and Recovery Phases

RESPONSE AND RECOVERY ACTIVITIES					
Phases 2a&b		**Phases 2c & 3a**			
Notification	**First Response**	**Restoration**			**Recovery**
		Characterization	**Remediation (Cleanup)**	**Clearance**	
Receive and assess information Identify suspect release sites Relay key information and potential risks to appropriate agencies	HAZMAT and emergency actions Forensic investigation Public health actions Screening sampling Determination of agent type, concentration, and viability Risk communication (e.g., public warnings and recommended protective actions)	Worker health and safety Detailed characterization of hazardous chemical Characterization of affected area/site(s) Site containment Environmental sampling and analysis Initial risk assessment Cleanup goals Waste management planning Continued risk communication	Worker health and safety Source reduction Decontamination strategy Remedial Action Plan Site preparation Waste management Decontamination of sites, items, or both Verification of decontamination parameters Seal/cap, decommission, or demolish if necessary Continued risk communication	Worker health and safety Clearance sampling and analysis Clearance decisions Continued risk communication	Renovate or replace Resumed Use/Re-occupation decision Potential environmental and public health monitoring Continued risk communication

1. Chlorine Gas Spill Example

The following example illustrates the decision-making criteria and process used in a theoretical deliberate chlorine release in the United States. Using information gleaned from a chlorine release, this example demonstrates specific interagency activities and associated decision criteria that could plausibly be used in the event of an actual deliberate chlorine release. The summary of the incident is presented below followed by Table B-2, which contains scenario-specific details from the chlorine example for each of the response phases. Refer to Appendix A for more details on exposure guidelines included with this scenario.

1.1. Incident Summary

A train carrying hazardous material was deliberately derailed in a residential/commercial area in the southeastern U.S. Three train cars contained chlorine. One chlorine rail car containing 90 tons of product released approximately 40 tons of chlorine, retaining the rest (50 tons of product) due to auto-refrigeration. The release of chlorine vapor migrated from the derailment site, over and through an adjacent working factory and then over a large number of commercial and residential areas in the city before it dissipated. Because chlorine gas is denser than air, some of the chlorine gas settled into low-lying areas and dissolved into the waters of a nearby creek located adjacent to the factory. A fish kill was subsequently observed due to this release.

The other chlorine rail cars were derailed and the integrity of these cars was initially unknown. Additionally, approximately 3,000 gallons of diesel fuel were discharged from one of the wrecked locomotives.

Potential threats to public health and the environment posed by this incident included: actual and potential exposure of humans and animals to chlorine vapors in the air; potential dermal exposure to chlorine and hydrochloric acid near the derailment scene; actual and potential chlorine exposure of aquatic life in nearby surface water bodies; and a threat of discharge of oil into a waterway. In addition, the other cars containing chlorine presented a serious threat of potential release into the environment.

The derailment and release killed several people, injured approximately 250, and required the evacuation of about 5,400 people within a one-mile radius of the incident. The response phases spanned a period of two weeks.

1.2. Response Phases

1.2.1. PHASES 2A&B

- **Notification:** The incident occurred in the early morning hours. The initial response was led by the local volunteer fire department and the county Sheriff's Office. The state EOC was notified of the incident. The railroad company reported the release of chlorine to the NRC. The state Department of Health and Environmental Control (DHEC), State Law Enforcement Division, County Emergency Services, Federal Railroad Administration, and the EPA were notified via a NRC report number. EPA's

Regional Duty On-Scene Coordinator dispatched Superfund Technical Assessment and Response Team (START) contractors to the local command post. EPA established an EOC and coordinated an information stream to appropriate agencies. EPA activated a UC and a PIO. National Response Team[132] were informed and activated to assist Regional NRT and the designated Federal On-Scene Coordinator (FOSC) in managing this incident. An initial evacuation of a 0.5-mile radius was ordered and persons located outside the evacuation area were advised to shelter-in-place.

- **First Response:** Personnel from the local volunteer fire department, the county Sheriff's Office, State DHEC, State Law Enforcement Division, County Emergency Services, Federal Railroad Administration and railroad company representatives were at the scene. These entities made the initial assessments of the conditions in and around the derailment scene. Mutual aid assets from other local agencies were on scene or *en route*.[133]

EPA collected all available data from local responders and initiated air monitoring in support of the response effort for protection of response workers as well as the general public. Given the magnitude and hazardous nature of the incident, EPA requested additional resources from Atlanta, including EPA staff, contractors, the ATSDR, and a team from the U.S. Coast Guard (USCG) National Strike Force (NSF Strike Team) that has Level A PPE capabilities.

START personnel in Level B protection entered th e hot area to monitor chlorine levels using single point monitors. Based on the chlorine levels and other factors (e.g., wind patterns, unknown integrity of the railcars), federal, state, and local officials decided that the evacuation area should be expanded to a 1.0-mile radius, a shelter-in-place area with a 2.0-mile radius should be established, and a mandatory curfew instituted.

Initial reports indicated that several fatalities and numerous injuries resulted from the release. Further investigations subsequently determined that nine persons, including the engineer, died from exposure to the chlorine gas. Eight of the deceased were found in areas lower than the crash due to the gas dissemination into low-lying areas.

Persons who were potentially exposed to chlorine were sent to local hospitals for decontamination and follow-up care. Unofficial reports indicated that approximately 250 people were admitted to the hospital emergency room for treatment.

[132]More information available at NRT website: https://nrt.org/. Accessed 2/7/2021.

[133]Mutual aid involves sharing resources and services between jurisdictions or organizations. Mutual aid occurs routinely to meet the resource needs identified by the requesting organization. This assistance can include the daily dispatch of law enforcement, emergency medical services (EMS), and fire service resources between local communities, as well as the movement of resources within a state or across state lines when larger-scale incidents occur. Mutual aid can provide essential assistance to fill mission needs. NIMS resource management guidance supports mutual aid efforts nationwide.

The Governor issued an executive order declaring a state of emergency for the county and schools and businesses were closed.

The local hospital established two triage units to handle the patient overflow. Exposed individuals were told to report to decontamination units set up at a local school. Two tents were established for decontamination and medical attention.

The FBI and National Transportation Safety Board began investigations of the derailment site as the railroad company began initiating operations to remove undamaged railcars and stabilize the damaged railcars. Concurrently, search and rescue operations were conducted by local officials.

1.2.2. PHASE 2C

- **Characterization:** UC tasked the Planning Section Chief to develop an IAP, a SAP, a HASP and an AAMP. EPA and USCG, with state and local assets, deployed for sampling and monitoring to define the chlorine gas plume and monitor air quality at locations in the surrounding community.

START and NSF Strike Team set up Area Rae™ chlorine monitors and established data monitoring centers; the operation was conducted in Level B. Chlorine monitors were placed around the area. Checkpoints were set up where responders entering the area of the incident were required to check in and out. These checkpoints were used to warn responders of the latest monitoring results and current activities in the area of the incident. A web-based server was created by a contractor for use in posting air monitoring data.

- **Remediation (Cleanup):** The site was managed by a task force which coordinated all sampling and analysis, decontamination, and health and safety issues. The sampling plan was modified as needed to include samples to verify decontamination efficacy, iteratively, during the remediation process. Representatives from EPA, CDC, potential UCG participation, FEMA, the state, the railroad company, and other stakeholders were selected to participate in the Technical Working Group.

EPA used a model (Areal Locations of Hazardous Atmospheres) to predict the chlorine gas plume movement. EPA also oversaw application of lime slurry to the incident scene area to minimize chlorine releases from the soils near the damaged chlorine tanker rail cars. The state investigated the scope of the fish kill and disposed of the fish carcasses. An EPA veterinarian mobilized to the site to assist local animal control officials with animal care issues in both the exclusion area and evacuated areas. The railroad company decontaminated and removed the railcars.

- **Clearance:** UC was tasked to develop the Clearance Sampling Plan using the clearance decision criteria agreed upon by technical SMEs. The detection limits were evaluated as sufficient to meet agreed upon clearance decision criteria. Sampling and analysis continued to verify decontamination efficacy and the area was cleared by UC.

EPA, NSF Strike Team, and START provided additional assistance to local officials in monitoring and evaluating conditions in buildings impacted by the chlorine release. One entry was conducted to recover a computer

processing unit that contained critical information to support the restart process for the impacted factory. No elevated chlorine levels were detected.

- **Phase 3 Restoration/Recovery:** The IC/UC, closely coordinating with the local agencies, cleared the residential and business areas for re-occupancy and communicated information to the community. All air and surface concentrations were below clearance decision criteria. Local and state Departments of Environmental Protection (DEPs) continued ambient air monitoring to ensure levels were below health-based exposure guidelines established by technical SMEs. The PIO continued to be in place to address public concerns.

The evacuation order was lifted. EPA conducted air monitoring for detection of chlorine and wipe sampling in homes prior to re-entry (testing surfaces for pH). Multiple buildings on site were entered with no detections noted on chlorine-specific monitoring equipment.

EPA, ATSDR, and all state agencies established a work group to begin working on a residential reoccupation plan for implementation at the time the evacuation was lifted. The group decided to produce a fact sheet that would be distributed to the public when they returned to their homes. The fact sheet described precautions that residents needed to take and addressed concerns regarding the effects that the chlorine may have had on the environment.

EPA investigated and monitored impacts of the release of chlorine and diesel fuel to the surface water bodies. State DHEC continued the investigation of streams and water bodies near the derailment, including the fish kill observed near the incident.

1.2.3. APPLICABLE TOXICITY VALUES FOR DECISION-MAKING

The example provided in Table B-2 demonstrates an outdoor release of chlorine gas. Detections at either the odor threshold or the detection limit of the handheld detectors were approximately 1 ppm, which is comparable to a 4-hour AEGL-2 as noted. The odor threshold is between 0.01 and 0.05 ppm, which is equivalent to the 10-minute AEGL-1. This level of detection prompted an evacuation within 2 miles of the release. Although no specific health-based criteria exist for surface wipe data, public health representatives based their decisions regarding clearance of potentially impacted areas on surface wipe data for pH and on the odor threshold. Detailed descriptions and references for exposure guidelines can be found in Appendix A. Figure 8 shows a comparison of exposure guidelines for chlorine gas.

Table B-2: Example Scenario 1—Large-Scale Chlorine Release

Phase	Health effects of concern	Activities and Decisions	Criteria used for decision-making	Notes
Phases 2a&b (0-12 hours, Day 1)				
Chemical release early morning from large tanker rail car Unknowns at this phase Activities included: determine types of chemicals, locations, source amounts Controls to minimize further responder/public exposure, deaths or severe injuries	**Immediate/near-term (acute) effects:** Deaths reported Upper respiratory distress Breathing difficulties, burning eyes General concerns and panic Some cases of psychosomatic illnesses Approximately 250 injuries reported with many hospitalized	**Emergency Response workers:** Air monitoring hot area during operations to control/remove source Spikes indicated by field instrumentation required responders to evacuate; Level B PPE **General public:** Local officials instituted shelter-in-place. People were told to shut off heater/AC system, close windows. Public advisories issued via radio and television. People within 2 miles evacuated.	**Liquid/gas odors** Any “positive” (not quantified) hits with gross level field identification tests **Visible liquid/gas** >DOT (Orange Book) large spill protection distances (day) Chlorine = 1.5 miles (night 4.6 miles) –>local decision-makers used 2 miles	**Decision-makers:** Local emergency and environmental health departments

Phase	Health effects of concern	Activities and Decisions	Criteria used for decision-making	Notes
Phases 2b&c				
Later Day 1 to Day 6 Activities included: control/remove source, decontaminate surrounding soil with lime slurry, and initiate clearance sampling in a phased approach. Multi-agency fact sheets under development Re-occupancy of the 2-mile area.	**Immediate/near-term (acute) effects:** Odor/mild irritation (minimal to none reported) Psychosomatic illnesses continue to be reported along with general public concerns.	**Response workers:** Air monitoring continued for hot area during operations to control source **General public:** Air monitoring for limited search and rescue operations **Phased re-occupancy strategy:** Modeling results indicated area of concern was 600 yards; supported by air monitoring; Modified evacuation area of 0.5 mile. Mandatory sampling of targeted facilities (schools, businesses) and voluntary sampling of homes for re-entry of areas outside evacuation area	Field detection >0.1 ppm required action (highest level was 3.7 ppm) MiniRae™ and AreaRae™ or equivalent used[134] "Non-detects" for chlorine with field instrumentation (and no odors/visible contaminant) Surface wiping for unusual pH Surface water sampling (pH) for ecological assessment. Fish kill due to chlorine release and runoff Due to fish kill, problem limited to fish carcasses	**Decision-makers:** Local emergency and environmental health departments together with federal agency support: HHS-ATSDR for re-occupancy fact sheets, EPA for environmental sampling

[134] AreaRAE, MultiRAE, MiniRAE are handheld gas sensors with 25 interchangeable sensors including photoionization (PID) for VOCs, NDIR for CO_2, and numerous solid-state sensors for ammonia, chlorine, formaldehyde, phosphine, etc.

Phase	Health effects of concern	Activities and Decisions	Criteria used for decision-making	Notes
Consequence Management Phase (recovery, reentry)				
Day 6 to Day 14 **Phased re-occupancy** ongoing and final removal of tank source By Day 14 all curfews lifted, facilities open and operations restored Multi-agency fact sheets distributed (ATSDR and state/local health departments) for re-occupancy concerns Federal (EPA) and state/local sampling teams Mandatory sampling in hot area and 600 yards out. Additional residents requested sampling: Over 750 homes businesses sampled	**Immediate/near-term (acute) effects:** None **Permanent/chronic injury/illness:** None Public concern will be high and required continuous: public assurances **Pets:** Four pets (2 dogs, 2 cats) were determined to have died from chlorine exposure (determined to have been outside in direct plume). Assurances to public required regarding pet health concerns.	**Response workers:** Limited/no PPE required End response work **General public:** Resumed use/re-occupancy (unrestricted) of all buildings and residences	Air monitoring is primary form of clearance sampling for the volatile/non-persistent chemicals, and targeted/surface sampling to support findings: "Non-detects" for chlorine with field instrumentation (and no odors/visible contaminant) Surface wiping for unusual pH Waste disposal for tanks, decontaminated soil, and fish carcasses Re-occupancy guidelines include recommendations to replace air filters, open windows and circulate air, throw out unprotected food (regular waste disposal), and flushing water systems for 2 min. Additional home inspections required to evaluate potential damage to critical infrastructure (electronics/ wiring, phone lines) damage from corrosive chlorine gas	**Decision-makers:** Local emergency and environmental health departments and local veterinarians Offered to sample residences beyond mandatory sampling areas; decision was supported by HHS, ATSDR and EPA. Multi-agency fact sheets developed and distributed

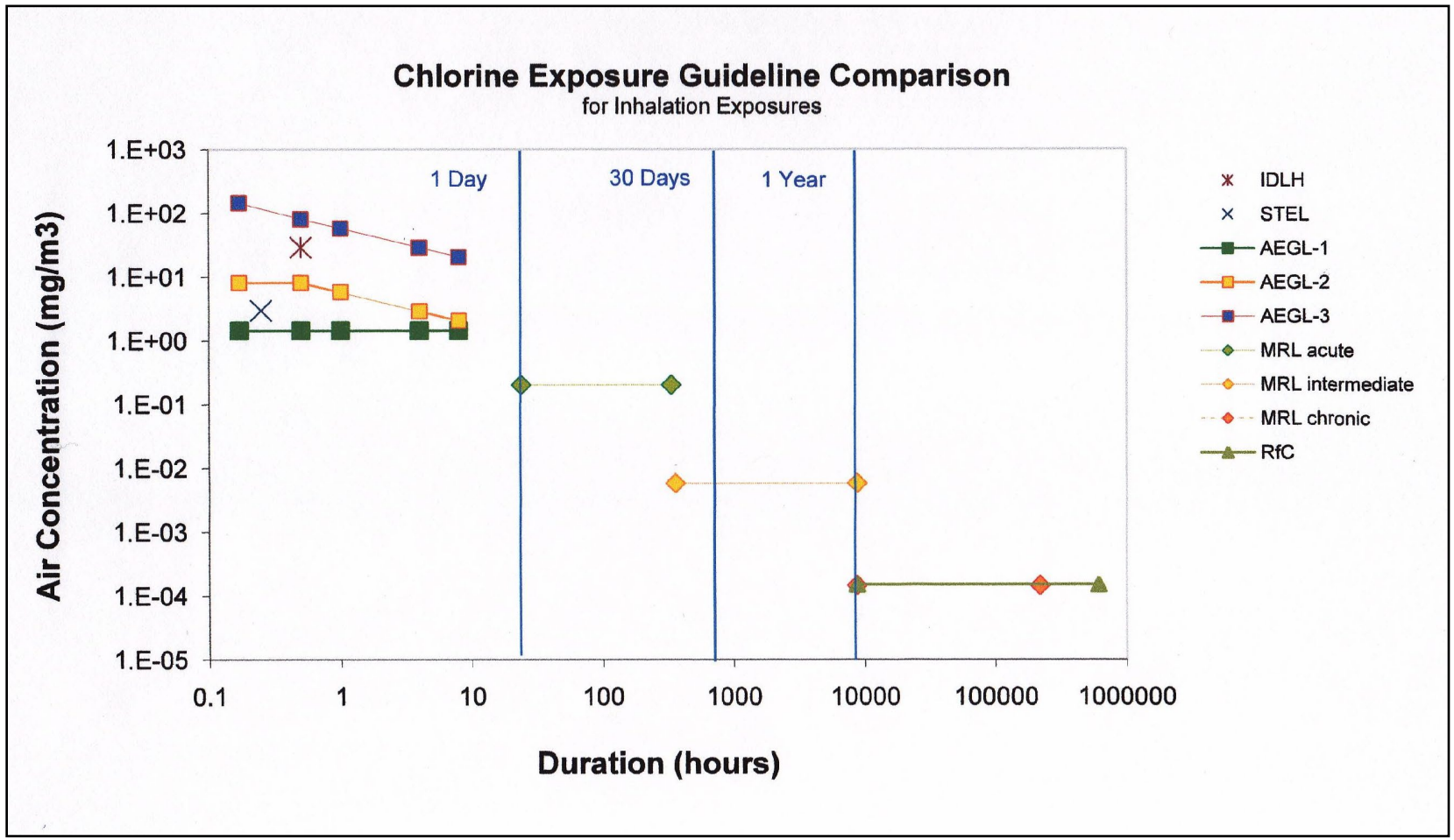

Figure 8: Chlorine Exposure Guideline Comparison for Inhalation Exposures

2. Spring Valley Case Study

This case study summarizes the ongoing investigation and remedial activities at the Spring Valley Formerly Used Defense Site (FUDS). The case study demonstrates the use of EPA's Superfund framework in the site-specific design and execution of the investigation and remediation. The study also highlights the collaborative decision-making process that has included input from representatives of the U.S. Army Corps of Engineers (the Corps), EPA, ATSDR, CDC, the District of Columbia Department of the Environment (DDOE), and the Spring Valley community.

The information summarized in this case study can be found on the Corps' technical support website for Spring Valley.[135] The website provides copies of the Site-Wide Work Plan, Remedial Investigation reports, Engineering Evaluation/Cost Analysis reports, and sampling and analysis plans (SAPs), as well as public communication products such as factsheets and news releases regarding the Spring Valley response and remediation activities.

2.1. Background

On Jan. 5, 1993, while digging a utility trench in the Spring Valley section of Washington, D.C., a contractor unearthed buried military ordnance. The U.S. Army Technical Escort Unit initiated an emergency response action that resulted in the removal of 141 ordnance items (43 suspect chemical items) from a burial pit.

Historical records search

On Feb. 3, 1993, the Corps began a search of historical records documenting the activities of the American University Experimental Station (AUES), which was active in the 1917 to 1920 timeframe. Adjacent to AUES was Camp Leach, an area that was used for troop training in trench and chemical warfare techniques. The historical search indicated that approximately 661 acres in the northwest section of Washington, D.C., were used during World War I (WW I) by the U.S. Government for research and testing of chemical agents, equipment, and munitions. Today, the Spring Valley neighborhood encompasses approximately 1,600 private homes, including several embassies and foreign properties, as well as the American University and Wesley Seminary.

While historical records indicate that much of the materials used at AUES were sent to other military installations after operations ceased, some items were buried. The archival search report documented the history of the area, including the evaluation of where munitions and other items were stored, expended or disposed of onsite. This information was obtained through the review of written records and the analysis of maps and aerial photos, and helped the Corps focus their site characterization. More than 50 Points of Interest (POIs) were identified based on the archival search report. The POIs represented

[135]Available at https://www.nab.usace.army.mil/Home/Spring-Valley/, last accessed 2/7/2021. Archived documents can also be found at http://SpringValley.ertcorp.com, last accessed 2/7/2021.

areas where chemical contamination would most likely exist, if present. Spring Valley POIs were prioritized, and many were investigated using geophysical surveying equipment, along with some chemical sampling of soil. It is unlikely that any historical records evaluation would identify 100 percent of the munitions burial locations. Certain records would not have been kept, and others were certainly lost or destroyed over the years. Nonetheless, a records evaluation does provide a logical first step in trying to prioritize areas for investigation and the best use of limited funds.

2.2. Site-Wide Work Plan

The Site-Wide Work Plan Spring Valley FUDS provides the details of the procedures, methods, organization, and resources being used to achieve project objectives. The mission of the Corps in Spring Valley is to identify, investigate, and mitigate threats to human health and safety or to the environment resulting from past DOD activities in the area.

2.2.1. DATA QUALITY OBJECTIVES FOR SITE INVESTIGATIONS

Environmental investigations at the Spring Valley FUDS are conducted to ensure that the data collected are of the right type, quality, and quantity to support defensible site decisions. The data quality objectives for this project were developed using this guidance: "Data Quality Objectives Process for Hazardous Waste Site Investigations."[136]

The CSM for the Spring Valley FUDS was initially developed by the Corps. In general terms, the CSM focuses on encountering chemical agent or arsenic (a Lewisite degradation product), and other contaminants that may have resulted from AUES operations. Potential receptors include private residents, students, construction workers, and groundskeepers. Potential exposure scenarios (regarding surface and subsurface soil, and bottle contents) include dermal contact, and direct ingestion and inhalation of fugitive vapors and particulates.

2.2.2. INITIAL INVESTIGATION RESULTS (1993-1995)

Of the more than 1,900 anomalies identified, a total of 840 anomalies were recommended for further study or removal. Nearly all of the anomalies were determined to be metallic debris from property development, but one piece of ordnance, a spent Livens smoke round, was found. Two other ordnance rounds were anonymously left at the investigation office trailer. An additional 3-inch Stokes mortar round was discovered during the digging of a basement. This round was unarmed. Approximately 20 other pieces of ordnance scrap items were also found. All of these items were safely removed from the site. No additional burial pits were identified, and no additional chemical warfare materiel was found. In addition to the geophysical investigations, a total of 260 soil samples were collected at 13 areas that included 17 POIs. Samples were taken from randomly selected locations, within each POI, as close as possible to the 1918 surface level. The samples were tested and analyzed by both the Corps and the EPA.

[136]U.S. EPA. (2000). Data Quality Objectives Process for Hazardous Waste Site Investigations (QA/G-4HW).

Analytical sampling results were compared to:

- EPA Region III Risk-Based Concentrations (RBCs) for residential exposures.
- Health-Based Environmental Screening Levels (HBESLs) (risk-based screening levels of chemical warfare agents) for residential exposures derived by the DOD.
- Site-specific background concentrations for inorganic chemicals.

Region III RBCs and the HBESLs were developed using chronic estimates of exposure of the general public and chronic toxicity values. Commonly, these risk-based screening levels are calculated for a $1x10^{-6}$ cancer risk or a hazard index of 1 for non-carcinogens. However, both the RBCs and HBESLs for non-carcinogens were adjusted downward by a factor of 10 to account for potential cumulative effects. Such screening-level assessments are often used to identify areas for further investigation and possible remediation. Generally, where analytical sampling results fall below screening levels, no further investigation or action is warranted under Superfund.

Although no chemical agents, chemical warfare agent-unique breakdown products, explosives or explosive breakdown products were found in any of the samples taken, several metals were identified that exceeded the EPA's RBCs. These metals were included in a quantitative baseline risk assessment. This assessment found no elevated health risk requiring remedial action. Arsenic was not identified as a chemical of potential concern for remedial action as the sampling results from these early investigations were not significantly different from site background concentrations.

These findings were documented in a Remedial Investigation Report dated June 1995. This report was followed by a No Further Action Record of Decision in June 1995. In this decision, the Army took responsibility for any future actions required if additional munitions or contamination related to past military activities were discovered.

2.2.3. FOLLOW-UP INVESTIGATIONS

In 1996, the D.C. Health Department reported to EPA that they had uncovered new information regarding the Spring Valley site. The Corps responded to each of the issues raised by the D.C. Health Department. As one of the issues addressed, the Corps conducted field investigations of the area located along Glenbrook Road. More than 600 items were recovered including 288 ordnance-related items. Of those items, 14 were evaluated to have chemical warfare agent, predominantly HD. Following this work, soil samples were collected from the recovery site. Test results indicated elevated levels of arsenic were present in portions of the area. Following a comprehensive risk assessment, the Corps determined that the top two feet of soil in the affected areas should be removed and replaced with new soil. This work began in December 2000 and was completed a few months later.

2.3. Site Investigation/Remediation Decision Rules

The general decision rule for soil excavations involving chemical agents of interest (including chemical agents and agent breakdown products) is: if the concentration of any of the chemical agents of interest

exceeds the comparison value, then further vertical or lateral excavation is warranted. If those comparison values are not exceeded, the excavation is considered complete and may be backfilled.

The general decision rule for hazardous waste constituents in soil or water is: If the concentration of any hazardous waste analyte exceeds the comparison value (RBCs or HBESLs), then one of several actions may be taken. These may include further vertical or lateral excavation and further sampling to determine extent of contamination. Or, a more formal risk assessment may be conducted to evaluate potential future risk if soils remain in place.

2.3.1. ADDITIONAL SOIL SAMPLING AND CLEANUP

A plan was developed to conduct arsenic sampling on 61 private residences and the southern portion of American University. These areas are near the site of the disposal pits.

Arsenic sampling was completed at 42 of the 61 properties. Eleven property owners would not grant permission and attempts to reach eight others were unsuccessful. Based on the results of this sampling, nine properties and several lots on the American University campus were recommended for further detailed sampling. This sampling was completed in January 2001.

One of these locations involved the area around the American University Child Development Center. Given the sensitivity of this area, soil sampling around the center was expedited and the results were provided to the university. The results identified arsenic levels higher than acceptable for a residential area. University officials relocated the Child Development Center to another area of the campus. Removal of the contaminated soil began in the summer of 2001. New soil was placed on the site, and restoration activities completed.

Following the discovery of elevated arsenic at the Child Development Center, the D.C. Health Department, EPA, and the ATSDR conducted an exposure study of the children attending the center. Study results did not indicate a health risk to the children.

At a public meeting in February 2001, the community turned out in large numbers to urge soil testing of the entire Spring Valley neighborhood. The Corps, in consultation with EPA and the DDOE, responded with a comprehensive soil sampling plan that proposed the sampling for arsenic on every property in Spring Valley (1,200 residential properties and 400 non-residential lots), with more intensive sampling in select areas. Sampling under this plan began May 31, 2001.

EPA proposed a soil cleanup/clearance goal of 20 ppm for arsenic contaminated soils. The level of 20 ppm arsenic falls within the levels associated with EPA's cancer risk range of 10-6 to 10-4 (0.43 ppm to 43 ppm, respectively), and is protective of potential long-term risks for noncancer effects. In addition, it exceeds the site-specific average background range of 5 ppm–18 ppm arsenic. The protective cleanup/clearance goal of 20 ppm for arsenic was agreed upon by the Corps, EPA and DDOE, and approved by both the Mayor's Scientific Advisory Panel and the Spring Valley Restoration Advisory Board.

More than 1,500 properties were sampled for arsenic. If a particular property was determined to have an elevated level of arsenic, then a more detailed grid sampling procedure was done. One hundred-fifty properties were identified with one or more grids above 20 ppm of arsenic.

2.3.2. BURIAL PUT 3 AT 4825 GLENBROOK ROAD

A number of test pit investigations have been carried out in and around Glenbrook Road due to the confirmed presence of a number of burial pits containing ordnance-related items: acids and other chemicals including various volatile organic chemicals; semi-volatile organic chemicals; and metals (most notably arsenic). In addition, HD, L, and agent breakdown products have been detected in soils.

During investigation of the burial pits, characterization samples were collected from the center of the floor of each pit and from the midpoint of each pit outer sidewall, halfway between ground level and the pit floor (on the outer boundary of the proposed excavation area) or near the elevation of scrap or any containers that were encountered. These samples were collected and analyzed and evaluated according to the Site Investigation/Remediation Decision Rules.

If it was determined that further excavation was required based on the results of the pit characterization sampling for agent and agent breakdown products, over-excavation of the pit was performed. If further excavation was required at the pit floor, the excavation proceeded one foot deeper, or until bedrock, saprolite or native soil was reached. If further excavation was required for a sidewall, the excavation was taken one foot farther.

Following the over-excavation of the pit, additional pit characterization samples were collected and the process was repeated until the pit was determined to be clear (according to Site Investigation/Remediation Decision Rules) for chemical agent or agent breakdown product, or until saprolite or native soil had been reached.

Due to the high probability of chemical munitions present in Burial Pit 3, investigations were conducted inside a negative pressure Engineering Control System (ECS) with air monitoring for chemical agent and blast/fragmentation suppression. The ECS was designed to contain metal fragments and attenuate blast in the case of an explosive release, and to minimize exposure of on-site personnel and the nearby public in the event of a release of a chemical agent. The ECS selected for the investigation of the pit included a Vapor Containment Cover placed over a metal structure designed to contain fragments and attenuate the blast from a 75 mm Mk II chemical projectile with an explosive burster, combined with a Chemical Agent Filtration System (CAFS). A Vapor Containment Cover is an impermeable fabric cover designed to prevent the release of vapors outside of the ECS. In addition, the ECS operates under negative pressure to contain a potential chemical release. The CAFS is specifically designed to monitor and remove chemical agent vapors and particulates. Workers within the ECS were monitored for exposure to chemical agents at the level of Worker Population Limits (WPLs) and STELs.

> **WPLs** are developed by the CDC for the DOD and are used to monitor identified areas where workers may be exposed to chemical warfare agents. The WPL is the maximum allowable 8-hour

concentration that an unprotected chemical worker could be exposed for an 8-hour workday and 40-hour week for 30 years without adverse effect.

STELs are developed by NIOSH and OSHA. The STEL is a 15-minute TWA exposure that must not be exceeded at any time during a workday. The STEL is the concentration to which it is believed that workers can be exposed continuously for a short period of time without suffering from: (1) irritation, (2) chronic or irreversible tissue damage, (3) dose-rate-dependent toxic effects, or (4) narcosis of sufficient degree to increase the likelihood of accidental injury, impaired self-rescue, or materially reduced work efficiency.

A Site-Specific Public Protection Plan was developed to educate the public in the vicinity of Burial Pit 3 on how to minimize their potential exposure in the event of a chemical release. The plan was designed to be implemented during intrusive activities associated with the investigations conducted within the ECS. The plan stated that, in the unlikely event of a chemical release, the Corps would implement a voluntary Shelter-In-Place program for individuals and organizations who reside, work, or routinely operate within the potentially impacted area surrounding Burial Pit 3 located at 4825 Glenbrook Road. Shelter-In-Place consists of staying indoors, closing all doors and windows, and shutting off central or window heat or air conditioning units. The public should remain indoors until notified by the Corps that it is "All Clear" to end Shelter-In-Place and to resume normal activities. The plan stated that the "All Clear" signal would not be given until project personnel confirmed that no chemical agent remained in the vicinity at a level that could cause harm to an individual.

An "AEGL-2 Distance" of 742 feet was used to define the area surrounding Burial Pit 3 that may be impacted by an uncontrolled release of Arsine.

An **AEGL-2** is the airborne concentration (expressed as ppm or mg/m^3) of a substance above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape.

Thus, the "AEGL-2 distance" defined the potentially impacted area where an exposed population may experience irreversible or other serious long-lasting health effects, or an impaired ability to escape associated with the unlikely event of a chemical release. Individuals within the "AEGL-2 Distance" would be advised to take active steps to protect themselves from exposure by sheltering-in-place. The predicted "AEGL-2 Distance" was calculated based on local meteorological conditions, and the type and quantity of suspect recovered chemical warfare materiel. Although the "AEGL-2 Distance" for Burial Pit 3 *without* engineering controls was estimated to be 742 feet, investigation of the pit utilized several engineering controls, including the ECS combined with a CAFS, to reduce the area potentially impacted at AEGL-2 levels outside of the ECS to zero.

It should be noted that an AEGL-2 was selected due to the lack of an AEGL-1. Although the inter-agency working group would have preferred a level of exposure consistent with reversible, non-disabling effects for the shelter-in-place decision in the event of an uncontrolled release, it was necessary to default to the AEGL-2 exposure level. The continuum of arsine-induced toxicity does not appear to include effects consistent with the AEGL-1 definition. The available human and animal data affirm that there is a very

narrow margin between exposures that result in little or no signs or symptoms of toxicity and those that result in lethality.

2.3.3. OTHER SITE WORK

ATSDR Health Consultation

The ATSDR published a Health Consultation for Spring Valley in September 2005. ATSDR concluded that excluding burial pits/disposal areas, the soil pathway at the American University/Spring Valley site does not represent a public health hazard. As such, exposure to the levels of chemical warfare agents or their breakdown products detected in soil is not expected to cause the health conditions reported by residents. Precautionary measures are being taken by the Corps, however, to remove soils with elevated arsenic levels.

Burial areas discovered within Spring Valley have been or are in the process of being remediated. ATSDR acknowledged that any remaining chemical warfare materials (e.g., other chemicals, explosives) in disposal areas (burial pits and surface disposal areas) could pose a chemical or physical hazard if disturbed. Of particular concern would be munitions or containerized materials that might still contain chemical warfare agent. The ATSDR recommendations included:

- Additional, but targeted, environmental sampling, most of which is already ongoing. ATSDR also recommended continued promotion of community awareness and interaction. The Public Health Evaluation should be consulted for their recommendations in their entirety.
- Additional surface soil analyses be conducted for residential properties. Specifically, ATSDR recommended surface soil analyses for AUES-related contaminants including explosives and their transformation products, CWAs and degradation products, and metals such as lead and mercury.
- Soil gas samples be taken at disposal areas, preferably prior to excavation, to evaluate the potential for exposure by a soil gas migration pathway. This could include existing disposal areas such as the Glenbrook Road area, where some WW I remnants remain in a burial pit (Pit 23) and in a surface disposal area at Lot 18.
- The Corps continues with its plan to conduct groundwater sampling, particularly in the area of the burial pits. This sampling will provide data regarding the possible nature and extent of groundwater contamination near burial pits and other disposal areas.

In 2010, exposure scenarios for workers and residents were evaluated after finding additional munitions and contaminated items and soil. The data were limited due to the length of time between exposure and

sample collection and because no indoor air samples could be collected. In 2016, a final analysis relied on the evaluation of worker transcripts to evaluate exposure.[137]

Groundwater Investigation

The Corps installed 45 monitoring wells between 2005 and 2010 in locations agreed upon by the Corps, EPA, and the DDOE to help determine whether there is contamination in the groundwater and where the groundwater is flowing. Sampling results identified elevated levels of perchlorate as high as 146 parts per billion (ppb) in the project area.

For perchlorate, analytical results are being compared to EPA's Interim Drinking Water Health Advisory of 15 ppb.

4825 Glenbrook Road - Remedial Investigation/Feasibility Study

In 2010, the Corps found low-level agent (predominantly L) in soil at the Glenbrook property where WW I disposal had occurred. At about the same time there was a release of arsenic trichloride in the ECS over the work area. Investigative work at the site was halted in 2010. The Corps conducted a risk assessment and remedial investigation/feasibility study (RI/FS) to determine what to do with the property. The RI/FS is being assembled with data gathered during the site investigation and removal actions. As part of the RI/FS, a human health risk assessment is also being completed.

The RI/FS process considered the exposure scenario (residential), toxicity of the contaminants of concern, impacted groundwater, the potential for vapor intrusion and Applicable or Relevant and Appropriate Requirements, and concluded with the development of site-specific cleanup/clearance goals.

2.4. Conclusions

The Spring Valley FUDS continues to be an extremely complex and challenging project.

Beginning in 1993 with the accidental discovery of military ordnance buried almost 80 years earlier, the site has developed into a multi-materials and surfaces investigation and remediation project involving soil, air, munitions, and potentially contaminated groundwater. The site involves multiple contaminants posing both potential short- and long-term risks that need to be addressed.

The Spring Valley case study demonstrates the use of EPA's Superfund framework in the site-specific design and execution of the investigation and remediation. As with most sites, the complex nature of this response does not lend itself to a "one-size-fits-all" approach to defining cleanup/clearance goals. Instead, the risk assessment and risk management activities have been tailored to site-specific conditions and have employed a collaborative decision-making process that is essential to every

[137]HHS. (2016, August). An Exposure and Health Effects Health Consultation: An Exposure and Health Evaluation of Former Workers and Residents to Chemical Contamination at 1825 Glenbrook Road. Health Consultation. Retrieved from https://www.atsdr.cdc.gov/sites/springvalley/atsdr_documents.html (website).

response. Current information on the progress of the Spring Valley cleanup since the completion of this case study can be found at the Spring Valley website.[138]

[138]Available at https://www.nab.usace.army.mil/Home/Spring-Valley/, last accessed 2/7/2021. Archived documents can also be found at http://SpringValley.ertcorp.com, last accessed 2/7/2021.

3. Fourth Generation Agent Event Example

The following example illustrates the decision-making criteria and process used in a theoretical fourth generation agent (FGA) event in the United States. While this event is hypothetical, the exercise demonstrates specific interagency actions and associated decision criteria, which could plausibly be used in an actual incident. The incident summary is presented below, followed by scenario-specific details for each response phase. Table B-1 contains toxicity values and Table B-2 gives a summary outline of events during each phase of the response.

3.1. Incident Summary

A couple drives from their home to a local restaurant for lunch. After eating lunch, the couple visits a bar and then strolls through a local park. Shortly afterward, the police are called to the area because the couple is found unresponsive on a park bench. The police and medical personnel respond to the scene and treat the incident as an opioid overdose. Narcan is administered to the couple, and they are transported to a local hospital.

Hospital personnel treat the couple for an opioid overdose. The patients do not respond well to the opioid overdose treatment, so the clinicians contact the Regional Poison Center in search of other plausible answers to the symptoms. Based on their symptoms, the poison center thinks their condition is possibly due to an adulterated street drug or a pesticide poisoning. They begin treatment with atropine and pralidoxime for a suspected pesticide or nerve agent poisoning and it is later confirmed by a specialized blood test to be a nerve agent poisoning. Over many days of treatment the patients slowly begin to respond.

Local law enforcement is notified that a nerve agent may have been used and that a terrorist attack or attempted murder has occurred. State and federal authorities are notified and mobilized to the scene as per Section 4.2.1 (Crisis Management). The state Emergency Operations Center activates the National Guard Civil Support Team (WMD-CST) to conduct sampling and field-confirmatory nerve agent analysis to include FGAs. Law enforcement, including the FBI, begins to retrace the couple's steps and identify five different locations where the poisonings may have occurred – their home, car, the restaurant, the bar, and the park. Officers deploy to each of these locations to secure the scene, protect the public and begin investigation.

During this time, a local law enforcement officer who initially responded to the couple's home falls seriously ill. The officer was accidentally exposed to the nerve agent during the initial investigation. It was determined that the couple's home was the likely site of their initial exposure. The FBI Hazardous Evidence Response Team obtains a result on M8 paper employed in the home that suggests nerve agent contamination. The M8 test spot is yellow/green and shifted to a more yellow color after about 10 minutes. The shift of color after this short period indicates the possibility of an FGA. Figure 9 illustrates the appearance of a positive FGA result.

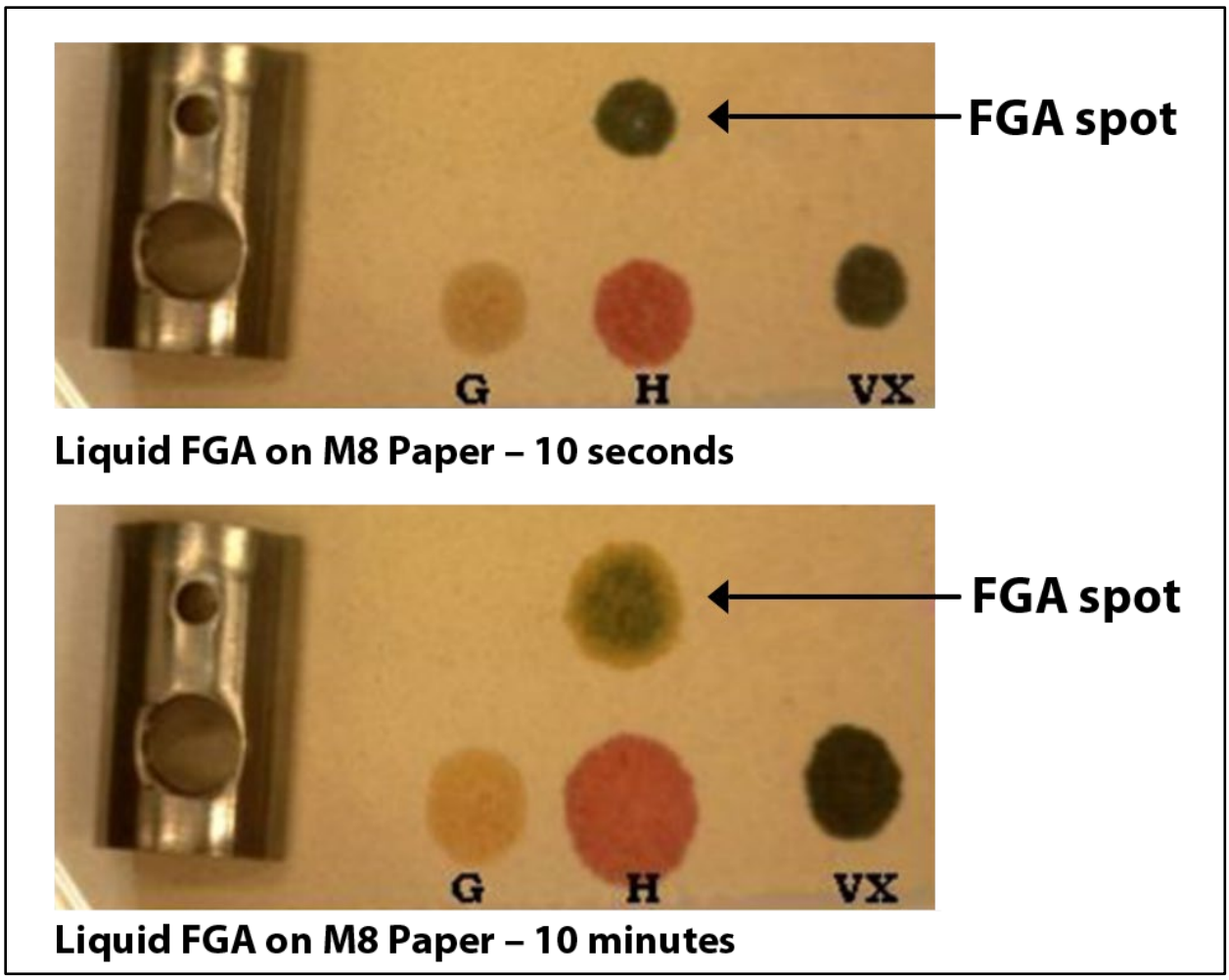

Figure 9: Liquid FGA on M8 Paper

During the residence sampling, the FBI detects a possible nerve agent in a perfume bottle inside the house. It is collected as evidence and sent to the FBI's laboratory for analysis. Later, the FBI laboratory confirms that the perfume bottle contained an FGA.

After the FBI completes its investigation, the cleanup will start under UC with the EPA, potential UC participation, state, local officials, and other stakeholders. National Response Team has been informed and is activated to assist RRT and the designated Federal On-Scene Coordinator (FOSC) in managing this incident. As the response shifts into Phases 2a-c, (Section 4.2.2), a Technical Working Group (TWG) with experts from multiple agencies is convened under UC to discuss sampling strategies and clearance decision criteria. The UC convened an Environmental Clearance Committee (ECC), who complete a site-specific risk assessment to derive the site cleanup goals.

Currently, the U.S. government has not published occupational exposure limits or general population cleanup goals for FGAs. FGAs also have no established Permissible Exposure Limits or Acute Exposure Guideline Levels. The EPA worked with the U.S. Army Chemical Biological Application and Risk Reduction during preparedness efforts to obtain any toxicology information that the Army held. According to one

study, a variant of FGA has intravenous and percutaneous toxicity that exceeds VX's toxicity by a factor of 1 to 8.[139] Based on this study, toxicologists recommend acute and chronic exposure action levels for the site cleanup. Extreme precautions must be taken to prevent exposure due to the highly toxic nature of the agent.

3.2. Response Phases

Each phase of the FGA scenario exercise required site-specific decisions. During each stage, the possible exposure to the general public and response workers was monitored using field screening and expedited on-site and off-site laboratory analysis.

3.2.1. PHASES 2A&B

- **Notification:** The local authorities notified appropriate agencies, including local hazardous materials (HAZMAT), police, fire, and possible property stakeholders. Local authorities notified the local FBI office, which deployed their Weapons of Mass Destruction (WMD) coordinator for forensic sampling to identify the hazardous chemical and criminal investigation activities. The FBI collected all available data from local responders. Unified Command was set up and included local, state, and federal response assets. A coordinated information stream was set up.

- **First Response:** Local HAZMAT-capable hospitals were alerted for the arrival of patients with cholinesterase inhibition, respiratory distress, and other symptoms of SLUDGE– (Salivation, Lacrimation, Urination, Diarrhea, Gastrointestinal cramps, Emesis) and DUMBBELS (Defecation, Urination, Miosis/Muscle weakness, Bronchospasm/Bronchorrhea, Bradycardia, Emesis, Lacrimation, Salivation/Sweating), which may be indicative of a nerve agent exposure. Diagnostics of cholinesterase suppression were employed by hospital laboratories. Portable diagnostics, such as EQM Research's Test-mate system, were also employed in a field laboratory under the umbrella of an extended Clinical Laboratory Improvement Amendments (CLIA) certificate. The public was notified about the incident and provided with instructions for reporting to public decontamination facilities. These facilities were set up for people who thought they might have been potentially exposed. Response workers utilized modified Level B (SCBA and a hooded chemical-resistant suit that protects against FGA with no exposed skin, i.e., taped or encapsulated B).

  Local authorities ordered the four different locations (restaurant, bar, park, and home) to be evacuated, and the car impounded. Evacuees were notified on the reason to leave the sites based on the possible high risk of exposure. Evacuees were also informed to monitor themselves for signs and symptoms (SLUGDE, DUMBBELS) and report themselves with such signs to a hospital. Under UC, a Joint Information Center was established, who provided routinely scheduled notifications to the local health department. A shelter-in-place was recommended for outlying areas on a case-by-case basis. State and local police enforced an evacuation/shelter-in-place. The EPA deployed federal assets for

[139]Pitschmann, V. (2014). *Overall View of Chemical and Biochemical Weapons*. *Toxins, 6*(6), 1761-1784. doi:10.3390/toxins6061761.

air monitoring but faced challenges. Any positive results on handheld screening meters (MX908, Proengin's AP4C, etc.) or M8 paper from surfaces were considered indicative of FGA presence. The data were sent to the UC to advise the local Health Department on evacuation and shelter-in-place actions.

3.2.2. PHASE 2C

- **Characterization:** UC tasked the Planning Section Chief to develop an Incident Action Plan, Sampling and Analysis Plan, Health and Safety Plan, and an Ambient Air Monitoring Plan. EPA deployed their VIPER[140] interface to network all monitoring instruments around the targeted areas. EPA's PHILIS (Portable High-Throughput Integrated Laboratory Identification System) units were mobilized to the site for sample analysis during the characterization and clearance phases. Several MINICAM™ portable gas chromatographs were obtained from the Army for near-real-time air monitoring but faced a challenge due to the extremely low volatility of FGAs. As such, air monitoring was discontinued. Additionally, the National Guard WMD-Civil Support Teams responding leveraged point detectors and bench-top analytical equipment, with results indicating an FGA. Surface wipes were taken to determine the contaminated area's extent, with responders collecting additional soil and bulk samples (carpet, stained areas) and analyzed on-site by the PHILIS mobile labs. Excess samples, which were unable to be analyzed on-site, were sent to Chemical Biological Application and Risk Reduction (CBARR), National Reference Labs, and the EPA Environmental Response Laboratory Network laboratories for FGA analysis.

- **Remediation (Cleanup):** Characterization results indicated that four locations were contaminated. The RAP addressed the complexity of decontaminating all sites simultaneously. UC tasked the Planning Section Chief to develop a RAP, waste disposal plan, and select a decontamination strategy for cleanup. EPA Office of Research and Development (ORD)/Center for Environmental Solutions and Emergency Response (CESER) provided research data to support various decontamination strategies and waste staging locations. EPA provided a waste disposal matrix to assist with transportation and disposal requirements. The sites were divided into separate operable units (OUs). Each OU was managed by a task force, which coordinated all sampling and analysis, decontamination, and health and safety issues for that specific unit. EPA, CDC, FEMA, state, local, tribal, and other stakeholders were selected to participate in the TWG. The decontamination of critical items, sensitive equipment, and other "special" items was considered in the overall plan. The TWG selected to dispose of certain media that are difficult to decontaminate, such as porous, permeable materials, and easy to remove items (carpet, chairs, tables, etc.). The group recommended the scabbling of concrete or complete removal where cleanup goals could not be achieved. Jurisdictional issues complicated transportation and disposal of the waste. The UC resolved the problems at a federal level by obtaining a certified hazardous materials incinerator's service.

[140]VIPER is a network-based communications system to enable real time transmission of data from field sensors to a computer or server for interpretation.

- **Clearance:** The Planning Section was tasked to develop the Clearance Sampling Plan using the clearance decision levels agreed upon by the TWG. Sampling and analysis continued to verify each OU's decontamination efficacy; the UC cleared each OU via the Environmental Clearance Committee.

- **Phase 3: Restoration/Recovery:** The UC (including public health professionals) cleared the last remaining OU, indicating that the entire site was cleared for resumed use/re-occupancy. All sampling media had FGA concentrations that met the clearance decisions. Local and state Departments of Environmental Protection discontinued ambient air sampling because concentrations remained below risk-based levels established by the TWG. The Public Information Officer continued to be in place to address public concerns.

3.2.3. APPLICABLE TOXICITY VALUES FOR DECISION-MAKING

Although site-specific information would be developed for any contamination event, Table B-3 shows a comparison of median lethal concentration and dose for FGA and other nerve agents that could be used to inform the decision-making process for clearance.

Table B-3: Overview of the gradual increase in the toxicity of CWA. LCt50, median lethal concentration; LD50, median lethal dose

Agent	LCt_{50} (mg·min/m^3), Inhalation	LD_{50} (mg/70 kg), Percutaneous (Liquid)	LCt_{50} (mg·min/m^3), Percutaneous (Vapor)
Tabun (GA)	70	1,500	15,000
Sarin (GB)	35	1,700	12,000
Soman (GD)	35	350	3,000
VX	15	5	150
FGA[141]	Unknown; one variant of A-series has intravenous and percutaneous toxicity that exceeds the toxicity of the VX by a factor of 5 to 8.		

Due to the lack of established occupational exposure limits for FGAs, extreme precautions must be taken to prevent any exposure. This guidance document's recommendations are based on the reported toxicity and the chemical and physical properties of FGAs.

3.2.4. EXPOSURE ROUTES

FGAs are low-volatility nerve agents, and like VX do not volatilize or evaporate readily. They will mostly be encountered as a bulk liquid or as a low-visibility liquid film on a surface. The most likely exposure route is skin contact, but FGAs may be absorbed by inhalation, mucous membrane contact (eyes, nose, mouth),

[141]National Center for Biotechnology Information, *Overall View of Chemical and Biochemical Weapons, Toxins,* vol. 6,6 1761-84. 4 Jun. 2014, doi:10.3390/toxins6061761.

or ingestion. After exposure, symptoms may occur within minutes to hours or up to three days. In general, the latent period between dermal exposure and symptom onset may be longer for FGAs than for VX. Inhalation, ingestion, or large dermal exposures will have shorter latent periods. Prompt administration of decontamination procedures and medical evaluation is critical. Personnel decontamination procedures should include a reactive decontaminant such as RSDL if dermal exposure is suspected. Additionally, due to the relatively long latent period, a post-decontamination monitoring protocol using serial acetylcholinesterase activity diagnostic measurements should be implemented with any individual suspected of dermal exposure to FGA.

3.3. Other Information

3.3.1. FGA SIGNS/SYMPTOMS

The presentation and timing of the onset of symptoms depends on the agent, dose, and exposure route. Regardless of the exposure route, patients may demonstrate some combination of SLUDGE and DUMBBELS. Seizures, coma, and death may occur in severe exposures.

3.3.2. PHYSICAL AND CHEMICAL PROPERTIES: FGA GENERAL CHARACTERISTICS

Table B-4 provides general physical and chemical properties of FGAs for use in decision making.

Table B-4: FGA Physical and Chemical Properties

Vapor Pressure	Extremely low vapor pressure; 5 to 10 times lower than VX
Density (vapor)	Heavier than air
Skin Absorption	Easily absorbed by the skin
Aqueous Solubility	Highly water-soluble
Soluble in	Acetone, benzene, ethanol, methanol, chloroform, saline
Flash Point	Greater than 300 degrees Fahrenheit
Persistence	Can remain on environmental surfaces for days or even many months, if not decontaminated

Table B-5 describes the phases of an example response to an FGA incident. This information is provided as a template and provides general information to be used along with the information in this framework document.

Table B-5: FGA Example Response: Phases of Chemical Response

Phase	Health effects of concern	Activities and decisions	Criteria used for decision-making	Notes
Phase 2a&b				
Day 1 (12-24 hours) Activities include determining the chemical of concern, locations, hot area Controls to minimize further responder/public deaths/severe injury Risk communication efforts to inform the public on the progress of the response	**Immediate/near-term (acute) effects:** SLUDGE, DUMBBELS, cholinergic crisis, and other general concerns Dozens of concerned citizens reporting symptoms at local hospitals	**Response workers:** PPE levels – Initially Level A after agent identification, reduced to Level B after field screening **General public:** Evacuation of the four site potential contamination areas and impounding car Decontamination of people who are likely exposed to the agent	Any "positive" detection with field identification tests/equipment (e.g., screening level field equipment and military M8 paper) Reports of symptoms or health effects	**Decision-makers:** Local emergency and environmental health departments

Phase	Health effects of concern	Activities and decisions	Criteria used for decision-making	Notes
Crisis Management **Characterization, Remediation, Clearance**				
Phases 2b&c (24-72 hours) Activities include continued identification of "sources" and field data to identify contaminated areas TWG established to determine sampling strategy and clearance goals Risk communication efforts to inform the public on the progress of the response	**Immediate/near-term (acute) effects:** Continued reports of upper respiratory distress, breathing difficulties, SLUDGE, and general concerns	**Response workers:** Air monitoring encountered some challenges and was discontinued Workers continued air sampling for the hot areas during operations to control/remove contamination **General public:** Initial shelter-in-place areas modified based on sampling results Hospitals and critical infrastructures cleared	Air sampling at the periphery of operable units. Exposure action levels identified for the protection of workers in PPE Wipe samples and laboratory-based analytical methods. Air sampling for the protection of the general public. Site-specific exposure action levels developed based on the extent of contamination, estimates of the duration of exposure, etc.	**Decision-makers:** UC: Local emergency and environmental health departments together with federal agency support: primarily HHS ATSDR and EPA for sampling

Phase	Health effects of concern	Activities and decisions	Criteria used for decision-making	Notes
Consequence Management Recovery/Re-entry				
Days 4 to 30+ Sampling teams using field tests/equipment followed by laboratory-based analysis Phased clearance Risk communication efforts to inform the public on the progress of the response	**Immediate/near-term (acute) effects:** None **Permanent/chronic injury/illness:** None	**Response workers:** PPE Levels determined by on-scene environment and cleanup phase End response work **General public:** Resumed use/re-occupancy (unrestricted) of site/facilities	**Approach used:** Surface wipes and clearance sampling to support findings/ assumption that decontamination is successful Surface wiping – Sample results would be compared with site-specific clearance goals developed for populations of concern Sampling of soil and bulk items – laboratory analysis results compared with risk-based clearance goals for FGA Waste disposal for contaminated material	**Decision-makers:** UC: EPA, HHS, supported by state/locals

4. Sulfur Mustard Event Example

The following example illustrates the decision-making criteria and process used in a theoretical HD chemical weapon attack in the United States. While this event is hypothetical, the exercise demonstrates specific interagency activities and associated decision criteria that could plausibly be used if the incident were real. The summary of the incident is presented below followed by Table B-6, which contains scenario-specific details from the HD example for each of the response phases. Refer to Appendix A for more details on exposure guidelines included with this scenario.

4.1. Incident Summary

The incident included both an airborne release of 55 gallons of blister agent, HD, over a populated harbor area in Connecticut, followed immediately by a truck explosion in the same area also releasing HD. The local responders identified HD during initial evaluation of the explosion site along with initial reports of symptoms. Later, continued reports of symptoms from persons not present near the explosion site, supported with intelligence information, led to discovery of the airborne release. Actual hot areas were not clear, and since HD is considered a relatively persistent chemical, concerns included contaminated people and vehicles that may have tracked contamination further from initial site.

Plume modeling was conducted via the IMAAC operational hub and area sampling showed some initial inconsistent results. However, significant environmental sampling was still necessary. Acute exposure action levels were evaluated to inform evacuation/shelter-in-place and responder PPE needs. Multiple agency experts, as part of the Technical Working Group, were convened under the auspices of the NRT and a discussion of sampling strategies and clearance decision criteria ensued. A consensus-based, interagency group was convened to determine a sampling strategy. A site-specific risk assessment was used to derive cleanup goals.

Each phase of the HD scenario exercise required site-specific decisions. During each phase, the possible exposure to the general public and response workers was monitored using field screening and expedited on-site and off-site laboratory analysis. Exposure guidelines for the general public can be found in Appendix A.

4.2. Response Phases

4.2.1. PHASES 2A&B

- **Notification:** Notified appropriate agencies including local HAZMAT, police, fire, and possible property stakeholders. Notified the local FBI office for forensic sampling to identify the hazardous chemical and for criminal investigation activities. Collected all available data from local responders. The EOC was set up and coordinated an information stream to appropriate agencies. Tied in local, state, and national HAZMAT response assets. UC initiated. PIO was established.

- **First Response:** Several deaths occurred; local HAZMAT recovered bodies. Bodies kept in secure HAZMAT morgue. Local HAZMAT-capable hospitals were alerted for arrival of patients with blistering,

respiratory distress, and other symptoms of HD exposure. Public decontamination facilities for exposed people set up by the local fire department and HAZMAT teams. Response workers settled on modified Level B (SCBA and hooded chemical resistant suit that provides protection against agents, with no skin exposed).

Evacuation was ordered for the inner harbor around explosion site, and limited areas of access were recommended for outlying areas on a case-by-case evaluation by the local health department. Evacuation/shelter-in-place was enforced by state and local police. Federal (EPA and USCG) assets were deployed for air monitoring and the data were sent to the EOC to advise local Health Department on evacuation and shelter-in-place actions. Visible liquid/gas, presence of odors or dead animals, and any positive hit on handheld screening meters (Proengin's AP4Ce), kits, or M8 paper were considered indicative of HD presence.

4.2.2. PHASE 2C

- **Characterization:** UC tasked the Planning Section Chief to develop an IAP, SAP, HASP, and AAMP. EPA and USCG, with state and local DEP assets, were deployed for sampling and monitoring to define HD plume. Samples were sent to National Reference Labs and the EPA Environmental Response Laboratory Network laboratories for analysis of HD and HD degradation products. Air monitoring and environmental sampling data were used with IMAAC modeling to delineate inhalation hazards, as well as to provide monitoring for response worker health and safety. IMAAC model data were sent to EOC/UC to advise the local Department of Health on continued evacuation/shelter-in-place actions. Soil, surface wipes, and water samples were taken to determine the extent of the hot area from HD explosion. Action levels for response worker for PPE levels were established.

- **Remediation (Cleanup):** UC tasked the Planning Section Chief to develop a RAP and waste disposal plan and to select a decontamination strategy for the HD cleanup. The site was divided into several separate decontamination units (DUs). Each DU was managed by a task force, which coordinated all sampling and analysis, decontamination, and health and safety issues for that specific DU. The sampling plan was modified as needed to include samples to verify decontamination, iteratively, during the decontamination process. EPA, CDC, the NRT, FEMA, state, property owners and other stakeholders were selected to participate in the Technical Working Group. Actions were taken to reduce source of HD release from surface water runoff into the nearby harbor. The decontamination of critical items, sensitive equipment, and other "special" items was considered in the overall plan. Disposal without decontamination was selected for certain media, such as polymeric handrails, which irreversibly absorb HD, making decontamination by many commercially available products ineffective. Disposal issues were handled by local and state DEP, obtaining the service of a local secure hazardous waste landfill.

- **Clearance Phase:** UC was tasked to develop the Clearance Sampling Plan using the clearance decision levels agreed upon by the Technical Working Group. Sampling and analysis continued to verify decontamination efficacy for each DU; each DU was cleared by the UC via the EU and the Technical Working Group. Air monitoring continued in each DU cleared, using exposure guidelines appropriate for clearance decision criteria, and appropriate site-specific, risk-based values.

- **Phase 3: Restoration/Recovery:** The UC (including public health professionals) via the EU and the Technical Working Group, cleared the last remaining DU, indicating that the HD site was cleared for resumed use/re-occupancy. All surface, soil, and air concentrations met the clearance decisions. Local and state DEPs continued ambient air monitoring to ensure levels remained below monitoring levels established by the Technical Working Group. PIO continued to be in place to address public concerns.

4.2.3. APPLICABLE EXPOSURE GUIDELINES FOR DECISION-MAKING

Although site-specific information would be developed for any contamination event, Figure 10 shows a comparison of available screening environmental guidelines for HD that could be used to inform the decision-making process for clearance. Detailed descriptions and references for these environmental guidelines can be found in Appendix A. Table B-6 shows an example response to an HD incident.

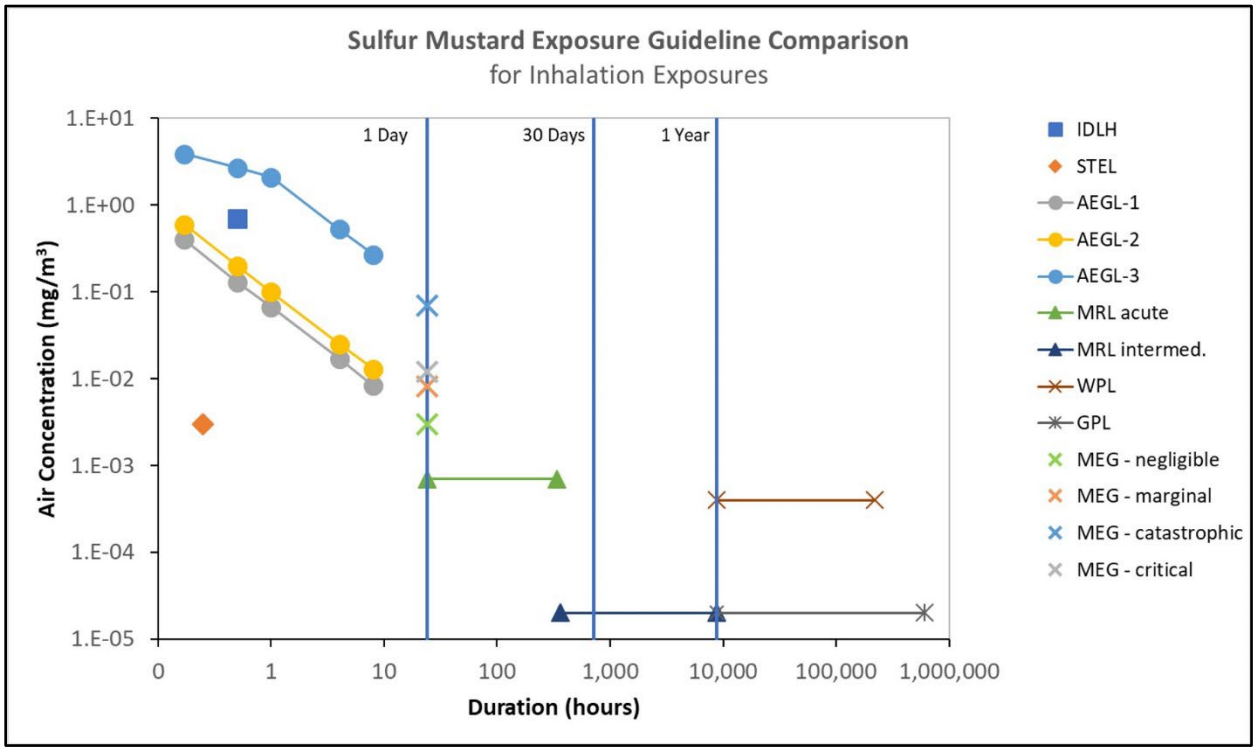

Figure 10: Sulfur Mustard Exposure Guidelines Comparison

Table B-6: Sulfur Mustard Example Response: Phases of Chemical Response

Phase	Health effects of concern	Activities and decisions	Criteria used for decision-making	Notes
Phases 2a&b Day 1 (12-24 hours)				
Activities include: determine types of chemical, locations, hot area Controls to minimize further responder/public deaths/severe injury Risk communication efforts to inform public on progress of response	Immediate/near-term (acute) effects: Several deaths, eye and skin irritation (some blistering), upper respiratory distress, breathing difficulties, general concerns Hundreds reporting injuries at local hospitals	Response workers: PPE levels— Initially Level A, subsequent to agent identification, reduced to Level B General public: Evacuation of inner harbor area around explosion site Local shelter-in-place decision Shut off heat/AC/close windows Public (people) decontamination	Visible liquid/gas Odors Any “positive” detection with field identification tests/equipment (e.g., screening level field equipment and Military M8 paper) Reports of health effects	Decision-makers: Local emergency and environmental health departments

Phase	Health effects of concern	Activities and decisions	Criteria used for decision-making	Notes
Phases 2b&c Days 2 and 3 (24-72 hours)				
Activities include: continued evaluation of air plume, identification of "sources" and field data to identify contaminated areas Technical Working Group established to determine sampling strategy and clearance goals Risk communication efforts to inform public on progress of response	**Immediate/near-term (acute) effects:** Continued reports of eye and skin irritation (some blistering), upper respiratory distress, breathing difficulties (*effects of HD can be delayed for 2-48 hours*)	**Response workers:** Air monitoring continued for hot area during operations to control/remove tanks Spikes indicated by field instrumentation required responders to evacuate—Level B and A (some inconsistency) **General public:** Initial shelter-in-place areas modified based on plume and sampling results Hospitals and critical infrastructures cleared	Air monitoring at periphery of hot area. Action levels identified for the protection of workers in PPE (e.g., > than AEGL 1 for 8 hr.) Wipe samples and laboratory-based analytical methods Air monitoring for protection of general public. Action levels developed based on extent of contamination, estimates of duration of exposure, etc. Relevant environmental guidelines may include 8-hour AEGLs for acute exposure durations, PALs or GLPs for longer term exposures	**Decision-makers:** Local emergency and environmental health departments together with federal agency support: primarily HHS, ATSDR and EPA for sampling

Phase	Health effects of concern	Activities and decisions	Criteria used for decision-making	Notes
Phase 3 (Recovery/ Reentry) Days 4 to 30+				
Sampling teams using field tests/equipment followed by laboratory-based analysis Phased clearance Risk communication efforts to inform public on progress of response	**Immediate/near-term (acute) effects:** None **Permanent/chronic injury/illness:** None	**Response workers:** No PPE required End response work **General public:** Resumed use/re-occupancy (unrestricted) of site/facilities.	**Approach used:** Air monitoring to corroborate soil, surface, and water clearance sampling to support findings/assumptions that decontamination is successful. **Surface wiping—**Sample results would be compared with site-specific clearance goals developed for populations of concern **Soil and destructive concrete sampling—L**aboratory analysis results compared with risk-based clearance goals for sulfur mustard Waste disposal for contaminated material	**Decision-makers:** Interagency through NRT-EPA, HHS, OSHA, supported by state/locals

5. References

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Appendix C: Security Classification Levels for Non-Traditional Agents

Table C-1: Summary of Classification Levels for Unclassified Non-traditional Chemical Agents Associated with Defensive Research, Development, and Acquisition (RDA)[142, 143]

UNCLASSIFIED **Eligible for Distribution A**	**CONTROLLED UNCLASSIFIED INFORMATION (CUI)** **Distribution B-E or FOUO**
Basic Characteristics: ▪ Names of agents ▪ Agent Non-Descriptive Codes ▪ IUPAC name/Structure ▪ Precursors ▪ Stimulants ▪ Low-resolution spectral data ▪ States of matter ▪ Volatility and Vapor pressure ▪ Persistence (qualitative) ▪ Relative toxicity (e.g., 10 times more dangerous than VX) ▪ Mechanism of action	USG-Owned Research, Development, Test and Evaluation (RDT&E) Data: ▪ Toxicity data/Reports ▪ High-resolution spectral data ▪ Pharmacological data ▪ Agent fate data ▪ Persistence (quantitative)

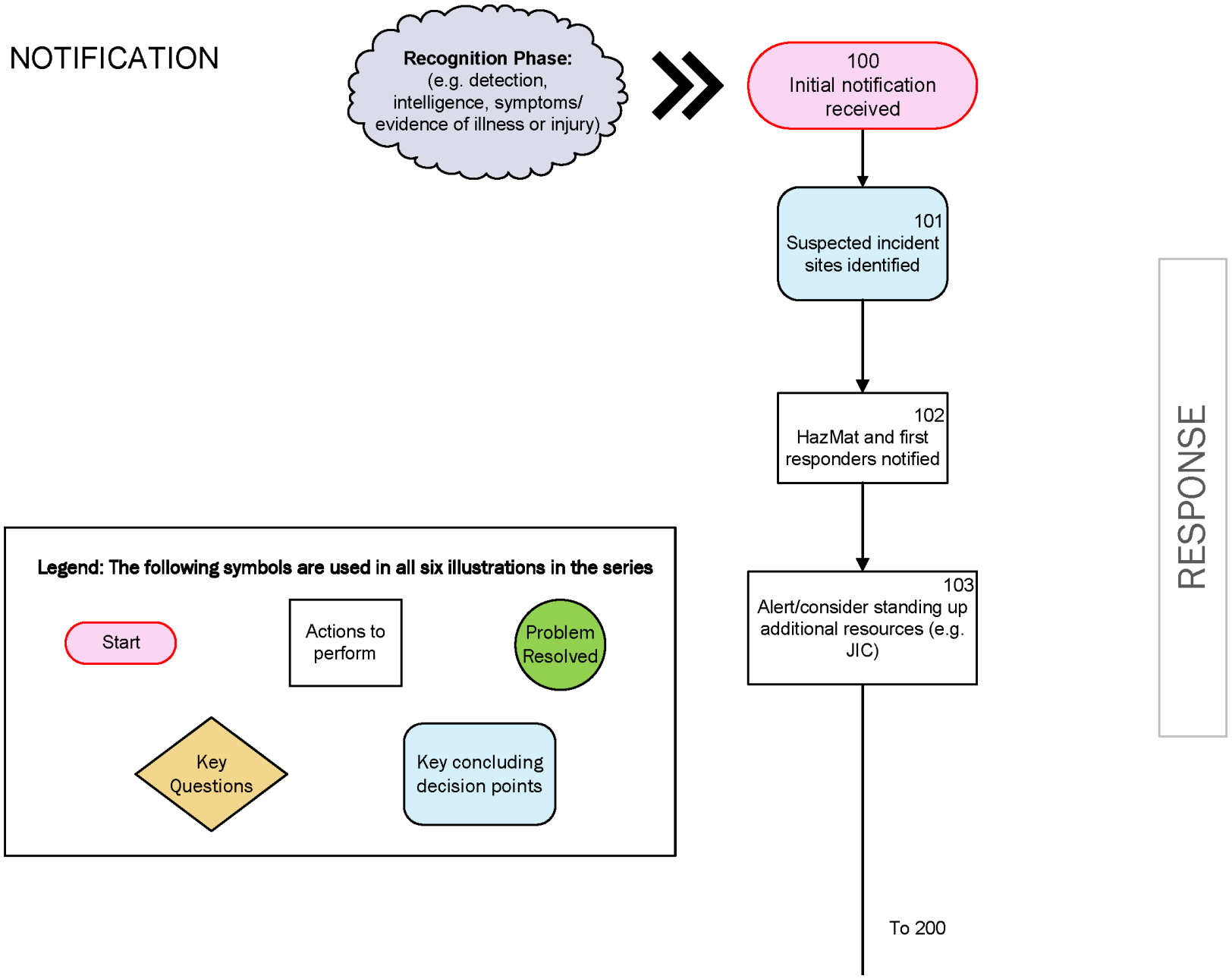
[142]Due to Schedule 1 changes made by The Organization for the Prohibition of Chemical Weapons Convention, three Fourth Generation Agents should now be treated as unclassified. As such, A-230, A-232, and A-234 are no longer governed under the Non-Traditional Agent Security Classification Guide.

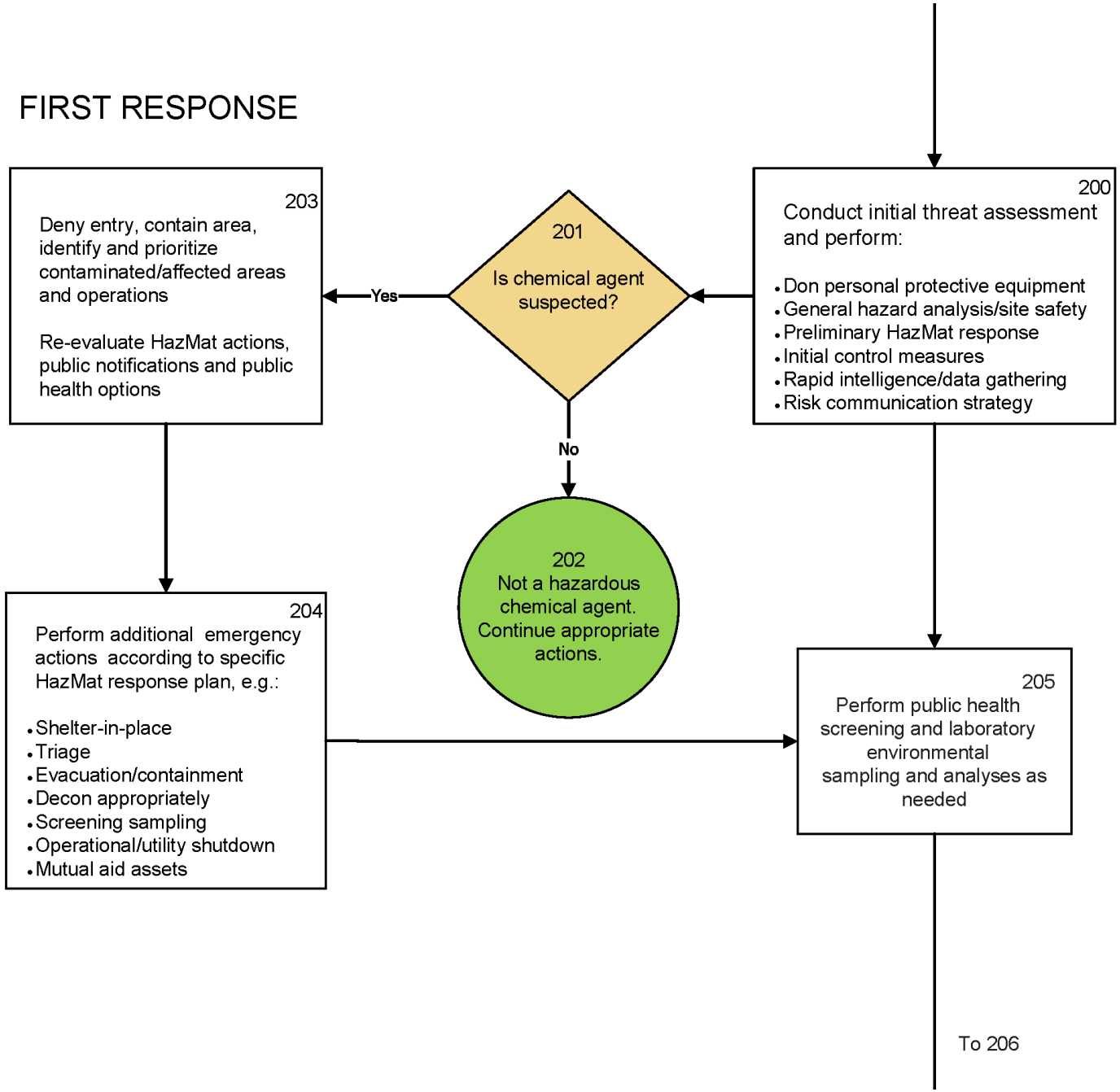
[143]The Classification Guidance for Non-Traditional Agents is available through the DOD ASD(NCB), 3050 Defense Pentagon, Washington, D.C. 20301-3050. Inquiries concerning content and interpretation should be directed to DASD (CBD) or OASD (NCB/CB).

UNCLASSIFIED **Eligible for Distribution A**	**CONTROLLED UNCLASSIFIED INFORMATION (CUI)** **Distribution B-E or FOUO**
Response Guidelines: ▪ How to detect/identify ▪ Protective equipment ▪ How to decontaminate ▪ How to treat/diagnose ▪ Symptoms/time to onset/duration ▪ FDA-approved medical countermeasures ▪ Toxicity Values (e.g., LD_{50}) ▪ Information for MSDS	RDT&E Data on Defensive Capabilities: ▪ Detection ▪ Decontamination ▪ Medical Countermeasures ▪ Protection

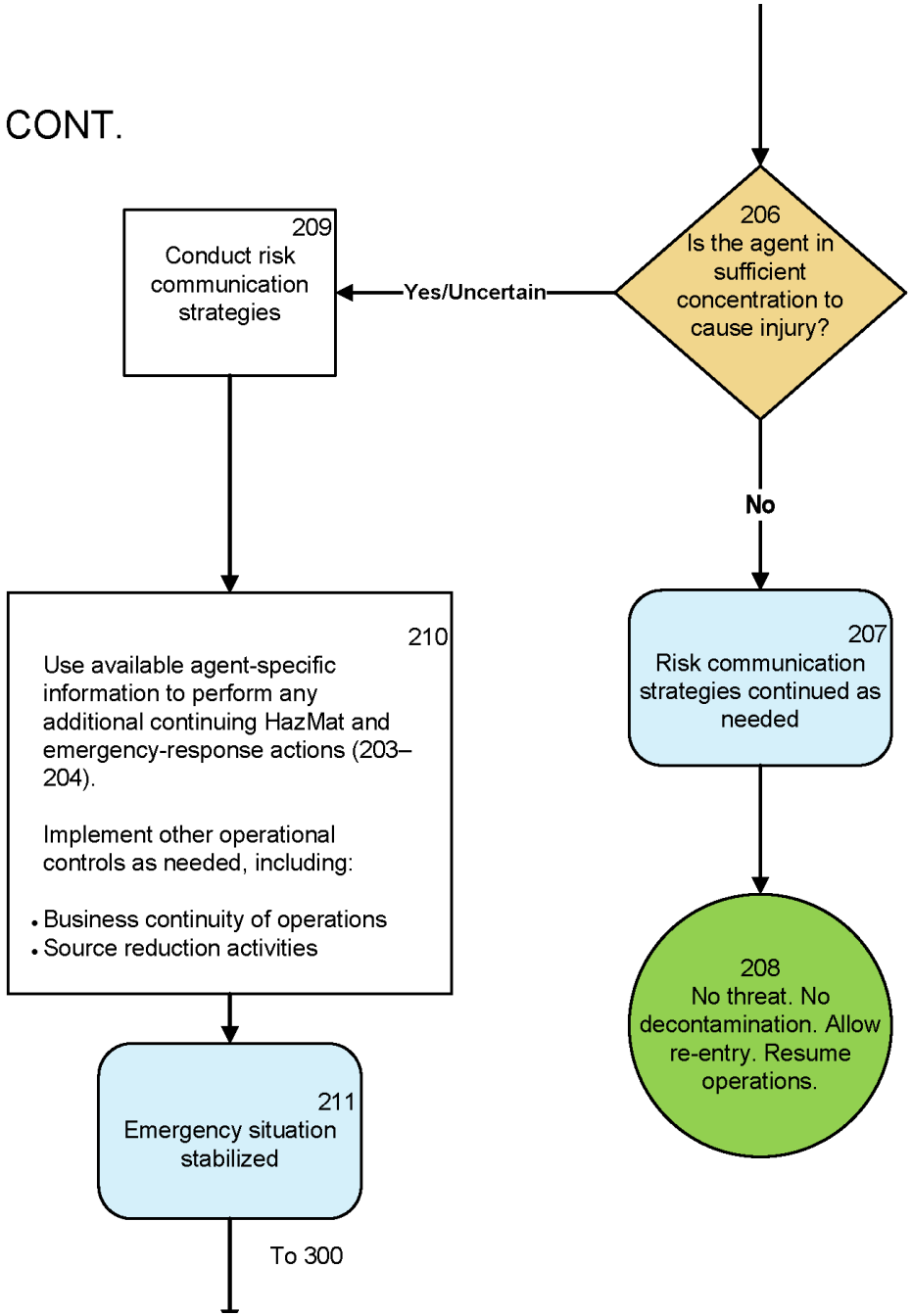
Appendix D: Chemical Incident Consequence Management Decision Flow

The detailed flow chart beginning on the page below highlights the critical steps that characterize the response to and recovery from a nationally significant or large-scale chemical incident.

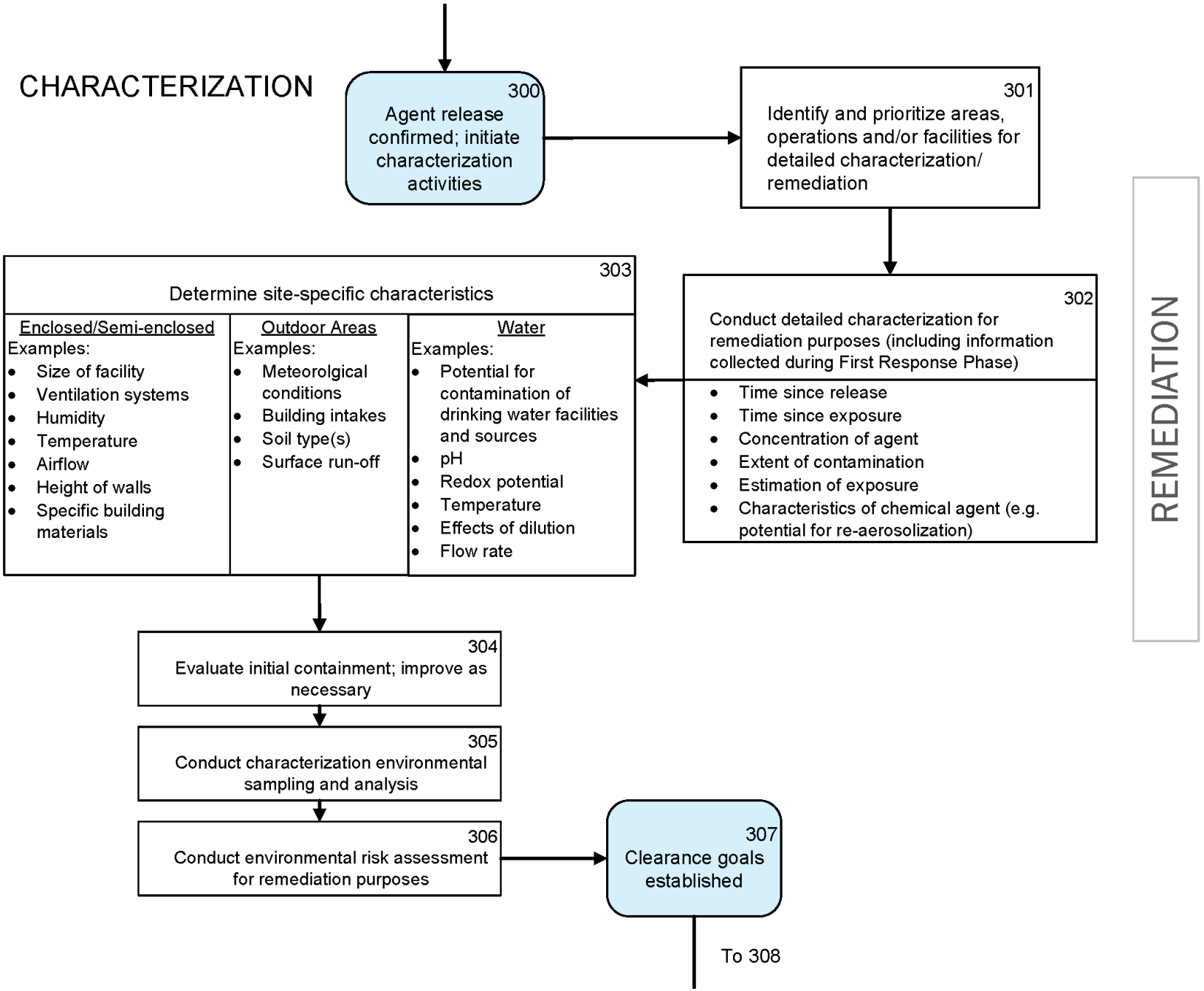

NOTIFICATION
Recognition Phase:
(e.g. detection, intelligence, symptoms/ evidence of illness or injury)
100
Initial notification received
101
Suspected incident sites identified
102
HazMat and first responders notified
103
Alert/consider standing up additional resources (e.g. JIC)
To 200
RESPONSE
Legend: The following symbols are used in all six illustrations in the series
Start
Actions to perform
Problem Resolved
Key Questions
Key concluding decision points

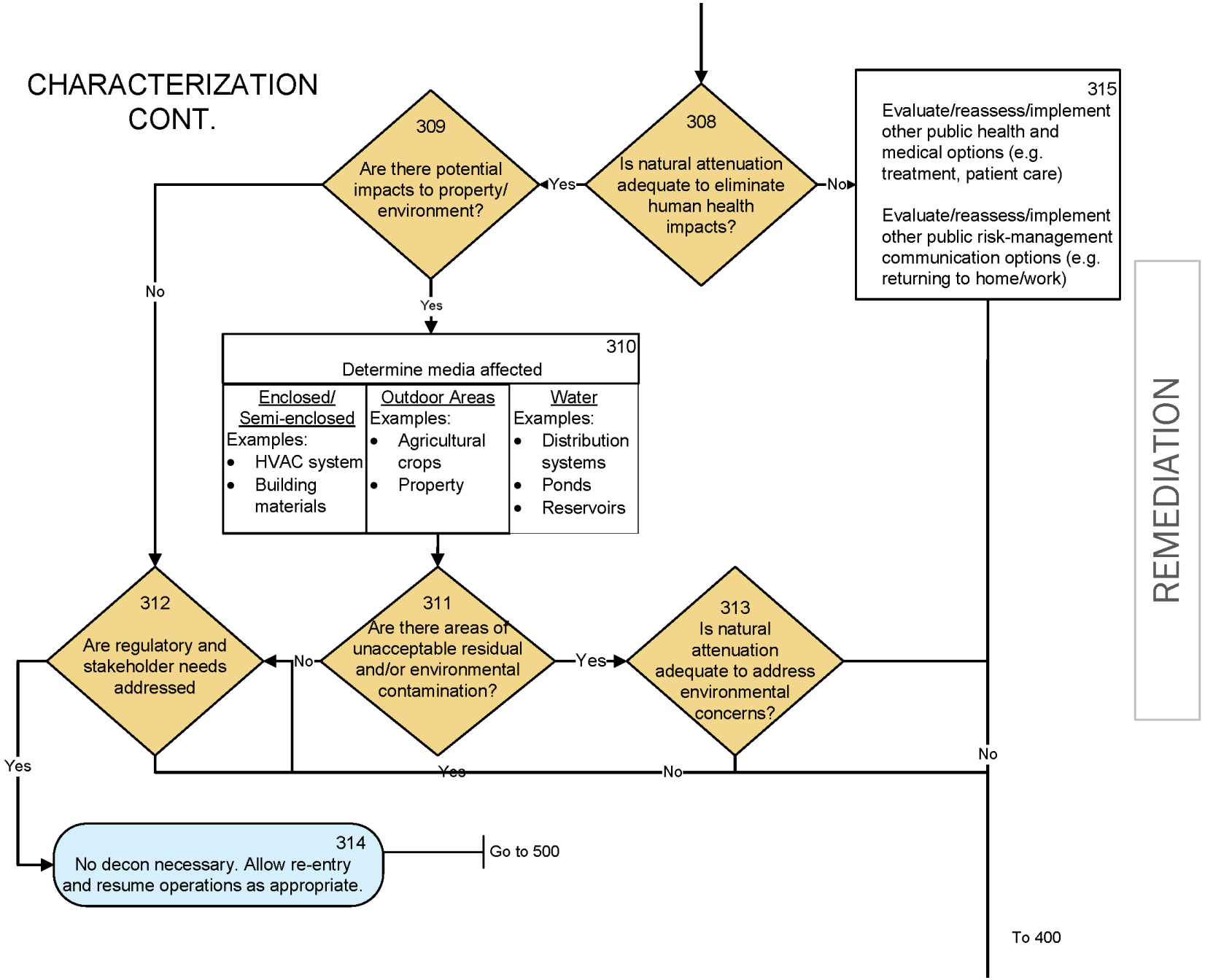

FIRST RESPONSE
200
Conduct initial threat assessment and perform:
• Don personal protective equipment
• General hazard analysis/site safety
• Preliminary HazMat response
• Initial control measures
• Rapid intelligence/data gathering
• Risk communication strategy
201
Is chemical agent suspected?
Yes
No
203
Deny entry, contain area, identify and prioritize contaminated/affected areas and operations
Re-evaluate HazMat actions, public notifications and public health options
202
Not a hazardous chemical agent. Continue appropriate actions.
204
Perform additional emergency actions according to specific HazMat response plan, e.g.:
• Shelter-in-place
• Triage
• Evacuation/containment
• Decon appropriately
• Screening sampling
• Operational/utility shutdown
• Mutual aid assets
205
Perform public health screening and laboratory environmental sampling and analyses as needed
To 206
RESPONSE

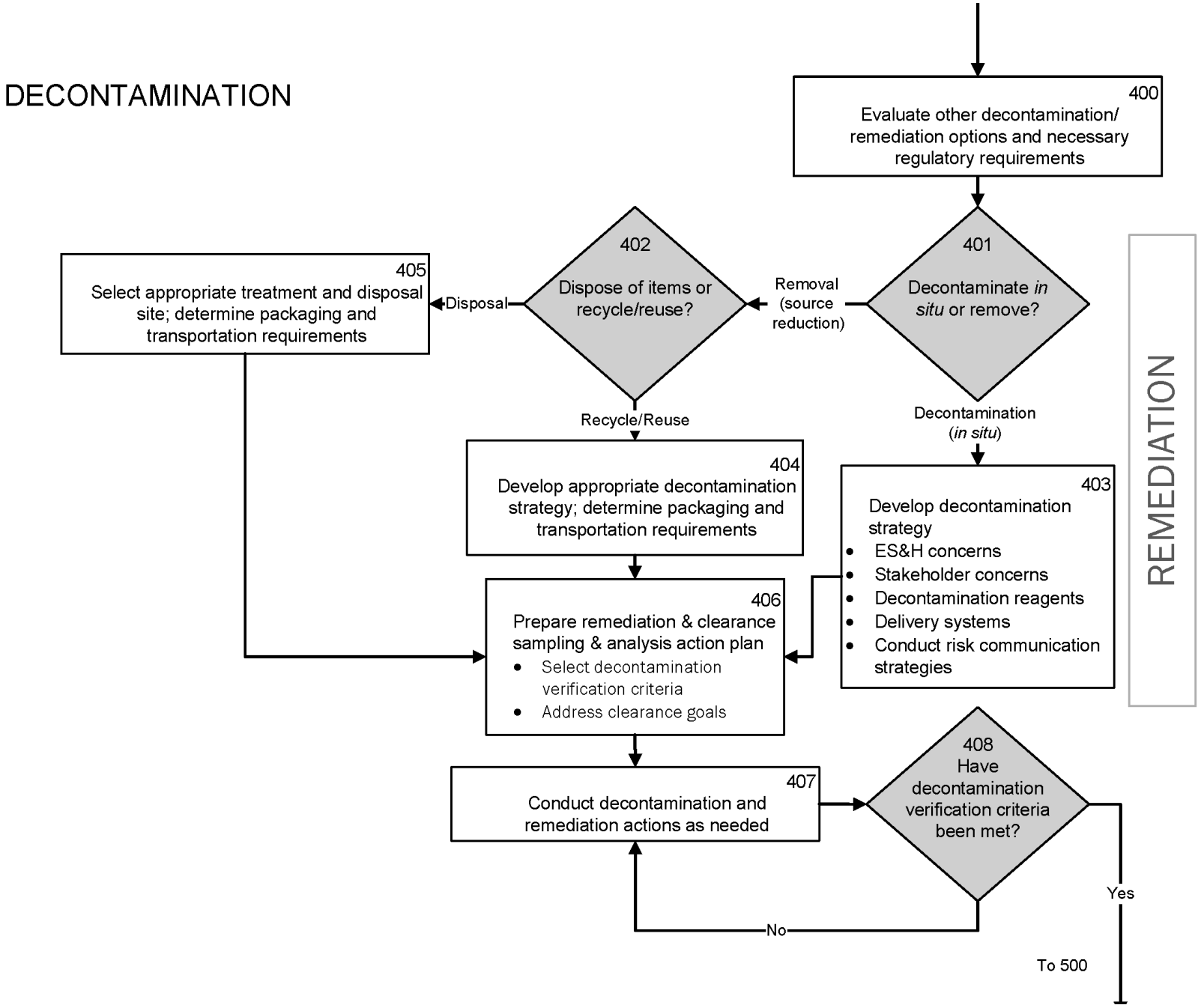
FIRST RESPONSE CONT.

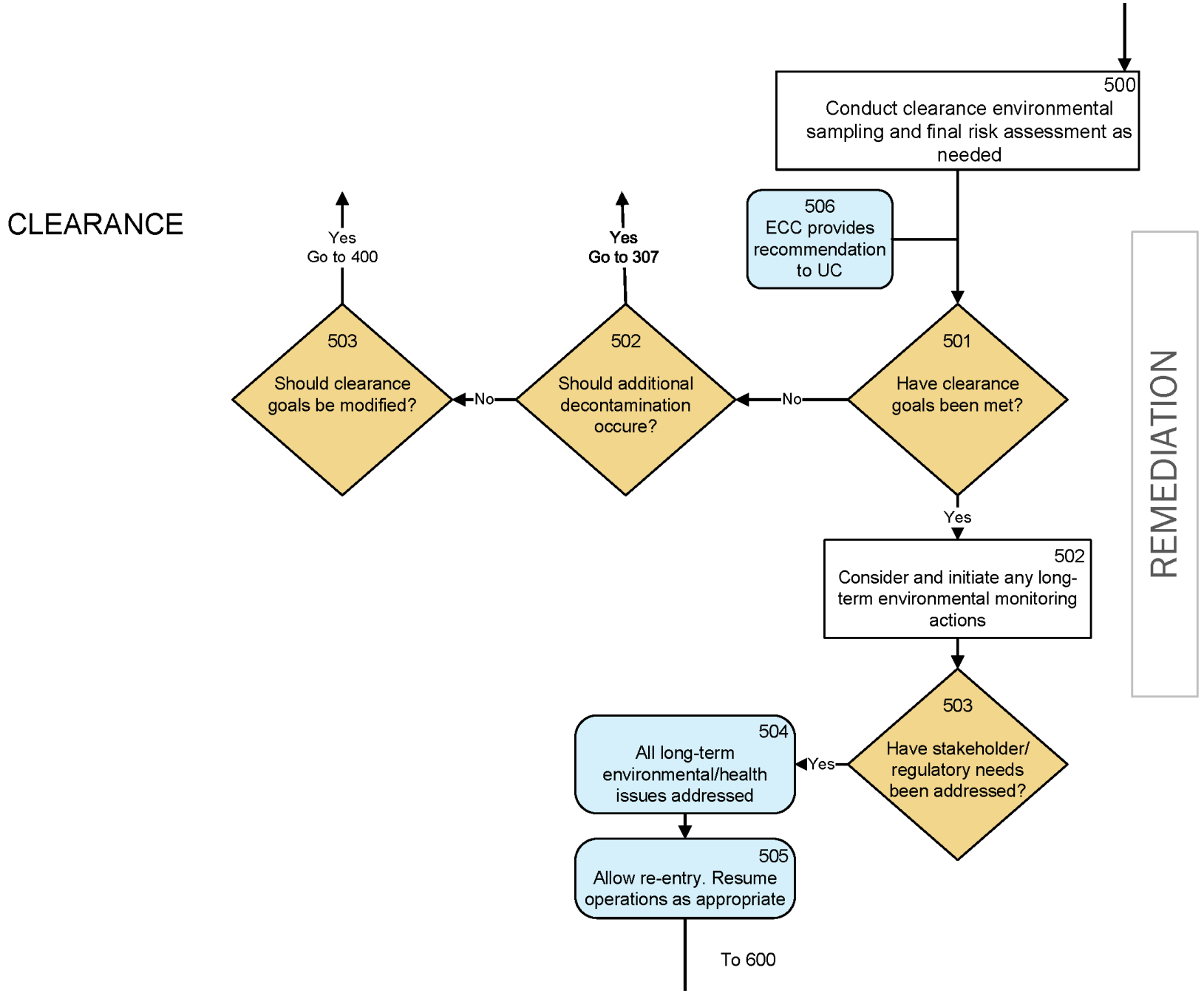


RESPONSE


CHARACTERIZATION
300
Agent release confirmed; initiate characterization activities
301
Identify and prioritize areas, operations and/or facilities for detailed characterization/ remediation
302
Conduct detailed characterization for remediation purposes (including information collected during First Response Phase)
Time since release
Time since exposure
Concentration of agent
Extent of contamination
Estimation of exposure
Characteristics of chemical agent (e.g. potential for re-aerosolization)
303
Determine site-specific characteristics
Enclosed/Semi-enclosed
Examples:
Size of facility
Ventilation systems
Humidity
Temperature
Airflow
Height of walls
Specific building materials
Outdoor Areas
Examples:
Meteorolgical conditions
Building intakes
Soil type(s)
Surface run-off
Water
Examples:
Potential for contamination of drinking water facilities and sources
pH
Redox potential
Temperature
Effects of dilution
Flow rate
304
Evaluate initial containment; improve as necessary
305
Conduct characterization environmental sampling and analysis
306
Conduct environmental risk assessment for remediation purposes
307
Clearance goals established
To 308
REMEDIATION


CHARACTERIZATION CONT.
309
Are there potential impacts to property/ environment?
Yes
308
Is natural attenuation adequate to eliminate human health impacts?
No
315
Evaluate/reassess/implement other public health and medical options (e.g. treatment, patient care)
Evaluate/reassess/implement other public risk-management communication options (e.g. returning to home/work)
No
Yes
310
Determine media affected
Enclosed/ Semi-enclosed
Examples:
HVAC system
Building materials
Outdoor Areas
Examples:
Agricultural crops
Property
Water
Examples:
Distribution systems
Ponds
Reservoirs
312
Are regulatory and stakeholder needs addressed
311
Are there areas of unacceptable residual and/or environmental contamination?
313
Is natural attenuation adequate to address environmental concerns?
No
Yes
Yes
No
No
Yes
314
No decon necessary. Allow re-entry and resume operations as appropriate.
Go to 500
To 400
REMEDIATION


DECONTAMINATION
400
Evaluate other decontamination/ remediation options and necessary regulatory requirements
401
Decontaminate *in situ* or remove?
Removal (source reduction)
402
Dispose of items or recycle/reuse?
Disposal
405
Select appropriate treatment and disposal site; determine packaging and transportation requirements
Recycle/Reuse
404
Develop appropriate decontamination strategy; determine packaging and transportation requirements
Decontamination (*in situ*)
403
Develop decontamination strategy
• ES&H concerns
• Stakeholder concerns
• Decontamination reagents
• Delivery systems
• Conduct risk communication strategies
406
Prepare remediation & clearance sampling & analysis action plan
• Select decontamination verification criteria
• Address clearance goals
407
Conduct decontamination and remediation actions as needed
408
Have decontamination verification criteria been met?
No
Yes
To 500
REMEDIATION


CLEARANCE
500
Conduct clearance environmental sampling and final risk assessment as needed
506
ECC provides recommendation to UC
501
Have clearance goals been met?
No
502
Should additional decontamination occure?
Yes
Go to 307
No
503
Should clearance goals be modified?
Yes
Go to 400
Yes
502
Consider and initiate any long-term environmental monitoring actions
503
Have stakeholder/ regulatory needs been addressed?
Yes
504
All long-term environmental/health issues addressed
505
Allow re-entry. Resume operations as appropriate
To 600
REMEDIATION

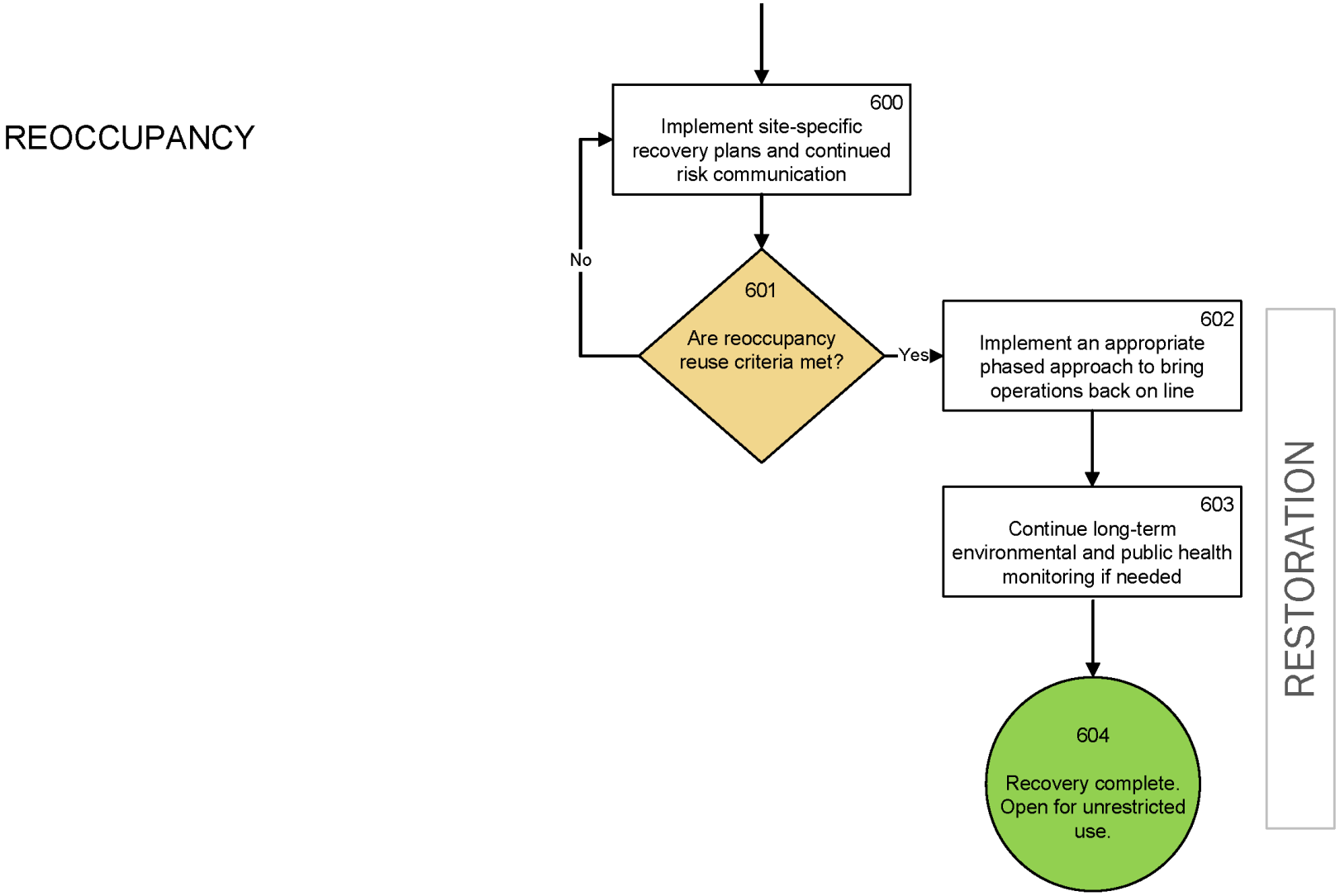


Figure D-1: Chemical Consequence Management Decision Flow

Acknowledgements

This Document Was Developed by the Chemical Incident Consequence Management Working Group:

Background: The 2018 Salisbury, United Kingdom, release of Novichok (a Fourth/Fifth Generation Agent or FGA) illuminates the need to develop guidance to mitigate serious public health and economic impacts. Federal Interagency Guidance, published in January 2019, addressed several issues including emergency medical management and workforce health protection but failed to address remediation and recovery guidance. FEMA formally requested that DHS S&T update or develop FGA remediation and recovery guidance.

Purpose: This stakeholder/SME working group was established to develop guidance for the remediation and recovery of contaminated facilities effected by a chemical agent for use by FSLTT partners. This guidance provides decision-makers with a consequence management framework to both plan for and execute response and recovery activities for a large-scale hazardous chemical incident in a domestic, civilian setting.

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