Condensed
Chemical Agent Field Guidebook
For
Consequence Management

(Field Guide)

August 25, 2015

DISCLAIMER

PARTICIPANTS

The Chemical Warfare Agent (CWA) National Preparedness Work Group consists of United States Environmental Protection Agency (EPA) On-Scene Coordinator (OSC) representatives from all 10 Regions as well as representatives from the National Homeland Security Research Center (NHSRC), Environmental Response Team (ERT), and Consequence Management Advisory Division (CMAD). The goal of the WG was to develop an operational guide, or playbook to provide a national approach to respond to a CWA incident. The result is this Comprehensive Chemical Agent Tactical Guidebook for Consequence Management (Guidebook). Additional guides, checklists, or appendices were developed or used in support of this Guidebook. CSS-Dynamac, the Decontamination Analytical & Technical Service (DATS) contractor for CMAD, assisted with preparation of this Guidebook.

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1. INTRODUCTION

This Chemical Agent Tactical Field Guide (Field Guide) was developed to provide a condensed overview for application in the field of key operational information needed during a response to a chemical agent (characterization, decontamination, and clearance activities) of. This Field Guide is only an overview, and more detailed information on chemical agent response and other topics is presented in the Comprehensive Chemical Agent Tactical Guidebook (Guidebook) (U.S. Environmental Protection Agency [EPA] 2015). The Guidebook and the associated Field Guide were a collaborative effort by a Technical Work Group who specialize in characterizing and cleaning up after a deliberate or unintentional chemical warfare agent (CWA) release.

1.1 Overview

This Guidebook focuses on the nerve agents tabun (GA), sarin (GB), soman (GD), cyclosarin (GF) and O-ethyl S-(diisopropylaminoethyl) methylphosphonthiolate (VX), and blister agents sulfur mustard (HD), Lewisite, and mustard mixtures. EPA currently considers nerve agents and blister agents the highest-priority chemical agents. Table 1-1 lists the priority chemical agents and summarizes some of their properties. Both nerve and blister agents were mass produced during the Cold War. Similar to many pesticides, nerve agents belong to the organophosphate group and are easily manufactured. Blister agents, or vesicants, are one of the most common CWA agents. The raw materials to make these CWAs are inexpensive and generally readily available. As science and threat assessments continue to evolve, EPA prioritization of CWAs may change and focus may shift to other CWAs.

1.2 Background

No single cleanup level or approach is appropriate for every scenario. In addition, inconsistencies can occur among agencies addressing separate aspects of a response. Different CWA environmental- or health-based exposure levels may be applicable to different phases of the response (for example, higher action levels may be applicable to the crisis management phase, while more stringent cleanup levels may be appropriate for the consequence management phase). Advance planning between EPA and all other agencies is necessary to ensure transparent and clear communication throughout all phases of the response and is strongly encouraged by national guidance documents such as the National Response Framework (NRF) (Department of Homeland Security [DHS] 2008). Therefore, the most effective response includes coordinated decision-making among federal, state, tribal, and local decision-makers.

1.3 Purpose

This document is intended to provide a starting framework for EPA planners and response technical advisors in determining cleanup strategies. Cleanup strategies should consider how to best determine and select protective environmental- and health-based exposure levels for various exposure conditions and scenarios while promoting a cost-effective, fiscally responsible cleanup.

Table 1-1. Chemical Agents Considered Priority by the EPA

NAME (SYMBOL)	PHYSICAL CHARACTERISTICS	PERSISTENCE	MEANS OF EXPOSURE	EFFECTS
Tabun (GA)	Evaporates quickly; Tasteless/colorless; Fruity odor; Spread in aerosol or liquid form; Heavier than air	1–2 days if heavy concentration	Skin contact or inhalation	Contraction of pupils, eye pain, and dim or blurred vision; runny nose; chest tightness; nausea and vomiting possible; twitching or convulsions when skeletal muscle reached
Sarin (GB)	Evaporates quickly; Odorless/tasteless/colorless; Absorbed slowly through skin; Evaporates quickly;	1–2 days will evaporate with water	Skin contact or inhalation	
Soman (GD)	Evaporates quickly; Clear, colorless, liquid. Discolors with aging to dark brown. Odor like camphor or rotting fruit; Evaporates quickly;	Moderate, 1–2 days	Skin contact or inhalation	Fluctuations in heart rate; loss of consciousness and seizure activity possible within 1 minute of exposure when agent concentration is high; eventual paralysis and death
Cyclosarin (GF)	A colorless room temperature liquid; Odor is described as sweet and musty; resembling peaches or shellac; Persistent liquid, flammable, with a flash point of 201 °F	Moderate, 1–2 days	Skin contact or inhalation	Similar to sarin. Effects seen in eyes (contraction of pupils, pain, dim or blurred vision), runny nose), and air ways (chest tightness); nausea and vomiting also possible; Twitching/convulsions result when skeletal muscle reached
VX	Odorless / tasteless; Oily consistency; Amber color; Spread in aerosol or liquid form; Heavier than air	High, 1 week if heavy concentration; As volatile as motor oil	Skin contact or inhalation	Fluctuations in heart rate; loss of consciousness and seizure activity possible within 1 minute of exposure when agent concentration is high; eventual paralysis and death
Sulfur Mustard (HD)	Pale yellow or amber color; Usually odorless but can smell like mustard, onions, or garlic; Can remain in environment for up to a week (but much longer if buried beneath soil surface); Heavier than air	Very high, days to weeks	Skin contact or inhalation	Pain not immediate; topical effects on the skin (blisters), in airways (coughing, lesions, and, in rare cases, respiratory failure), and in eyes (itchiness, burning, and possible cornea damage); nausea and vomiting possible
Nitrogen Mustard (HN-3)		Very high, days to weeks	Skin contact or inhalation	Skin blistering; respiratory tract damage
Mustard Lewisite (HL)	Properties are dependant on exact composition; munitions grade has a composition of 63/37 weight percentage L & H. Garlic-like odor, if there is sufficient H present.	Semi-persistent; Very high, days to weeks	Skin contact or inhalation	Skin blistering; respiratory tract damage
Lewisite (L)	Evaporates quickly; Pure- oily, colorless and odorless. Impure - yellow brown to violet black liquid with strong penetrating geranium odor; Heavier than air	Moderate	Skin contact or inhalation	Effects similar to those of mustard; skin blistering, burning, watery, or swollen eyes; upper airway irritation; systemic blood poisoning

2. FRAMEWORK FOR DECISION-MAKING

Cleanup decision-making should involve a flexible process that includes situation-specific considerations and the most current science and engineering techniques and approaches. A flexible process is required that considers numerous factors to achieve a result that balances local needs and desires, health risk considerations, costs considerations, technical feasibility, and other factors.

The goals of a decision-making process are summarized below.

1. **Transparency** – Information about the basis for cleanup and other decisions should be available to stakeholder representatives and ultimately the general public.
2. **Inclusiveness** – Representative stakeholders should be involved in decision-making activities.
3. **Effectiveness** – Technical subject matter experts (SME) should analyze remediation options, assess various technologies to assist in decisions optimal for the incident, and consider clearance decisions and cleanup goals.
4. **Shared Accountability** – The final decision to proceed should be jointly made by federal, state, tribal, and local officials in Unified Command (UC).

2.1 Management Infrastructure to Support Decision-Making

The NRF (DHS 2008) and the National Incident Management System (NIMS) (FEMA 2013) have established a comprehensive, all-hazards approach to enhance planning and preparedness for the management of domestic incidents. The NIMS Incident Command System (ICS) is a tool that can be used to manage tactical operations of an incident regardless of the size or complexity. The ICS is a modular system that expands as the incident expands. An Incident Commander (IC) has the jurisdictional authority to direct response activities. However, for large-scale incidents, the IC normally functions within the UC with other agencies and state, local, and tribal responders.

A Technical Working Group (TWG) of SMEs from various agencies should be convened as soon as possible and scaled to the needs of the specific incident. The TWG provides multi-agency, multi-disciplinary expert input on the optimization analysis, including advice on technical issues, analysis of relevant regulatory requirements and guidelines, risk analysis, and development of cleanup options and clearance decisions. The purpose of the TWG is to provide expert technical input to the IC/UC and not to make decisions. The TWG should include federal, state, tribal, local, and private-sector SMEs in such fields as environmental fate and transport modeling; technical remediation options analysis; time, cost, risk, and benefit analysis; and relevant regulatory requirements. The group may not be physically located at the Incident Command Post (ICP), and may conducted operations remotely. Experts in the TWG may review data and documents; provide technical input to the IC/UC; and meet with incident management officials. Also, the TWG may be asked to participate in meetings with the Joint Field Office (JFO) United Coordination Group.

The Environmental Clearance Committee (ECC) is an independent peer-review body that can be established to provide additional credibility and confidence that clearance goals have or have not been achieved in the remediation effort. The ECC functions as an advisory group to the IC/UC and determines if clearance goals have been met. In an incident where multiple jurisdictions are affected and more than one ECC is established, affected federal, state, and local authorities will make every effort to coordinate and communicate with the ECC(s) and various jurisdictions to ensure consistency across jurisdictions as well as to most effectively and efficiently utilize the resources of the ECC.

Additional information about the NIMS, ICS, and ICS functions is available at https://www.fema.gov/national-incident-management-system.

2.3 Planning Documents

Planning documents are essential during the decision-making process, from the initial response to final recovery. Example planning documents are listed below.

- **Quality Assurance Project Plan (QAPP)** – The QAPP establishes site-specific data quality objectives (DQO) for

the project. The QAPP sometimes includes a Field Sampling Plan (FSP). Appendix 1 provides example QAPP/FSP templates.

- **Health and Safety Plan (HASP)** – The HASP establishes overall site-specific safety requirements, work areas, and levels of personal protection equipment (PPE). Appendix 2 provides an example HASP template.
- **Ambient Air Monitoring Plan (AAMP)** – The AAMP establishes air monitoring protocols, sampling frequency, and spatial distribution to ensure the safety of response workers and the nearby public. The AAMP is used to determine plume migration, provide evacuation guidance, and provide shelter-in-place actions, if needed. Real-time air monitoring can be combined with discrete or composite air samples submitted for laboratory analysis. The AAMP may be used throughout the crisis and consequence management phases. Appendix 3 discusses air monitoring instrumentation need for the AAMP and provides the EPA air monitoring tables for CWAs.
- **Sampling and Analysis Plan (SAP)** – The SAP establishes the number and spatial distribution of samples for all matrices during the consequence management phase of site recovery. The AAMP may be incorporated into the SAP.
- **Remedial Action Plan (RAP)** – The RAP establishes decontamination technologies and methods for site remediation and cleanup.
- **Remediation Guidance** – Remediation guidance identifies key activities and issues that must be considered after an incident involving a CWA release.
- **Data Management Plan (DMP)** – The DMP identifies the data management process and procedures for work activities associated with data collection.
- **Uniform Federal Policy (UFP) QAPP** – The UFP for QAPPs is a consensus quality systems document prepared by the Intergovernmental Data Quality Task Force (IDQTF), a working group of representatives from EPA, the Department of Defense (DOD), and the Department of Energy (DOE).

3. RESPONSE AND RECOVERY ACTIVITIES

Response activities can be grouped into two broad categories: crisis management and consequence management. Under these categories, six phases are designated as shown in Table 3-1 (LLNL 2012). The overall goal of a response to a CWA incident is to protect human health and the environment, achieve an acceptable level of cleanup, and return a site to normal operations to the extent feasible. However, many activities are required to make final decisions regarding acceptable cleanup goals and clearance. Multiple agencies use many terms to describe the phases listed in Table 3-1 to represent the general timeline of required response and recovery activities. However, in most cases, multiple activities occur concurrently, so the concept of an absolute, strict, step-by-step process for individual activities is not realistic.

3.1 Crisis Management

Crisis management during a response typically is characterized by a lack of knowledge and uncertainties during the immediate aftermath of the release. The source of the release may still be present. In general, priority is given to life-saving and First Aid actions, such as evacuation, sheltering in place, and protection of emergency workers. Figure 3-1 presents a flowchart outlining the main actions performed and decisions made during crisis management.

Crisis management can be divided into the notification and first response phases as discussed below. It should be noted that although attributes of each phase are discussed below, successful cleanup must be governed by a dynamic and flexible process. Thus, the phases should not be construed to be discrete. For example, risk communication is essential during each phase.

Table 3-1. CWA Incident Response and Recovery Activities Phases

RESPONSE AND RECOVERY ACTIVITIES					
CRISIS MANAGEMENT		CONSEQUENCE MANAGEMENT			
		Restoration			
Notification	First Response	Characterization	Remediation (Cleanup)	Clearance	Recovery
Receive and assess information Identify suspected release sites Relay key information and potential risks to appropriate agencies	HAZMAT and emergency Actions Forensic investigation Public health actions Screening and sampling Determination of agent type, concentration, and viability Risk communication (for example, public warnings and recommended protective actions) Evacuations	SAP and QAPP Detailed characterization of CWA Characterization of affected area(s) or site(s) Site containment Continued risk communication Initial risk assessment Clearance goals Environmental sampling and analysis	Remediation and decontamination strategy RAP Worker health and safety Site preparation Source reduction Decontamination of sites, items, or both Treatment Verification of decontamination parameters Waste disposal Continued risk communications	Clearance sampling and analysis Clearance decisions Continued risk communication	Renovation Resumed use or reoccupation decision Potential environmental and public health monitoring Continued risk communication

Note: Adapted from LLNL 2012

Within the established perimeter of the incident site (the area impacted by the CWA release), decisions need to be made regarding areas for evacuation, sheltering-in-place actions, and restricted-use actions. During both the crisis and consequence management phases, a variety of containment actions may be taken to prevent the spread or movement of a CWA, including the following:

- Cordoning off all areas known or suspected of being contaminated
- Turning off a facility's heating, ventilation, and air conditioning (HVAC) system
- For a CWA deliberately released indoor, sealing off all air ducts, windows, doors, and vents with 6-millimeter polyethylene sheeting
- Ensuring site security by establishing procedures to restrict entry of unauthorized personnel (for example, posting signs, installing physical barriers, or using guards)

Establishing standard work areas to control site access and the spread of CWA contamination

3.2 Consequence Management

This component of a response constitutes the longest part of site recovery activities and includes site characterization, which requires determining the extent of CWA contamination, cleanup and decontamination activities, and the final restoration and recovery of the site for proper resumed use or re-occupancy. Data acquired during the consequence management phase must be adequate for evaluating options (cleanup approaches) as well as for making final clearance decisions. Most key steps and elements in the cleanup decision-making process take place during consequence management.

3.2.1 Restoration Phase

This consequence management phase typically involves identifying infrastructure and population(s) affected and fully characterizing potentially contaminated areas. By confirming that areas have not been affected, the IC can allow a rapid return to normal operations for these areas, including roads, airports, businesses, hospitals, residences, and other areas. The restoration phase can further be divided into the following phases:

- **Characterization Phase** – Detailed characterization of the CWA and site or area(s); preparation of the SAP; risk communication and risk assessment clearance goals set
- **Remediation (Cleanup) Phase** – Remediation technologies and procedures selected and implemented; preparation of RAP; cleanup activities; waste transportation and disposal
- **Clearance Phase** – Remediation efforts evaluated to determine if the site is cleaned up sufficiently to allow release for resumed use or re-occupancy

During the characterization phase, additional site and scenario data are gathered. Example site characterization activities include the following:

- Developing a detailed description and determining the dimensions of the area(s) affected (both natural and man-made)Estimating the extent of contamination, including potentially contaminated surface areas and volumes of materials, using maps, building blueprints, and water distribution system maps (including connections and components of water distribution system)
- Identifying material types, such as non-porous (such as glass and metals), semi-porous (such as walls and concrete), or porous (such as ceiling tile and carpet)
- Documenting environmental conditions during and after the CWA incident (such as ambient temperature, humidity, exposure to sunlight, cloud cover, wind speed and direction, rate and directional flow of water, and rainfall)
- Predicting where runoff from precipitation and early decontamination activities may have spread CWA contamination
- Applying mathematical models to characterize the fate and transport of a CWA (such as air, groundwater, and surface water models)

Decontamination technologies and procedures are used to clean up affected sites and areas. The decontamination process is iterative, with continual decontamination activities and re-characterization of the decontaminated areas to determine if additional decontamination is required, until clearance levels are reached. Decontamination technologies use mechanical, physical, chemical, biological, or natural degradation and natural attenuation methods to physically remove, chemically treat, biologically degrade, or naturally dissipate CWAs (Environment Canada 2005). Section 5 of this Guidebook, Decontamination, discusses some decontamination technologies for specific CWAs for surface "hot spots," large volumetric spaces, and sensitive equipment.

3.2.2 Recovery Phase

During this phase of the response, final decisions are made regarding resumed use and re-occupancy of contaminated sites and facilities. Plans for determining if long-term environmental monitoring is required also should be considered to ensure achievement of clearance levels and determine if site controls or restrictions are necessary. Continued risk communication is important during the recovery 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.

Risk communication is a vital component of risk analysis and critical to effective risk, crisis, and consequence management during and after a CWA incident. The goal of effective risk communication is to share information and inform the public about actions taken to reduce risk. The risk should not be over- or understated. Practical information should be communicated, including response guidance about government and public responsibilities during and after the incident. Trusted community leaders should deliver these messages in a simple and straightforward manner (DHHS 2002). Risk communication is

RISK COMMUNICATION
According to the Department of Health and Human Services (DHHS), risk communication is "an 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, opinions, or reactions to risk messages or to legal and institutional arrangements for risk management" (DHHS 2002).

a continuous process because knowledge about risks may be fragmentary at first but increase over time. Effective risk communication builds public knowledge and trust over time.

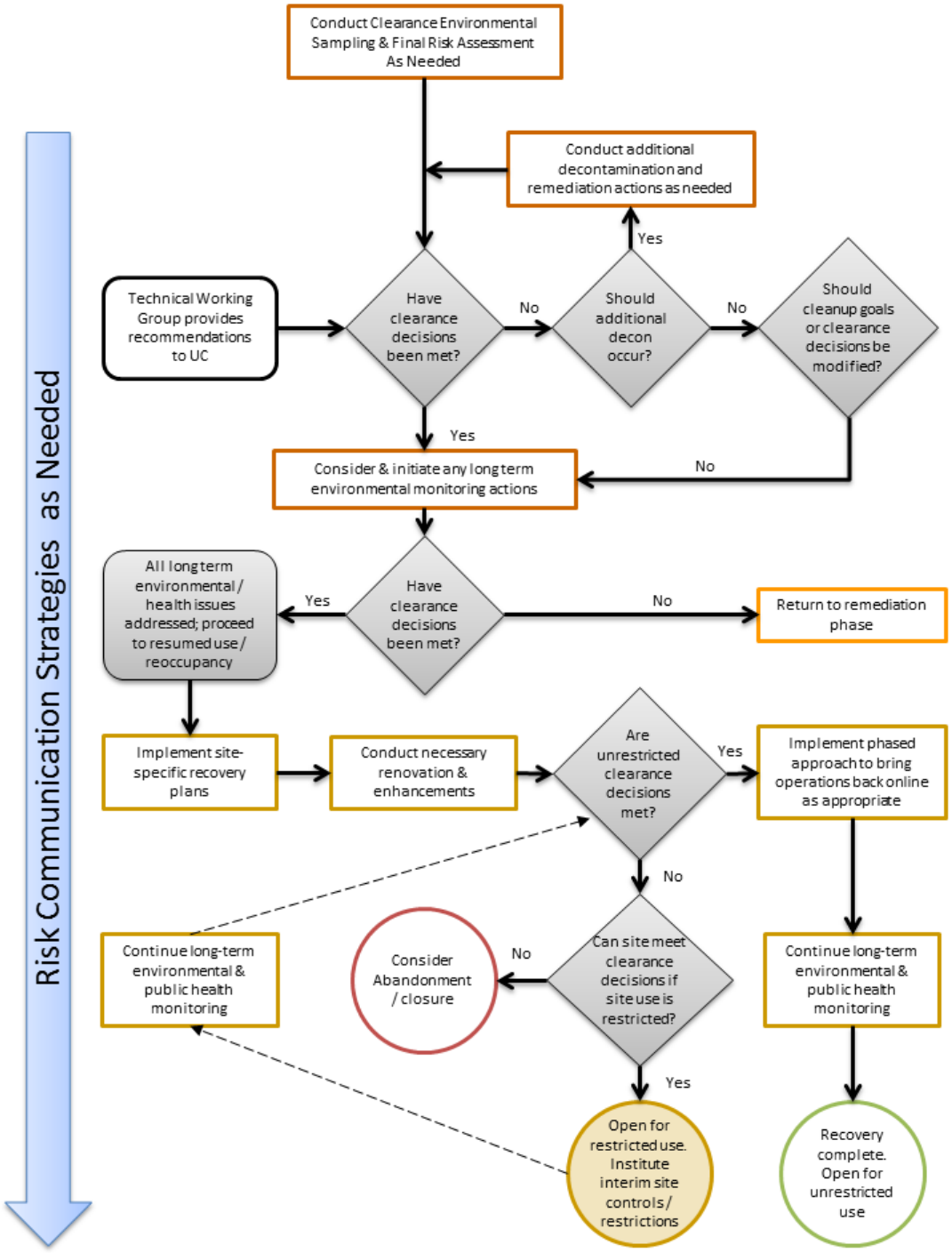

Figure 3-2. Actions Performed and Decisions Made During the Recovery and Restoration Phases of Consequence Management

4. SAMPLING

This section provides an overview of environmental sampling and discusses sampling objectives for a CWA event, sampling plans, sampling resources, sampling strategies, data management, the sampling checklist, and sampling methods.

4.1 Overview

Environmental sampling during a CWA event has three distinct phases: field screening during initial stages, characterization sampling, verification sampling, clearance sampling, and long-term environmental monitoring during restoration.

4.1.1 Field Screening

Field screening usually occurs during first response in order to determine if CWA contamination is present and is likely to use judgmental sampling as a primary strategy to determine locations with the greatest likelihood of contamination that need to be evaluated first (Emanuel et al. 2008).

4.1.2 Characterization Sampling

Characterization sampling typically is used to obtain information concerning the extent and magnitude of contamination to guide remediation. Uses of characterization sampling data include estimating potential exposure to the CWA and deciding decontamination locations, items, materials, and methods (DHS 2006).

4.1.3 Verification Sampling

Verification samples are collected from previously contaminated areas and surfaces to determine if contamination remains, and is performed during the remediation process to determine if decontamination or a related process was effective or sufficient in removing contamination.

4.1.4 Clearance Sampling

Clearance sampling allows objective determination of whether clearance goals have been met and a site or facility is ready for final preparation for re-occupancy. Clearance sampling is conducted after decontamination activities are complete and before removal of critical barriers and is used to confirm that the contaminated site or facility no longer poses an unacceptable health risk.

4.1.5 Long-Term Environmental Monitoring

After successful clearance, it may be necessary to conduct long-term environmental monitoring, which ensures that no areas of CWA contamination remain and that possible sinks of CWA contamination do not go undetected (such as through seepage from porous materials).

4.2 Sampling Objectives for a CWA Event

The sampling objectives are to determine the types, numbers, and locations of samples required to provide the information needed to draw conclusions regarding the contamination. The general sampling objectives listed below may be applicable to a CWA contamination event (Occupational Safety and Health Administration [OSHA] 2008).

- **Immediately Assess Potential Contamination:** Determine, in real-time, if a release is occurring or has occurred at a site or facility.
- **Identify Bulk Material:** Determine if a bulk material, such as a liquid or powder is a source or is contaminated with a CWA. On-site analysis may be used for preliminary assessment, but laboratory analysis provides confirmation.
- **Perform Initial Agent Identification:** Determine the identity of the CWA, presence of the agent, formulation, toxicological properties, persistence, break-down products, and other physical properties.
- **Characterize Actual or Potential Exposure Pathways:** Consideration must be given to degradation properties and how the chemical behaves in various media (soil, air, water, sediment, and biota).
- **Determine Contamination of Articles:** Determine if the surfaces of articles are contaminated.

- **Determine Extent and Location of Contamination (Characterization Sampling):** Characterization sampling is performed to determine qualitatively, and if possible, semi-quantitatively, the extent and magnitude of contamination. It is also used by cleanup personnel to determine CWA fate and transport, and to determine decontamination plans and for comparison of results with future clearance samples.

Determine the Effectiveness of Decontamination (Verification Sampling): Determine if decontamination has eliminated or reduced CWA contamination to established cleanup goals.

Conduct Post-Decontamination Sampling (Clearance Sampling): Final post-decontamination sampling is conducted inside and outside of an area designated as contaminated above an established cleanup goal.

4.3 Sampling Plans

A sampling plan is an executable plan of action that addresses the sampling and analytical requirements of a specific situation and is formulated in accordance with the sampling strategy. A sampling plan must specify the sampling approaches, methods, and analyses as well as the number, types, and locations of samples to be collected in a given physical space. The plan also must address quality control (QC) considerations (DHS 2007).

SAP development is governed by the amount of information known about the agent; whether the release location is known; and whether the agent has been modified, degraded, or enhanced. For a covert release, the areas of contamination may be less well defined and the SAP may require more initial judgmental sampling to support an optimal overall SAP (Emanuel et al. 2008).

4.3.1 Data Quality Objectives

The SAP should employ a DQO process (EPA 2006 and 2000) and be written in the context of a QAPP that meets the requirements in the UFP QAPP guidance (EPA 2005). DQOs should be derived for each sampling objective. DQOs are scalable but should be as specific as the objective and decision statement require.

4.3.2 Initial Assessment

Figure 4-1 summarizes actions to evaluate first response data and the steps leading to characterization. Initial assessment includes identifying the following (EPA 1989):

- Potential sources, including CWA(s), concentrations, time of release, and known or expected locations of contamination
- Pathways for CWA contamination, including media, methods, rates of migration, time, and loss or gain of functions
- Receptors, including types, sensitivities, time, concentrations, and numbers

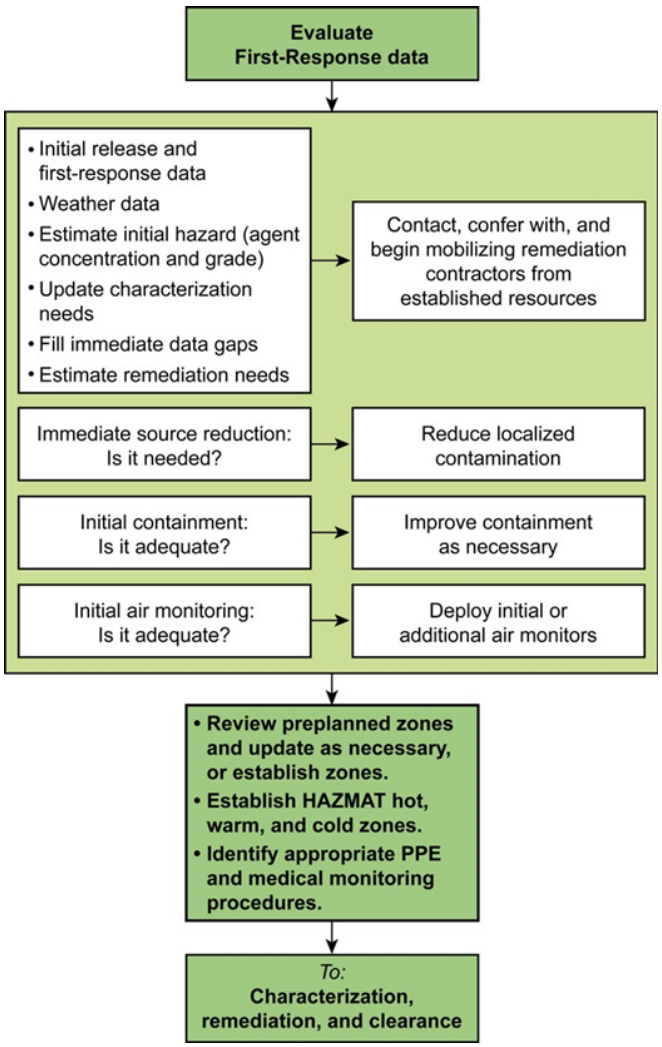

Figure 4-1. First Response Data Evaluation & Steps Leading to Characterization

4.3.3 Initial Preparations and Plans

A detailed site- and incident-specific environmental

characterization SAP is developed incorporating the initial assessment results. The characterization sampling plan should address data gaps for areas not assessed during initial assessment and incorporate recommendations from the TWG and expert resources (DHS 2006).

4.3.4 Laboratory Methods

The EPA's Environmental Response Laboratory Network (ERLN) laboratories have CWA laboratory certification. EPA's "Selected Analytical Methods for Environmental Remediation and Recovery" (SAM) identifies testing methods for environmental contaminants (EPA 2012).

The searchable SAM document is at http://www.epa.gov/sam/. Appendix 5 contains the SAM 2012 Appendix A of selected analytical methods for CWAs. OSCs are directed to use the ERLN's recommended sample collection and analytical methods contained in SAM.

The selection of an appropriate detection technique depends on the analyte, required detection levels, how quickly analytical results are needed, and the degree of analytical accuracy desired. In particular, the laboratory must be able to assess samples using methods with detection limits lower than the selected clearance goals.

If the CWA is a regulated toxic industrial chemical (TIC), it is likely that formally validated methods are available for chemical analysis. When validated methods are not available, then best practices or newly developed and documented (but unvalidated) methods adapted from chemical literature may be used by a qualified laboratory.

4.3.5 Planning for Sampling Lag

Sampling analysis lag commonly occurs when repetitive sampling efforts produce samples faster than the laboratory can analyze them. Therefore, multiple samples collected simultaneously may be processed and analyzed in a staged manner to achieve the result of sequential sampling. An iterative sampling procedure can be more generally referred to as adaptive sampling (see Section 4.5.3.2 for more details).

4.4 Sampling Resources

Sampling resource personnel and equipment may include the following:

- Contractors ready to respond on short notice
- Sampling teams with up-to-date training on health and safety and sampling
- Analytical laboratories with experience, certification, and security
- Facility operators and maintenance contractors knowledgeable about HVAC system operation
- Numerical modeling and sampling design experts
- Data management and documentation specialists to organize a database for environmental sampling results; existing tools used by people familiar with them preferred
- Remediation experts with experience in planning and performing environmental remediation projects, including preparation of a QA/QC plan using DQOs
- Construction workers to place containment barriers for CWA contamination and isolation barriers for sensitive equipment and to conduct prompt source reduction under hazardous conditions

Waste management authorities, waste disposal facility owners, and wastewater management authorities The National Response System (NRS) mechanism by which the OSC mobilizes technical resources is available at http://www.epa.gov/oem/content/nrs/snapshot.htm. If feasible, contracts should be put in place with environmental consultants and cleanup contractors for characterization and decontamination work.

Sampling must be centered on well-defined, site-specific objectives. A sampling strategy should consider the following *essential* information inputs:

- Chemical toxicity and relative exposure risk for the CWA of concern
- Chemical properties that influence the CWA's fate and transport
- Actual and potential exposure pathways that may require environmental sampling
- Professional (qualitative) judgment as to possibility of contamination in a given area using a "zone"

determination system

Other information relevant to designing the decontamination approach

The sampling team will work systematically and thoroughly, zone by zone. Zones should be assessed simultaneously to the extent possible. Within a suspected area or zone, sampling teams should work from the outside inward toward the suspected source.

4.5.1 Characterization Sampling Strategy

All characterization sampling should be designed to answer specific questions identified before sampling begins. The SAP describes the selected sampling strategies, provides specific information on sampling locations, and includes a variety of supporting information. Potential sampling locations should be assessed for the likelihood that they will support necessary decisions or answer characterization questions.

4.5.1.1 Zone Approach

The condition of a facility or CWA-contaminated area likely can be qualitatively assessed starting with an area or areas of confirmed (or assumed) CWA contamination around the release location. These areas are known as "zones." Upon initiation of site characterization sampling, each zone is assigned a class ranging from 1 through 4 (or 5). Areas near the release location are referred to as Class 1 zones, while 'clean' areas are Class 5 zones. Table 4-1 summarizes the five zone classes and assigns each zone class a unique color to simplify its representation.

Table 4-1. Summary of Zone Classifications

ZONE CLASS	COLOR	DEFINITION	SUPPORTING DATA
Class 1 Extremely High Likelihood of Being Contaminated	Red	Confirmed presence or very high confidence that contamination is present and area fails clearance criteria	Reliable prior knowledge, visual inspection, or screening or analytical data
Class 2 High Likelihood of Being Contaminated	Orange	Unconfirmed presence but high likelihood that contamination is present and area fails clearance criteria	Reliable screening or analytical data from other site or facility zones, and area is near threat agent release location with viable transport and dispersion mechanisms
Class 3 Low Likelihood of Being Contaminated	Blue	Unconfirmed presence but low likelihood that contamination is present or that area fails clearance criteria	Reliable screening or analytical data from other site or facility zones, and area is a significant distance from threat agent release location with no viable transport and dispersion mechanisms
Class 4 Extremely Low Likelihood of Being Contaminated	Yellow	High confidence that contamination is not present or that area passes clearance criteria	Characterization data, successful decontamination data and clearance sampling results, or other data and factors indicating no reasonable potential for incident-related contamination that fails clearance criteria
Class 5 Released	Green	Released for unrestricted use by ECC and local health department	ECC review and approval protocols

Ad Hoc Approach to Support Source Reduction in Class 1 Zones

An *ad hoc* approach to sampling in Class 1 zones consists of collecting samples as needed to find items and materials for removal and to guide the decontamination or removal of surfaces and materials.

Detailed Characterization in Class 2, 3, and 4 Zones

Class 2 Zones: CWA contamination is considered likely in Class 2 zones. The process begins with judgmental sampling of materials and surfaces where a CWA is expected to be present and to have persisted. Samples should include permeable materials that, if contaminated, are likely to be outgassing. Air samples also may be collected.

Class 3 Zones: CWA contamination is considered possible but unlikely in Class 3 zones. The process is the same as for Class 2 zones.

Class 4 Zones: CWA contamination is considered *highly unlikely* in Class 4 zones, so the EU may decide that no further sampling is necessary. Otherwise, a purely judgmental approach or a combined judgmental with random sampling approach is appropriate.

Class 5 Zones: CWA contamination is considered not present in Class 5 zones. Class 5 zones have been released for unrestricted use by the ECC and local health department.

Reclassification: If CWA contamination is found through either judgmental or probability-based sampling, the area may be reclassified as a Class 1 zone.

4.5.1.2 Detailed Characterization Based on Dispersal Pattern and Decontamination Method

The most efficient characterization strategy depends on the dispersal pattern and decontamination method. If there is much uncertainty about the spread of CWA after its initial release, then sampling must have a much broader scope unless the entire suspected area is to be treated. The area(s) of greatest concentration and greatest potential for exposure may not be the same, and the potential for exposure may differ for different CWAs. Both types of areas must be considered when developing characterization SAPs.

4.5.2 Numerical Modeling Approach

Computer-assisted mathematical and physical modeling of dispersion can help identify areas of greatest expected concentration and help prioritize characterization actions. However, considerable sampling is always required. Unless a model has been developed as part of pre-incident planning, completion of a viable model may not be possible within the time required for characterization.

4.5.3 Visual Sample Plan (VSP) Sampling

The sampling approach specifies the number, type or method, and location (spatial or temporal) of sampling units selected for measurement, and also includes an explanation and justification for the numbers and types of samples collected.

The following sections discuss a judgmental sampling approach and a probability-based sampling approach, which are compared in Table 4-2.

Table 4-2. Judgmental versus Probability-based Sampling Approaches

	JUDGMENTAL	PROBABILITY-BASED
Advantages	• Can be less expensive than probability-based designs • Can be very efficient with knowledge of the site or facility • Easy to implement	• Provides ability to calculate uncertainty associated with estimates • Provides unreproducible results within uncertainty limits • Provides ability to make statistical inferences • Can handle decision error criteria
Disadvantages	• Depends on expert knowledge • Cannot reliably evaluate precision of estimates • Depends on personal judgment to interpret data relative to study objectives	• Random locations may be difficult to locate • Optimal design depends on an accurate model

Source: EPA 2002

4.5.3.1 Judgmental Sampling Approach

In a judgmental environmental sampling approach, sampling locations are determined based on professional judgment. It can be used to sample items or areas most likely to be contaminated to quickly determine if a zone is contaminated. However, with judgment sampling, probability and confidence statements cannot be made (EPA

2002). There are two types of judgmental sampling: targeted and biased. Targeted sampling is used in areas where samples previously tested positive. Biased sampling involves collecting samples from near areas of known contamination, high-traffic areas, and surfaces likely to be encountered by occupants after re-occupancy (DHS 2006).

4.5.3.2 Probability-based Sampling Approach

Probability-based sampling applies sampling theory and involves random selection of sampling locations. When a probability-based approach is used, statistical inferences can be made about the sampled population from the data obtained from the sampling units. Probability-based sampling is appropriate for quantitative comparisons with risk-based exposure levels (EPA 2002).

Random Sampling

Simple random sampling is the most fundamental probability-based sampling design. Its primary benefit is that it protects against selection bias by guaranteeing selection of a sample representative of the sampling frame provided that the sample size is not extremely small.

Stratified Sampling

When some information is known about the CWA, how it was dispersed, or environmental factors, stratified random sampling may be conducted. In general, a sampling area is subdivided into separate areas and a sampling strategy is implemented separately within each stratum. If the sampling strategy within each stratum is random, then the term "stratified random sampling" is used.

Systematic Sampling

Systematic sampling, also called "grid sampling" or "regular sampling," consists of collecting samples at locations or over time in a specified pattern. Systematic sampling ensures that the target population is fully and uniformly represented in the set of *n* samples collected. To make systematic sampling a probability-based design, the initial sampling location is chosen at random.

- **Grid Sampling - Locating patches of a given size:** During grid sampling, samples are collected at regularly spaced intervals over space or time. An initial location or time is chosen at random, and then the remaining sampling locations are chosen so that all locations are at regular intervals over an area (grid) or time (systematic).
- **Transect Sampling - Locating an unknown event:** When the location of the contaminant is unknown, sampling may be conducted using transects, which requires the sampling team to move along a fixed path or series of fixed paths.
- **Margin Sampling – Sampling hot spots: I**f the level of contamination needs to be above background levels to be classified as a hot spot and if the level of contamination within a hot spot is relatively consistent or varies widely.
- **Population Estimation - Sampling to extinction**: Population estimation sampling is used to sample a representative portion of a larger population.

Ranked Set Sampling

Ranked set sampling increases the chance that the collected samples will yield representative measurements (measurements that span the range of low, medium, and high values in the population). Ranked set sampling can be more cost-efficient than simple random sampling because fewer samples require collection and analysis (EPA 2002).

Adaptive Cluster Sampling

Adaptive cluster sampling involves the selection of an initial probability-based sample. Selecting this design requires two key elements: (1) choosing initial sample units and (2) choosing a rule or condition for determining adjacent units to be added to the sample. An adaptive sampling approach typically is used to optimize the number and

location of samples collected to define the statistical or spatial distribution of a quantity, such as contaminant distribution.

Composite Sampling

Composite sampling includes sampling of multiple surfaces with one medium and CJR sampling as discussed below.

Multiple Surfaces Sampled with One Medium: This type of composite sampling involves physically sampling several judgmental locations with one medium to form a new environmental sample (a composite sample). The chemical or biological analyses of interest then are performed on aliquots of the composite sample.

Combined Judgmental and Random (CJR) Sampling: The CDC and DHS sponsored the development of a CJR sampling approach (Sego et al. 2007 and 2010) that includes both judgmental and probability-based samples. The CJR sampling approach uses a Bayesian methodology that allows investigators to determine the number and location of probability-based samples required in combination with a given number of judgmental samples to obtain a specified level of confidence (X percent) that a high percentage of a building or area (Y percent) has no detectable contamination. The CJR sampling approach should be used when little or nothing is known about where a release occurred (such as a covert release). The CJR approach also is appropriate for certain designated zones.

4.5.3.3 Determination of the Number of Probabilistic Samples

For both situations described above, the number of probability-based samples is based on the number of judgmental samples so that if all judgmental and probability-based sample results are negative, a statement can be made that there is X percent confidence that at least Y percent of the area does not have detectable contamination. The desired X and Y percentage values should also be risk-based and strike a balance between very costly and unreasonable nearly 100 percent sampling and a more reasonable number of samples.

4.6 Data Management

It is recommended that a DMP be used so that field personnel and data managers can provide consistent, quality-assured data. DMPs must be in place before characterization samples are collected. It is imperative to have a data collection, processing, storage, and reporting system in place that efficiently manages data to ensure and document its integrity. EPA SCRIBE is the current EPA data management system developed for use by OSCs (see Section 4.6.2).

4.6.1 Sampling and Data Management Support Tools

If possible, comprehensive sampling and data management decision support tools should be used to facilitate data management and help design the sampling approach.

4.6.2 VSP, SCRIBE, and VIPER

The Pacific Northwest National Laboratory (PNNL) has developed the VSP to facilitate the development of DQOs, sampling design plans, and mapping of sampling locations (Matzke et al. 2007). VSP is freeware and can be downloaded from http://vsp.pnl.gov/.

The EPA ERT has developed a wireless-network-based communications system called VIPER, which uses commercially available technology and custom software called the VIPER Survey Controller. The system is designed to enable real-time transmission of data from field. The software allows the capture, aggregation, persistence, communication, and visualization of sensor data in a manner applicable to a wide range of environmental field monitoring equipment scenarios. More information on the VIPER system is available at http://www.epaosc.org/site/site_profile.aspx?site_id=5033.

4.6.3 Geographic Information Systems (GIS)

A GIS allows the spatial display of maps, sampling data points, and other spatial information. Users can manage various layers and map views of information and data within a GIS. With engineered drawings of a site or facility, GIS

preserves the spatial scales, and vectorized information is embedded in the files. Analytical results may be overlain in the GIS to provide a spatial map of sampling results.

4.6.4 Spatial Analysis and Decision Assistance (SADA)

The SADA decision support tool (EPA 2000) provides several variations of adaptive sampling protocols. The most robust method in the SADA tool is the uncertainty rank method, which is similar to the percentile rank method except that it brings the cleanup goal concentration into the performance metric to focus on delineating the boundary between clean and contaminated areas.

5. DECONTAMINATION

The goal of decontamination is to remove, reduce, or render inactive any CWA contamination from an area so that all criteria for site clearance are met and that normal operations can resume. Incident-specific decontaminating reagents and delivery systems are selected, depending on the nature and extent of CWA contamination and other site parameters identified during characterization.

Decontamination activities are documented in the RAP (EPA 1995), and steps must be taken when implementing the RAP to prevent further environmental impacts. If multiple types of CWAs are present, each CWA requires careful consideration when planning the decontamination strategy.

5.1 Evaluate Decontamination Capabilities

Before implementation of an incident-specific RAP several decisions regarding decontamination capabilities need to be made including the following:

- Equipment to have on hand, either for general use or dedicated to decontamination
- Extent and types of decontamination supplies to store
- Location and number of staging areas or warehouses for equipment and supplies and potential waste-disposal facilities
- Selection of potential contractors to use as members of the decontamination team

Consideration of waste-related transportation requirements and costs, which may be substantial

Decontamination-related decisions can have a major impact on waste-disposal costs and may present substantial non-technical (such as legal and regulatory) challenges when disposal occurs.

5.2 Contain and Isolate DeContamination Zones

Containment to prevent the spread of a CWA to uncontaminated areas should begin during the first phases of the response and continue into the characterization and consequence management phases of the response. If containment barriers also are used to isolate contaminated areas and equipment during decontamination, they must be reviewed for adequacy as isolation barriers for the decontamination approach selected.

Containment areas set up during characterization may correspond to decontamination zones, however, in some cases, smaller decontamination zones may be desirable, especially when volumetric decontamination technologies or fumigants are used. The decontamination zones can be ranked, prioritized, and treated separately during the response.

5.3 Evaluate Monitored Natural Attenuation

Natural attenuation in the context of this Guidebook refers to a decrease in the concentration of a CWA into less hazardous concentrations through natural environmental degradation catalysts, such as heat, light, and volatilization (Ho et al. 2006; Talmage et al. 2007a and b). Its progress and effectiveness must be continually assessed through appropriate sampling and monitoring.

If contaminated indoor air is allowed to escape outdoors to facilitate attenuation, the concentration of CWA must be monitored to determine the hazard level. If escaping air may be hazardous, remediation teams should capture or treat the air before it is released outside.

5.4 Develop the Decontamination Strategy

Decontamination planning activities can begin when data are obtained from site characterization actions identifying the areas and types of materials requiring decontamination. The RAP describes a decontamination strategy that discusses the following:

- Area and facility-specific information, a summary of the CWA incident, members of the project team, and a summary of characterization sampling and air monitoring results
- Alternatives to engineered decontamination actions, if any, such as monitored natural attenuation
- Facilities and areas requiring decontamination
- Materials and structural components decontaminated *in situ*, removed, or both
- Surface decontamination technologies to be used
- Gas- or vapor-phase decontamination technologies to be used
- Chemical compatibility of structural components and materials to be treated with the selected decontamination reagent(s)
- Any pre-decontamination work required, such as sealing off or partitioning areas
- Monitoring of the effectiveness of decontamination
- Decontamination process parameters and their acceptable ranges
- Specific clearance goals to be met
- Decisions regarding spread of CWA by HVAC system or other means
- Waste management and safety, including selection of staging areas and waste-storage areas
- Reference to the clearance SAP, a HASP, and an AAMP, if required, to monitor for any uncontrolled release of decontaminant outside a treatment area
- A thorough description of actions to be taken, the order in which they are to occur (project schedules), and who will perform such actions

A QA/QC plan that specifies DQOs or an equivalent process

The assumptions, decisions, and timing of the decontamination strategy and areas requiring decontamination are summarized below.

5.4.1 Perform Source Reduction

Source reduction during the decontamination phase may begin during the first response or characterization phases of an incident. Understanding a site or facility and its contents as well as making general decisions about decontamination and disposal before an incident expedites source reduction.

Before decontamination, decisions need to be made concerning which materials and structural components requiring decontamination will be (1) reused either on site or off site or (2) not reused but packaged and removed for disposal either as waste or through recycling. A qualitative cost–benefit analysis should be part of the decision process to determine retention versus disposal of items.

For sites and facilities where gas- or vapor-phase decontamination is conducted, source reduction of materials that will remain on site (such as equipment) and structural elements may include prior surface treatment. Appendix 6 provides details on various decontamination methods.

5.4.2 Select Decontamination Technologies

The selection of decontamination technologies depends on the specific CWA used in an attack, items requiring decontamination, and the materials involved. Also, many different types of areas may require decontamination. Decontamination methods can be deployed in different orders depending on incident-specific conditions. In a complex situation, the following three types of decontamination technology may be required:

- Exposed-surface decontamination reagents for large-area surface cleaning, which must address both non-porous and porous surfaces
- Gas- or vapor-phase decontamination reagents to ensure that air handling systems and hidden and hard-to-reach spaces are sufficiently decontaminated, and a method to contain and control the gases

Technologies to decontaminate sensitive electronic equipment and small, personal, or valuable items, such as artwork

Tables 5-1 through 5-3 summarize different decontamination technologies for different types of CWAs. Different incident scenarios involve different distributions of the types of decontamination needed. The most appropriate decontamination strategy also depends on the CWA used.

Table 5-1. Decontamination of Sensitive Items

DECON TECHNOLOGY	HD		VX		G AGENTS		CORROSIVENESS	TOXICITY	DEPLOYMENT	COST	RESIDUE	SOURCE
	Contact Time	Efficacy	Contact Time	Efficacy	Contact Time	Efficacy						
Forced ventilation	Days to weeks	Material-dependent	Days to weeks	Material dependent	GB: hours Others: days to	GB: best All: material dependent	L	L	L	L	No	Nonproprietary; widely available
mVHP[1]	24 hr	✓	24 hr	✓	24 hr	✓	L	L	M	H	No	Proprietary
ClO_2[2]	30	Good	Hours	Poor	Hours	None	M-H	M-H	M	L	Yes; must be neutralized to minimize	Proprietary; Sabre
Solvent Bath[3]	15 min	>99.0%	15 min	>99.99%	15 min	>99.93%	L	L	H	—	No	Proprietary; Battelle and Guild

Notes:

✓ Technology stated to be effective, but numerical value not given
— Data not available
For corrosiveness, toxicity, and cost, L indicates low, M indicates medium, and H indicates high.
For deployment, L indicates easy, M indicates moderately difficult, and H indicates highly difficult.
For residue, YES indicates the presence of visually noticeable residue that must be cleaned off before reuse.

1. Vaporous hydrogen peroxide with ammonia; large chamber tests (Wagner et al. 2004a)
2. Brickhouse 2005
3. Coupon test data from Rossin 2005

5.5 Prepare Remedial Action Plan and Related Documents

The incident-specific RAP specifies the decontamination method(s) to be used and many other details. The RAP is implemented in a series of daily (or other specified interval) IAPs as defined in the NIMS.

Sampling performed to directly support the decontamination process can be documented in the RAP or in a separate related document. Similarly, SAPs must be prepared for any monitoring of key process variables specific to the selected decontamination strategy, such as temperature and concentration of a gaseous reagent.

5.6 Perform Site Preparation

The Operations Section's Decontamination and Sampling Groups perform all incident- and site-specific site preparations specified in the RAP. If gas- or vapor-phase decontamination technologies are used, site preparation before decontamination may include the following actions:

- Subdividing spaces with temporary walls, sealing leaks and openings, leak testing, or tenting

- Installing and testing oxidant-generation systems and systems for monitoring oxidant concentrations, temperature, and humidity, and testing for low-level gas or vapor
- Installing and testing NAUs and air filter systems
- Modeling (to ensure low costs) and airflow measurements to determine the approximate amount and direction of air movement

5.7 Prepare Clearance Environmental Sampling and Analysis

The EU, with input from the TWG, develops the clearance SAP and justification for the sampling and evaluation scheme used to confirm the effectiveness of decontamination. Section 7, Clearance, describes the clearance SAP and actions implemented during the clearance phase in more detail.

5.8 Perform Decontamination

After the IC/UC (1) approves and submits the necessary documents, (2) applies for and receives any regulatory permits needed for off-site actions, and (3) determines substantive requirements for on-site actions, the designated personnel carry out the decontamination, with oversight by the Operations Section's Decontamination Group. After decontamination, the EU and the Decontamination Group, with input from the TWG, evaluate the results for completeness and to ensure that process criteria have been met. The EU, Decontamination Group, or both, may recommend more decontamination activities, if warranted.

6. WASTE DISPOSAL

Section 300.130(a) of the NCP (EPA 2014) states that the EPA is authorized to take response measures deemed necessary to protect the public health, welfare, or environment from discharges of oil or releases of hazardous substances. Section 300.135(d) of the NCP (EPA 2014) states that the OSC coordinates response efforts with other appropriate federal, state, and private response organizations. This section provides information regarding waste management decisions during remediation after a CWA attack.

6.1 Structure of Environmental Waste Regulations

Although the Clean Air Act and Clean Water Act are good examples of comprehensive statutes passed to address an entire medium (air and water), other statutes, such as the following, deal with particular problems:

- CERCLA, enacted to address cleanup of accidental spills or sites with chronic environmental damage
- RCRA, enacted to address the handling, management, and final disposal of solid and hazardous wastes
- Safe Drinking Water Act, enacted to address the purity of drinking water supplied to the public by public drinking water suppliers

Hazardous Materials Transportation Act and DOT's Hazardous Materials Regulation provisions enacted to govern the placarding, packaging, and safe transportation of HAZMATs destined for disposal at hazardous waste treatment, storage, or disposal facilities

Appendix 7 provides a general list of waste disposal regulations, and Appendix 8 provides waste disposal information, including a summary of multi-media CWA toxicity and exposure values. The sections below discuss listed and characteristic waste, the Hazardous Debris Rule, and hazardous waste identification and management.

6.1.1 Listed and Characteristic Waste

EPA uses two approaches for defining RCRA hazardous waste, listed and characteristic. "Listed wastes" are identified on four separate waste lists for F wastes, K wastes, P wastes, and U wastes. F wastes are wastes from common manufacturing and industrial processes. K-listed wastes are produced from a specific industrial process. P- and U-listed wastes are for commercial chemical products being discarded or that have been spilled in an essentially pure form.

Table 5-2. Decontamination of Surfaces

DECON TECHNOLOGY	HD		VX		G AGENTS		CORROSIVENESS	TOXICITY	DEPLOYMENT	COST	RESIDUE	SOURCE
	Contact Time	Efficacy	Contact Time	Efficacy	Contact Time	Efficacy						
DF-200[1]	30 min	>99.8%	30 min	>99.8%	30 min	>99.9%	L	L	M	M	Yes	Proprietary; Modec, Inc., EnviroFoam Technologies Inc.
L-Gel[2]	24 hr	100%	24 hr	69% on asphalt 99% on concrete	24 hr	98% on asphalt 99% on concrete	M	L	M	M	Yes	Proprietary; LLNL
HTH[3]	5 min	✓	5 min	✓	5 min	✓	H	H	H	L	No	Non-proprietary; easily formulated
STB[3]	30 min	✓	30 min	✓	30 min	✓	H	H	M	L	No	Non-proprietary; easily formulated
Bleach[3,4]	5 min	✓	5 min	✓	5 min	✓	H	H	M	L	No	Non-proprietary; widely available
CASCAD[5]	5 min	>99.95%	5 min	✓	5 min	>99%	L	L	M	M	Yes	Proprietary; Allen-Vanguard
GDS 2000[6]	1 min 3 hrs	>99.8% 99.87%	1 min 3 hrs	>99.8% 99.97%	1 min 3 hr	>99.8% 99.95%	—	—	M	—	Yes	Proprietary; Kärcher Futuretech
Decon Green[7]	20 min 15 min	99.9% 99%	20 min 15 min	>99.9% 96%	20 min 15 min	>99.9% 90%	H	H	M	M	Yes	Proprietary; Strategic Technologies Enterprises
Liquid ClO_2[8]	Minutes	Good	Hours	Poor	—	None	M-H	M-H	M	L	No	Non-proprietary; widely available
All-Clear[9]	—	—	—	—	30 min	95%	L	L	M	—	—	Proprietary; Kidde
BIT[10]	sec-min	98%	sec-min	99% >99.999%	sec-min	99%	L	L	M	M	No	Proprietary; L3 Titan

Notes:

- ✓ Technology stated to be effective, but numerical value not given
- — Data not available
- For corrosiveness, toxicity, and cost, L indicates low, M indicates medium, and H indicates high.
- For deployment, L indicates easy, M indicates moderately difficult, and H indicates highly difficult.
- For residue, YES indicates the presence of visually noticeable residue that must be cleaned off before reuse.

1. DF-200 efficacy measured in surface testing on chemical agent-resistant coating (CARC) coupons in DOD testing
2. Surface testing on concrete and asphalt surfaces, respectively (Raber et al. 2002), alkyd paint, polyurethane paint, and indoor-outdoor carpet
3. Hoenig 2002; CDC 2004
4. Household bleach (5% sodium hypochlorite in water) diluted by adding 1 part bleach to 9 parts water (McGuire et al. 2001)
5. Laboratory stirred-reactor data from Allen-Vanguard 2005
6. First numbers: laboratory stirred-reactor data (Franke and Toepfer 2002). Second numbers: field tests on painted metal at 12.5°C, includes cold water wash after treatment (Toepfer 2002).
7. Agent removal on CARC coupons (Wagner 2004)
8. Extrapolation from performance of vaporous chlorine dioxide; performance of liquid may differ
9. USGN 2005
10. Binary Ionization Technology (BIT) from L-3 Communications/Applied Technologies/Titan Corporation; numbers primarily for painted surfaces (CARC); additional numbers for VX for bare metal surface

Table 5-3. Decontamination of Volumetric Surfaces

DECON TECHNOLOGY	HD		VX		G AGENTS		CORROSIVENESS	TOXICITY	DEPLOYMENT	COST	RESIDUE	SOURCE
	Contact Time	Efficacy	Contact Time	Efficacy	Contact Time	Efficacy						
Natural attenuation	Days to weeks[1]	Material-dependent	Days to weeks[2]	Material-dependent	GB: hours Others: days to weeks	GB: best All: material-dependent	L	L	L	L	No	Non-proprietary; widely available
Forced ventilation	Days to weeks[1]	Material dependent	Days to weeks[2]	Material dependent	GB: hours Others: days to weeks	GB: best All: material dependent	L	L	L	L	No	Non-proprietary; widely available
Hot-air ventilation	Days[1]	Good	Hours	Good	Hours	GB: good Others: material-dependent	L	L	M	L	No	Nonproprietary; A&E firm
Steam	Hours	Good	Hours	Good	Hours	Poor	L	L	M	L	No	Nonproprietary; A&E firm
mVHP	Hours	Good	Hours	Good	Hours	Good	L	M	M	M	No	Proprietary; STERIS
Ammonia (gas)	—	Good	—	Poor	—	Poor	M	M	M	M	Yes	Nonproprietary; A&E firm
Ammonia (gas) and steam	Minutes	Good	Days	Good	Minutes	Good	L	M	M	M	Yes	Nonproprietary; A&E firm
ClO_2	Minutes	Good	Hours	Poor	Hours	Poor	H	H	M	H	Yes; must be neutralized to minimize corrosion	Proprietary; Sabre
Ozone[3]	—	Good	Hours	Fair	—	—	M	H	M	M	No	Nonproprietary; A&E firm
Perchloryl fluoride	—	Fair (thin films only)	Hours	Poor	—	—	H	M	H	H	Yes	Nonproprietary; Limited Distribution; A&E firm
Nitrogen tetroxide	Hours	Good	—	—	—	—	H	H	H	M	No	Nonproprietary; A&E firm

Notes:
— Data not available
A&E - Architecture and Engineering
Numerical values for efficacy not available, so qualitative indicators used
For corrosiveness, toxicity, and cost, L indicates low, M indicates medium, and H indicates high.
For deployment, L indicates easy, M indicates moderately difficult, and H indicates highly difficult.
For residue, YES indicates the presence of visually noticeable residue that must be cleaned off before reuse.

1. Although fresh mustard is volatile, several hours exposure to air causes exposed surfaces of mustard to polymerize, forming an impermeable shell that prevents further evaporation.
2. For VX, efficiency depends on droplet size.
3. See Wagner et al. 2000 for efficacy with VX and GD

The second approach that EPA uses to define hazardous wastes is based on the particular characteristics of the waste. EPA evaluates four characteristics of hazardous waste: ignitability, reactivity, corrosivity, and toxicity. Characteristics applicable to CWAs are further discussed below.

Reactivity

For solid wastes generated from remediation efforts after a CWA attack, only the following reactivity criteria potentially apply:

- Reacts violently with water
- Generates toxic gas, vapors, or fumes when mixed with water in a quantity sufficient to present a danger to human health and the environment

A cyanide- or sulfur-bearing waste that, when exposed to a pH less than or equal to 2 or greater than or equal to 12.5, generates toxic gas, vapors, or fumes in a quantity sufficient to present a danger to human health and the environment

Toxicity

None of the CWAs considered in this Guidebook appears in the toxicity listing at 40 CFR 261.24. Therefore, decontamination wastes would not be classified from a regulatory perspective as hazardous waste on the basis of the characteristic of toxicity under federal RCRA regulations.

With minor exceptions, treatment residuals are classified as summarized below for hazardous waste treatment.

- When the waste treated is "characteristic," the treatment residuals are hazardous waste only if they also exhibit a "characteristic."

When the waste treated is a "listed" waste, the treatment residuals also retain the "listed" waste classification (40 CFR 261.3[c][2][i] and 40 CFR 261.3[d]).

6.1.2 Hazardous Debris Rule

Debris is considered to be a RCRA hazardous waste when it contains a listed hazardous waste or exhibits a characteristic of hazardous waste identified in 40 CFR 261.21 through 261.24 (40 CFR 268.2[h]). Under the Hazardous Debris Rule (40 CFR 268.2[g]), when listed hazardous waste is treated by alternative hazardous debris treatment standards (specified extraction or destruction technologies), the resulting treated waste is no longer considered a hazardous waste. In addition, EPA can make a case-by-case determination that debris treated by other methods no longer contains a listed hazardous waste and thus is exempt from RCRA regulation (40 CFR 261.3[f][2]). Therefore, debris contaminated with a listed hazardous waste that has been treated using one of the specified technologies or if it no longer contains the listed waste (the listed waste has been neutralized) the debris is no longer is considered hazardous. For characteristic waste, if the treated waste no longer exhibits the hazardous waste characteristic, it is exempt from hazardous waste regulation.

6.1.3 Hazardous Waste Identification and Management

During CWA decontamination, the most likely method of storage for any hazardous waste generated is in a container, such as a 55-gallon drum, roll-off container, shipping container, railroad car, or storage tanks. The RCRA container storage requirements at 40 CFR 265.171 through 174 and additional requirements at 40 CFR 262.34 apply to all waste storage resulting from remediation activities.

6.2 Waste-Related Implications of the National Response Framework

Response to a release of oil or HAZMATs under the NRF is addressed by the NRF's Emergency Support Function (ESF) #10, Oil and Hazardous Materials Response. HAZMATs addressed under ESF #10 include chemical weapons of mass destruction (WMD), whether accidentally or intentionally released. ESF #10 directs that responses to the release of HAZMATs be conducted under the NCP process.

Under the NCP, the most typical response to a CWA attack is removal actions used to respond to an immediate release or threat of a release of hazardous substances. Most removal actions related to a CWA release likely are

classified as emergency removal actions and are streamlined to quickly address the immediate nature of the threat. The NCP provides that on-site actions do not require permits. The NCP requires on-site actions to comply with substantive state and federal requirements. CERCLA and the NCP offer such exemptions to allow rapid emergency response.

6.3 Assumptions for Regulatory Determinations Regarding CWA Waste

Regulatory determinations regarding waste characterization, further waste management, and disposal requirements are case-by case-determinations. To provide a context in which to make regulatory determinations regarding waste and for the purposes of illustration in this Guidebook, the assumptions summarized below apply with regard to the nature of remediation activities.

1. Decontamination wastes include materials such as spent decontamination fluids, PPE, cleaning materials used in the decontamination process, and items at an incident location that will be disposed of and not reused.
2. Wastes do not include any pure CWAs. Any pure agent or undispersed CWA from a failed device is addressed and removed as part of the initial emergency response.
3. All CWA items to be disposed of are decontaminated before off-site disposal to (1) eliminate potential cross-contamination of the CWA, (2) eliminate the potential for secondary source production, (3) reduce the exposure of decontamination workers to the CWA, and (4) facilitate waste handling and transportation.
4. Potentially toxic CWA degradation products are neutralized or reacted to non-toxic degradation products by decontamination procedures.
5. Decontamination is performed until all CWAs have been neutralized. However, for an actual incident, it may not be practical, necessary, or cost-effective to sample some waste items to a level that ensures that no residual CWA remains.
6. All decontamination waste streams are contained until treatment, and monitoring can ascertain that the waste streams are not toxic to personnel or the environment from the presence of unreacted CWA, excess bleach, or other incident-related wastes.
7. Likely decontamination methods include, but are not limited to, chlorine bleach solutions, chemical decontamination foam, modified vaporous hydrogen peroxide (mVHP), and natural attenuation or the use of hot air or steam.
8. A CWA terrorist attack at a large site invokes the provisions of the NRF and all appropriate provisions of the NCP. All disposal activities occur under existing environmental regulatory frameworks at state and federal levels.

The regulatory analysis in this section corresponds only to a remediation effort based on the assumptions summarized above. The assumptions are based on the expected, most-likely scenario to be addressed by a remediation effort and were evaluated in light of federal regulations. Actual remediation activities should be analyzed on a case-by-case basis and consider the possibility of more stringent state regulations with coordination of federal, state, and local officials through the local JFO.

6.4 Regulation of CWA Waste Streams under RCRA

This section addresses the federal regulation of waste streams from decontamination activities. As part of pre-incident planning for a decontamination effort, the owner or operator of a site or facility must consult state-specific regulations and appropriate state agencies regarding pertinent waste-related requirements.

6.4.1 Origin of the Waste Stream (Disposal vs. Reuse)

During remediation, some materials and structural components are likely to be decontaminated for reuse, whereas other materials may be removed from the site for decontamination and subsequent disposal. In

general, materials that will be decontaminated and reused at the site do not qualify as solid or hazardous wastes. Spent decontamination fluids or materials, carpet, furniture, computers, telephone sets, and other components that are discarded and not reused require management and disposal as waste.

Regulation of decontamination wastes begins when the decision has been made to discard items or when spent decontamination fluids or materials are recovered. For items that qualify as solid waste, the generator requirements under RCRA are triggered, requiring a determination about if the solid waste also qualifies as hazardous waste (40 CFR 264.11).

6.4.1.1 Characterizing Waste Streams from Decontamination Technologies

One of the primary waste streams from decontamination is spent decontamination solution or material used to implement the decontamination activity. If the spent solution is a liquid and treated and disposed of through discharge to a publicly owned treatment works (POTW) or waterway, the discharges is regulated by the Clean Water Act (see Section 6.6).

The following four decontamination methods are recommended for decontaminating a site: Bleach solutions in water, Sandia Decontamination Foam Technology (DF-200), mVHP, and Natural attenuation or the use of hot air or steam.

Spent decontamination solution, PPE, carpet, furniture, computers, telephones, and other site components disposed of through transport to a landfill or other non-Clean Water Act treatment facility are regulated depending on classification as a hazardous or non-hazardous waste based on characterization. The first step is to determine if a waste is a solid waste, then if it is an excluded solid waste or RCRA hazardous waste (either listed or characteristic waste as discussed below).

6.4.1.2 Listed Waste

None of the decontamination materials or CWAs considered in this Guidebook are listed wastes at the federal level. However, some of the CWAs considered in this Guidebook are P-listed wastes. Cyanogen chloride (CK), hydrogen cyanide (AC), and phosgene (CG) carry the wastes codes P063, P033, and P095, respectively. Regardless of whether the decontamination technologies have neutralized the CWA, spent decontamination waste streams from remediation of these three CWAs may be listed hazardous wastes.

In the event of a CWA release as a result of a terrorist attack, it is unlikely that a CWA would be released in pure form or that specific information regarding the manufactured chemical composition would be known. In such situations, EPA policy is to assume that a source, CWA, or waste is not a listed hazardous waste. When information is inconclusive or unavailable to make a listed waste determination, EPA allows the site owner or operator to assume that the source, CWA, or waste is not a listed waste. Therefore, when information needed to make a listed waste determination is unavailable, waste streams from remediation of cyanogen chloride (CK), hydrogen cyanide (AC), and phosgene (CG) are not be classified as listed hazardous wastes.

6.4.1.3 Characteristic Waste

Spent Decontamination Solution or Material

Bleach solution in water may be considered a RCRA hazardous waste if it exhibits a hazardous waste characteristic. However, once the solution is treated to adjust the pH (to greater than 2 but lower than 12.5), the waste no longer is considered hazardous because of the corrosivity characteristic.

The manufacturer of Sandia Decontamination Foam indicates that the foam is naturally biodegradable with a low environmental hazard. It is assumed that the residues do not exhibit any hazardous waste characteristics after completely neutralization of the CWA.

The modified mVHP technology process that is recommended uses ammonia in addition to hydrogen peroxide. It assumed that the ammonia component does not result in decontamination residuals exhibiting a hazardous waste characteristic. However, standard waste stream monitoring should be conducted to verify that ammonia concentrations meet all applicable requirements.

For natural attenuation or the use of hot air or steam, the only decontamination solution or material recovered is condensate or runoff from steam. Assuming that the CWA has been fully reacted, the recovered steam does not exhibit any hazardous waste characteristic. For all residual solids, filters, or liquid waste streams, monitoring is recommended to ensure any recovered decontamination waste stream does not exhibit any characteristics of RCRA hazardous waste.

PPE, Carpet, Furniture, Computers, Telephones, and Other Site Components

After decontamination, site components are considered hazardous waste only if, at the time of generation (when the decision is made to dispose of an item), an item exhibits a characteristic of hazardous waste or if the item has been contaminated with a listed waste. After appropriate decontamination, site components previously contaminated with CWAs are assumed to not exhibit any hazardous waste characteristic. Section 6.4.2 below summarizes preliminary decontamination waste regulations.

6.4.2 Disposal as Non-hazardous Waste

With respect to wastes from decontamination, the decision to accept solid waste declared non-hazardous by the proper decision-making authorities is ultimately up to the individual Subtitle D landfill. The type of facility appropriate for decontamination wastes and waste-handling procedures are controlled by state regulations governing solid wastes. Because of the unique nature of wastes potentially resulting from a CWA attack, discussions with likely disposal facilities during the pre-planning stages are crucial to efficiently remediate a site after a CWA attack.

6.5 Disposal Under the Clean Water Act

Recovered decontamination solutions and materials (such as bleach solution or Sandia Decontamination Foam) or rinse waters may be disposed of either to a sewer (a POTW) or surface water body if prerequisites for such discharges can be met. Table 6-2 summarizes pretreatment requirements before discharge to a POTW. Discharges to a POTW or surface water body under the Clean Water Act under an NPDES permit are exempted as hazardous wastes under RCRA (40 CFR 261.4[a][1] and 40 CFR 261.4[a][2]). The local POTW pretreatment program must include the federal pretreatment requirements of 40 CFR 403 and may include additional, more stringent local standards. Based on such prohibitions, bleach in water solution potentially requires pH adjustment before discharge to a sewer (Haffenden and Kimmell 2002).

Decontamination solution discharged to a surface water body is regulated by the NPDES discharge program. A permit is required for a discharge to a surface water body under the NPDES discharge program because the discharge from a remediation effort is considered an off-site action (Haffenden and Kimmell 2002).

6.6 Issues Under the Clean Air Act

Ambient air monitoring must be implemented during all phases of remediation to that ensure no fugitive emissions are released. The level and frequency of air monitoring must be part of a site-specific AAMP (Haffenden and Kimmell 2002). Fugitive emissions in this case are not regulated under the Clean Air Act. Appendix 3 provides air monitoring information.

6.7 State-Specific Regulatory Schemes

An evaluation of state-specific CWA regulations (Appendix 8) provides good insight into of the development of state regulations on chemical remediation efforts. States with domestic CWA munitions stockpiles tend to have well developed laws and regulations. Utah, the state with the largest stockpile, has regulatory precedents for all

CWAs. For future CWA incidents, Utah provides a good example of how wastes related to CWAs are regulated for disposal.

Table 6-2. Pretreatment Requirements before Discharge to a POTW

PRETREATMENT REQUIREMENTS	DESCRIPTION	CFR CITATION
Materials Destined for POTW	Any decontamination solution or material destined for a POTW must be pretreated if necessary before discharge to a local POTW.	40 CFR Part 403
Materials and parameters prohibited from discharge to a POTW	Pollutants that pass through the POTW at concentrations that violate the POTW's NPDES permit and pollutants that inhibit or interfere with POTW operation, sludge processes, use, or disposal	40 CFR 403.5(b)
	Discharge of pollutants to POTWs that create a fire or explosion hazard in the POTW	40 CFR 403.5(b)
	Discharge of corrosive (pH less than 5.0) pollutants	40 CFR 403.5(b)
	Discharges that obstruct flow and discharges at a flow rate or concentration that result in interference	40 CFR 403.5(b)
	Increase of temperature of wastewater entering the treatment plant that results in interference but in no case raises the POTW temperature above 104 °F (40 °C)	40 CFR 403.5(b)
	Any trucked or hauled pollutants except at discharge points designated by the POTW	40 CFR 403.5(b)
	Discharges that would result in the presence of toxic gases, vapors, or fumes within the POTW at a quantity that may cause acute worker safety problems	40 CFR 403.5(b)

7. CLEARANCE

Clearance is a determination that further cleanup is not required or that cleanup has met the criteria necessary for site or facility reuse or re-occupancy. The overall approach to achieving clearance is a risk analysis process that includes Risk Assessment and Risk Management (National Academy of Sciences [NAS] 2012). Risk assessment is a method that provides evaluation of options to be used in risk management to reduce risks (NRC 2009). Throughout this clearance phase, a mechanism should be established to communicate with stakeholders, such as property owners; federal, state, tribal, and local government officials; and representatives of labor and community groups (EPA 2009a).

7.1 Clearance Process

A clearance goal sets the amount of residual contamination for a specific contaminant that provides acceptable protection of human health and the environment. (DHS 2008). Clearance goals ultimately should be site-and situation-specific to ensure that clearance decisions are protective of human health and the environment. Clearance decisions must take into account factors including previous actions and decisions made during crisis management, type of CWA contamination, feasibility, PPE and safety requirements for cleanup workers, and waste management.

7.1.1 Risk Assessment

A risk is the likelihood or probability of a given hazard at a given concentration causing a particular level of loss or damage. Risk assessments include the four steps outlined below.

1. A hazard assessment to determine the type(s) of health effects associated with CWA exposure.
2. Dose response is assessed to determine the relationship between exposure and health effects.
3. The level of exposure is determined for various uses and individuals.
4. Risk characterization is conducted, which combines exposure and dose response information to provide a numerical estimate of risk. Risk assessment provides "Information" on potential health risks, while risk management is the "Action" taken based on consideration of all information.

Clearance goals should be set appropriately at health protective levels for the appropriate populations using site-specific information on CWA identity, exposure, and health effects. Although numerous standards and regulatory guidelines exist, there are no pre-determined cleanup approaches or levels universally applicable to every CWA release incident. Health-based exposure guidelines can be used for both qualitative and quantitative risk assessments.

7.1.2 Qualitative Assessments

Risk assessments can be initiated at different phases of the response and should be flexible enough to allow the quantification and evaluation of risk for different groups and for different purposes e.g., clearance versus temporary re-entry, which may include qualitative assessments applied at different stages of the site restoration decision-making process. Such as characterization, evaluation of cleanup options, implementation of the chosen cleanup alternative, and clearance sampling. Table 7-1 lists some guidelines for TICs and CWAs.

Qualitative assessments evaluate the potential for human exposure to chemicals and must consider both acute health risks associated with short-term exposure and potential chronic health effects associated with low-level residual chemical concentrations remaining after cleanup. Qualitative risk assessments can be developed by comparing measured environmental chemical concentrations to benchmarks of toxicity and exposure.

Qualitative risk assessments may vary with the different phases of a response and can be used to assess different locations within a response site, depending on the complexity of the response. Initial characterization assessments may identify areas not likely contaminated, potentially resulting in an accelerated decision process and early reopening of these areas. Alternatively, such areas may be set aside for later clearance evaluation.

7.1.3 Quantitative Assessments

Throughout the different stages of an incident, it is recommended that all exposures, even low-level exposures, be assumed to have some level of risk (unless sufficient data indicate otherwise) after accounting for background chemical exposures, biological make-up, and population variability.

In a quantitative risk assessment, measurements of all media that may be contaminated are examined. Quantitative assessment requires a clearance SAP. The exposure assessment not only provides direct measurements of chemical concentrations, it also identifies and defines site-specific receptors based on site characterization data. The human health risk assessment should take into account background chemical exposures, genetic make-up, and population variability (Office of Science and Technology Policy [OSTP] 2013).

- When developing clearance goals, always coordinate with stakeholders to identify risk perceptions and concerns that may require public education.
- Effective and frequent communications can help avoid subjective perceptions of risk made by individuals.

The detection of chemicals at a site or facility does not imply an unacceptable risk to human health. Risk from chemical exposure less than a target risk range of 1×10^{-4} to 1×10^{-6} for chemicals that cause cancer or a hazard index equal to or exceeding 1 for chemicals that have a threshold may be deemed "acceptable" and provide an "ample" margin of safety. The target risk range, hazard indices, and toxicity values are used in risk-based calculations to derive concentrations in each medium of concern that require some action such as cleanup or institutional control.

7.1.4 Uncertainties and Confidence Issues

Uncertainty is inherently associated with environmental data and its interpretation. These uncertainties may be minor and result in undisputed data and decisions. However, it is more likely that many uncertainties will arise associated with sampling, analytical results, exposure estimates, toxicity data, and other factors. It is of paramount importance that these uncertainties are communicated not only to IC/UC but also to the public.

Risk characterization identifies all uncertainties and confidence and technical feasibility issues for stakeholders to provide input and risk managers to make decisions.

Exposure Guidelines: Despite the availability of many quantitatively derived human toxicity and health-based exposure guidelines, there may not be an existing exposure guideline appropriate for a CWA release incident. Two examples of methods that may be used in such situations are summarized below.

- Review available toxicity data (from animal studies, human studies, anecdotal information, etc.) to determine if a human exposure value can be estimated using the same procedures and principles used to develop the exposure guidelines.

Use structural modeling to estimate toxicity. Examples of structural modeling include quantitative structure-activity relationship (QSAR) modeling and the modeling of surrogate or relative potency chemical toxicity information.

Toxicity and Exposure Data: Many of the acute and short-term exposure guidelines described in Table 7-1 are prescribed for use only during emergency response decisions. These acute and short-term values likely are inappropriate as final clearance goals. Ideally, the full range of exposure guidelines and the underlying bases and assumptions should be evaluated for appropriateness to the phase of cleanup under consideration.

Feasibility: Feasibility concerns include technical, operational, and economic issues that affect the development of clearance goals. These concerns, along with concerns that should be considered during the development of clearance goals and decision criteria are summarized below.

Technical Issues:

- Ability of analytical capability and laboratory capacity to support clearance goals
- Ability of the decontamination options to be applied to incidents of varying scale
- Ability of field screening instruments to detect CWAs at operationally useful levels
- Surfaces, media, and material resistant to currently available decontamination technologies
- Long-term effectiveness

Operational Issues:

- Organizational conflicts and policies
- Social acceptability
- Government regulations
- Whether or not management supports the task or site project

Economic Issues:

- Cost-effectiveness of the system
- If benefits outweigh costs
- Project feasibility based on time and resource constraints

7.2 Clearance Decisions

Clearing any site or facility for re-occupancy requires determining if environmental sampling data indicate that the clearance goal and any other criteria have been met. The selected clearance goal(s) must be ***feasible to achieve and acceptable to those affected***. This decision should be made with as much input as possible by those affected and should consider all available information. However, it is of paramount importance that all potential health effects are evaluated when determining preliminary clearance goals and clearance criteria used to make the final decision for ultimate resumed reuse or re-occupancy.

- Clearance goals that have considered detection limits often are required in order to develop clearance SAP objectives.
- A range of clearance goals and decontamination methods should be compared.
- The overall estimated direct cleanup cost, length of time to final clearance, and indirect economic impacts should be considered.

The EU, in coordination with Planning and Operation Section special units or branches, will prepare a report on remediation actions, including details on decontamination and data from clearance sampling. The report should include a data quality assessment and statistical evaluation of results.

Clearance decisions may include quantitative and qualitative assessments applied at each stage of site restoration activities (see Sections 7.1.2 and 7.1.3). Such assessments may involve issues unique to the site-specific circumstances and development of risk-based clearance goals. Other confounding factors may include crisis management or first response activities, the nature and toxicity of breakdown products, collateral hazards, and waste generation.

7.3 Clearance Sampling and Analysis Plan

The ultimate goal of the clearance SAP is to support the clearance criteria for re-occupancy. Clearance SAP objectives must be site-specific. Typical objectives of a sampling design for environmental data collection for clearance include the following:

- To support a decision about if CWA contamination levels exceed a threshold of unacceptable risk
- To determine if certain characteristics of affected human populations differ
- To identify the location of "hot spots" (areas having high levels of CWA contamination) or plume delineation

To characterize the nature and extent of CWA contamination at a site

It is recommended that a DMP be prepared so that field personnel and data managers can provide consistent, quality-assured data that can be used for decision-making purposes, efficient project archiving, and sharing with stakeholders (see Section 4.6). In addition, a DMP allows OSCs to establish protocols for data control, consistency, reliability, and reproducibility throughout the life of the project. Finally, the DMP establishes a framework for consistent documentation of the quality and validity of field and laboratory data compiled during consequence management.

Clearance decisions must consider factors such as previous actions and decisions made during crisis management, the type of chemical contamination, feasibility, PPE, safety requirements for cleanup workers, and waste management.

The clearance SAP must include specific information on the numbers of samples collected, exact sampling locations, and the rationales for the sampling and selection of the sampling locations. The SAP must specify the sampling methods, sample packaging and transport procedures, and sample documentation procedures. In addition, the SAP should identify the individuals who will instruct the necessary sampling personnel, collect the necessary supplies, and perform all sampling-related activities.

Both the Planning and Operations Sections must review data continuously and work closely with the contractor to ensure that all sampling guidance is followed. It is important that the data are managed locally and constantly to ensure consistent production of high-quality data.

7.4 Sampling Strategy and Methods

The clearance sampling strategy should determine sampling locations and methods. Samples can be collected using a grid system and may be collected randomly (unbiased), judgmentally (biased), or both. Sample collection procedures depend on the media to be sampled. A searchable SAM document is available at http://www.epa.gov/sam/ or http://www.epa.gov/sam/SAM_2012_07162012.pdf (for the PDF file). Appendix 5 contains the SAM 2012 Appendix A of selected analytical methods for CWAs.

In addition, the sampling strategy and methods must consider that a CWA may sorb into some materials, and then outgas after decontamination. If so, then bulk samples of these materials should be collected. If results are positive for CWA contamination, it should be assumed that the material poses a low level of exposure associated with some level of risk. Consequently, the materials may require removal or sealing, or long-term monitoring may be required.

Laboratory-based methods often have the required sensitivity for clearance decision-making and are rigorous. The analytical laboratory's work should follow good laboratory practices and standard operating procedures for CWA.

7.5 Long-Term Monitoring

After clearance goals are met, long-term monitoring requirements will be determined with guidance from local public health officials and other stakeholders. The clearance goals should be suitable as action levels for long-term monitoring. The duration of long-term environmental monitoring depends on CWA- and site-specific conditions. Repeated sampling for the presence or dissipation of released CWAs can be conducted weekly for at least 1 month to confirm that concentrations remain at or below acceptable levels. Source strength and degree of dispersion throughout the site can be evaluated to determine the duration of air monitoring. Release of more persistent CWAs may require longer monitoring durations.

7.6 Summary of Clearance Actions

Clearance is an iterative process that may be continuously refined throughout the consequence management phase. Effective risk communication should be a priority throughout the process to facilitate re-occupancy of an affected area or facility. Decisions on clearance should be based, in part, on recommendations from the Clearance Committee evaluating decontamination efficacy data and clearance sampling results. The process for re-entry should be closely coordinated with the IC/UC and stakeholder groups. Table 7-2 summarizes the clearance actions.

Table 7-2. Summary of Clearance Actions

PERSONNEL	ACTION
Planning Section: EU, with input from the TWG	Review and revise incident-specific clearance SAP as necessary
PIO	Communicate with the public
IC/UC	Approve incident-specific clearance SAP if it was revised.
Operations Section: Sampling Group	Perform clearance sampling
Planning Section: EU, with input from Decontamination Group, TWGs, and Clearance Committee	Evaluate clearance SAP results Determine if clearance goals are met Recommend additional decontamination, if necessary
Planning Section: EU, with input from Clearance Committee	Write final report on remediation actions for submittal to IC/UC
IC/UC	Review final report to ensure site, regulatory, and stakeholder needs are met Make recommendations about whether site and items have been effectively remediated
Public Health Officials	Determine whether to initiate restoration activities in all or parts of the site; if not, additional decontamination may be warranted

8. WORKER HEALTH AND SAFETY

Emergency responders should familiarize themselves with the sources cited as references in this section and elsewhere in this Guidebook to develop a basic understanding of the major classes and types of CWAs and their properties. This section discusses worker health and safety, including the background and regulatory basis, requirements and training, and elements of health and safety.

8.1 Background and Regulatory Basis

This section does not discuss health and safety issues associated with individual agents in detail instead but provides an overview. Comprehensive information about the various CWAs is presented in the Appendices of this document. Emergency responders should maintain a working knowledge of the agent categories and their general properties (EPA 2011).

Emergency response and recovery related to a CWA release are somewhat similar to conventional HAZMAT incident response and recovery. However, there are important differences that may have profound implications for responders. CWAs may be designed to be lethal in very small amounts. Further complicating the response and recovery, emergency responders may need to follow special procedures to treat the incident site as a crime scene. These factors pose unique challenges to those charged with responding to an incident (EPA 2011).

EPA is responsible for supporting state and local responders addressing the environmental consequences of a CWA incident to minimize or mitigate human health threats. In this capacity, EPA can provide a range of capabilities, including site characterization, source containment, preliminary decontamination, ambient air monitoring (for health and safety purposes), and preliminary waste staging. As in the case of conventional HAZMAT response and recovery, each incident is unique, and cleanup procedures as well as site-specific HASPs must be developed based on the site-specific hazards (EPA 2011). Appendix 2 provides a generic CWA HASP, and Appendix 3 provides relevant air monitoring information.

8.2 Requirements and Training

This Guidebook is intended for use by emergency responders who have received, at a minimum, the 40-hour OSHA Hazardous Waste Operations and Emergency Response (HAZWOPER) training and annual refresher training as prescribed in 29 CFR 1910.120 (http://www.osha.gov/pls/oshaweb/...id=9765).

By itself, this section is not intended to prepare responders to work in areas contaminated with CWAs. This information must be integrated into existing emergency responder training and HASPs.

8.2.1 40-Hour HAZWOPER

Emergency responders must receive an initial 40-hour HAZWOPER training, followed by annual 8-hour HAZWOPER refresher courses that comply with the OSHA regulations at 29 CFR 1910.120.

8.2.2 Medical Monitoring

Emergency responders must receive initial and annual medical monitoring and clearance. Medical examinations are performed to establish an employee's baseline health status and to determine if an employee's health status changes over time because of occupational exposures. In addition, medical examinations are used to determine if employees are capable of performing their duties while wearing PPE under conditions that may be expected at a work site (EPA 2008).

8.2.3 CWA Awareness

Before entry onto the site is allowed, site workers should complete CWA awareness training covering potential hazards at the job site, required PPE, signs and symptoms of exposure, and work practices and engineering controls to limit exposure. The training should also cover decontamination as outlined in the requirements at 29 CFR 1910.120(e)(2).

8.3 Elements of Health and Safety

This section discusses program elements that specifically address the health and safety of emergency responders who will participate in CWA incident response and recovery.

8.3.1 Medical Monitoring and Surveillance

Medical monitoring and surveillance will be performed during employee entry and exit from the site. Employees will be monitored for symptoms such as heat stress, cold stress, and exposure. During on-site emergency response and recovery activities, the Health and Safety (H&S) Supervisor will direct health and safety efforts as directed by OSHA at 29 CFR 1920.120(b)(2)(i)(B). In the case of CWA exposure, health care providers must provide emergency responders with follow-up treatment and medical evaluations to monitor for possibly chronic or latent health effects.

8.3.2 Health and Safety Plan

In accordance with 29 CFR 1920.120(b)(1)(i), a site-specific HASP must be kept on site, and it must address the health and safety hazards for each phase of site operations and must specify the requirements and procedures for employee protection. At a minimum, the HASP should include the following:

- A safety and health risk or hazard analysis for each site task and operation
- Employee training assignments
- PPE to be used by employees for each site task and operation
- Medical surveillance requirements
- Frequency and types of air monitoring, personnel monitoring, and environmental sampling techniques and instrumentation to be used, including methods of maintenance and calibration for the monitoring and sampling equipment
- Action levels for air monitoring and personnel monitoring (see Appendix 4)
- Site control measures in accordance with the site control program
- Decontamination procedures
- An emergency response and recovery plan meeting the requirements for safe and effective responses to emergencies, including necessary PPE and other equipment
- Hospital location, hospital route map, and emergency telephone numbers
- Confined space entry procedures
- A spill containment program
- Sign-off sheet for signatures of personnel that have read the HASP

The site specific HASP provides for pre-entry briefings held before the initiation of any site activity and at other times as necessary to ensure that employees are apprised of the site-specific HASP and that the HASP is being followed. The HASP is an ever-changing document as information changes and updates are required.

8.3.3 Training

Before any work is performed at a hazardous waste or CWA incident site, the employer must provide its employees with initial training based on the tasks and operations that employees will perform and the associated anticipated exposures. Not only should this training cover the CWA involved, it should also discuss risks associated with the work to be conducted at the site, including auxiliary risks such as hazards related to heavy machinery, heat stress, and the decontamination process and chemicals (OSHA 1998).

8.3.4 Exposure Limits and Personal Protective Equipment

The recommendations for PPE should be based on a site-specific hazard analysis of possible hazards, including skin contact with a blister agent, air concentrations, heat stress, and other anticipated hazards. All PPE should be used with appropriate additional administrative controls, including medical surveillance, employee training,

Table 8-1 lists inhalation Exposure Guidelines (IDLH, STEL, AEGL, PAL, MRL, WPL and GPL) for Selected CWAs. Table 8-6 lists Environmental Screening and Exposure Guidelines (RBC, MEG, PAL, and PRG) for Selected CWAs for drinking water, soil and surfaces.

Table 8-1– Inhalation Exposure Guidelines for Selected CWAs

INHALATION EXPOSURE GUIDELINES FOR SELECTED CWAS					
Guideline	**Duration (hr)**	**Sarin (mg/m3)**	**Sulfur Mustard (mg/m3)**	**Lewisite (mg/m3)**	**VX (mg/m3)**
IDLH[1]	0.5	0.1	0.7	NA	0.003
STEL[1]	0.25	0.0001	0.003	NA	0.00001
AEGL-1[2]	0.17	0.0069	0.4	NA	0.00057
AEGL-1	0.5	0.004	0.13	NA	0.00033
AEGL-1	1	0.0028	0.067	NA	0.00017
AEGL-1	4	0.0014	0.017	NA	0.00010
AEGL-1	8	0.001	0.0083	NA	0.000071
AEGL-2	0.17	0.087	0.6	NA	0.0072
AEGL-2	0.5	0.05	0.2	0.47	0.0042
AEGL-2	1	0.035	0.1	0.25	0.0029
AEGL-2	4	0.017	0.025	0.070	0.0015
AEGL-2	8	0.013	0.013	0.037	0.0010
AEGL-3	0.17	0.38	3.9	3.9	0.029
AEGL-3	0.5	0.19	2.7	1.4	0.015
AEGL-3	1	0.13	2.1	0.74	0.010
AEGL-3	4	0.07	0.53	0.21	0.0052
AEGL-3	8	0.051	0.27	0.11	0.0038
PAL-1[3]	24	0.0002	0.0008	NA	0.000017
PAL-1	720	0.000018	0.0001	NA	0.0000018
PAL-1	2160	0.000018	0.0001	NA	NA
PAL-2	24	0.001	0.013	0.01	0.00063
PAL-2	720	0.00073	0.0029	NA	0.000073
PAL-2	2160	0.0002	0.00097	NA	NA
PAL-3	24	0.015	0.35	0.037	0.0022
PAL-3	720	NA	NA	NA	NA
PAL-3	2160	NA	NA	NA	NA
MRL acute [4]	24	NA	0.0007	NA	NA
MRL acute	336	NA	0.0007	NA	NA
MRL intermed.	360	NA	0.00002	NA	NA
MRL intermed.	8760	NA	0.00002	NA	NA
WPL	8760	0.00003	0.0004	NA	0.000001
WPL[1]	219000	0.00003	0.0004	NA	0.000001
GPL	8760	0.000001	0.00002	NA	0.0000007
GPL[1]	613200	0.000001	0.00002	NA	0.0000007

NA = not available

[1] Chemical Exposure Guidelines - available at http://cdc.gov/NIOSH/ershdb/index_name.htm

[2] Acute Exposure Guideline Levels (AEGLs) – available at http://www.epa.gov/opptintr/aegl/

[3] Provisional Advisory Levels (PAL) – available at http://www.epa.gov/nhsrc/index.html

[4] ATSDR Minimal Risk Levels (MRL) – available at http://www.atsdr.cdc.gov/mrls

Table 8-2 - Environmental Screening and Exposure Guidelines for Selected CWAs

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

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

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

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

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

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

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