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Remediation Guidance for Major Airports After a Chemical Attack

Annexes

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Date: August 26, 2010

Name/org: Ellen Raber/LLNL, Global Security

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Remediation Guidance for Major Airports After a Chemical Attack Annex A

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Annex A. Considerations for the Notification Phase

This Annex uses Los Angeles International Airport (LAX) as the model airport for issues relevant to the Notification Phase. For more information on topics, such as the command structure created during the Notification Phase, refer to the *National Response Framework* (NRF; see DHS, 2008) and the National Incident Management System (NIMS, 2008).

The Notification Phase begins with recognition that an incident has occurred or is likely to occur. Identification of an incident involving a chemical warfare agent (CWA) or toxic industrial chemical (TIC) could be made from images from cameras or related surveillance or monitoring equipment; intelligence information; or phone calls or direct communication with LAX personnel, including Airport Police, eye witnesses, or others.

Principal activities of the Notification Phase are to receive and assess available information, and to relay key information to appropriate response organizations. Activities do not necessarily occur in sequential order as described in this Annex but may start at different times, run concurrently, or continue beyond the Notification Phase.

To evaluate incoming information and ensure that appropriate initial actions are taken, the Airport Police Dispatch Center notifies appropriate internal and external first response organizations (see Figure A-1). Notification of secondary response organizations is shown in Figure A-2. Airport Police implement plans for the physical space, requisite communications systems, and personnel needed to staff a Joint Coordination Center (JCC) that serves as a communication hub. As part of the pre-planning effort, Los Angeles World Airport (LAWA) management has developed a notification matrix and protocol that identifies Federal and local agencies to be contacted for incidents involving CWAs or TICs. The notification protocol can include pre-determined incident-classification criteria, prepared communications text, and notification priorities. Examples of pre-determined incident classes include credible threats, hoaxes, or confirmed releases of CWA or TIC. Objectives of the initial notification of key response organizations are to establish the Incident Command Post (ICP) and response command structure, and to mobilize response assets. Under the NRF, technical and policy issues are addressed at the lowest possible organizational level. In most cases, this level is the Incident Command (IC) or Unified Command (UC), which is located in the ICP.

The LA City Fire Department and Airport Police implement plans to establish an ICP at an appropriate location near the incident scene. The Airport Police Supervisor or LA Fire Department representative acts as the Incident Commander, depending on who is first to arrive at the incident scene. The senior LA Fire Department representative will take command of the ICP upon arrival at the scene. The Incident Commander will initially address life-safety issues. However, within the first few hours of determining that a CWA or TIC incident has occurred as a result of criminal activities, the FBI will likely take control of the scene for intelligence and evidence gathering, but it most likely will not take command of the IC or UC.

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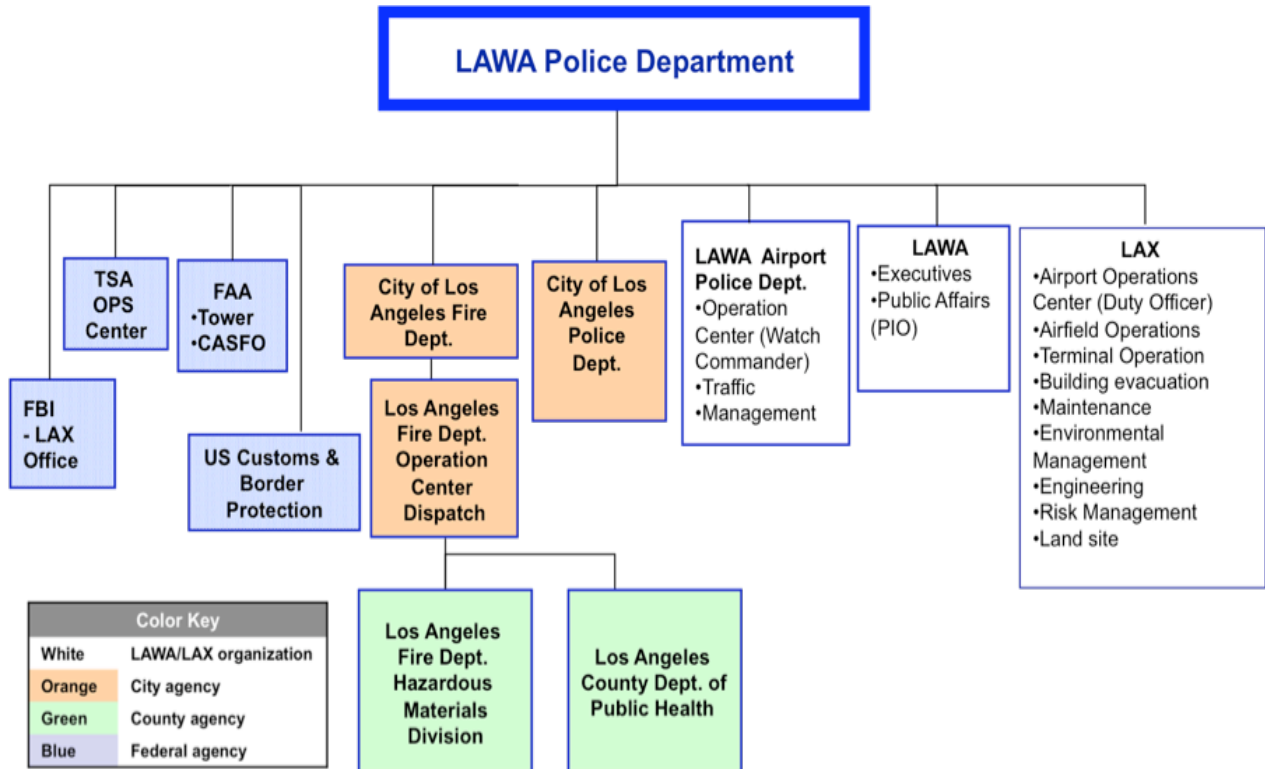


Figure A-1. Post-incident initial notification of first responders.

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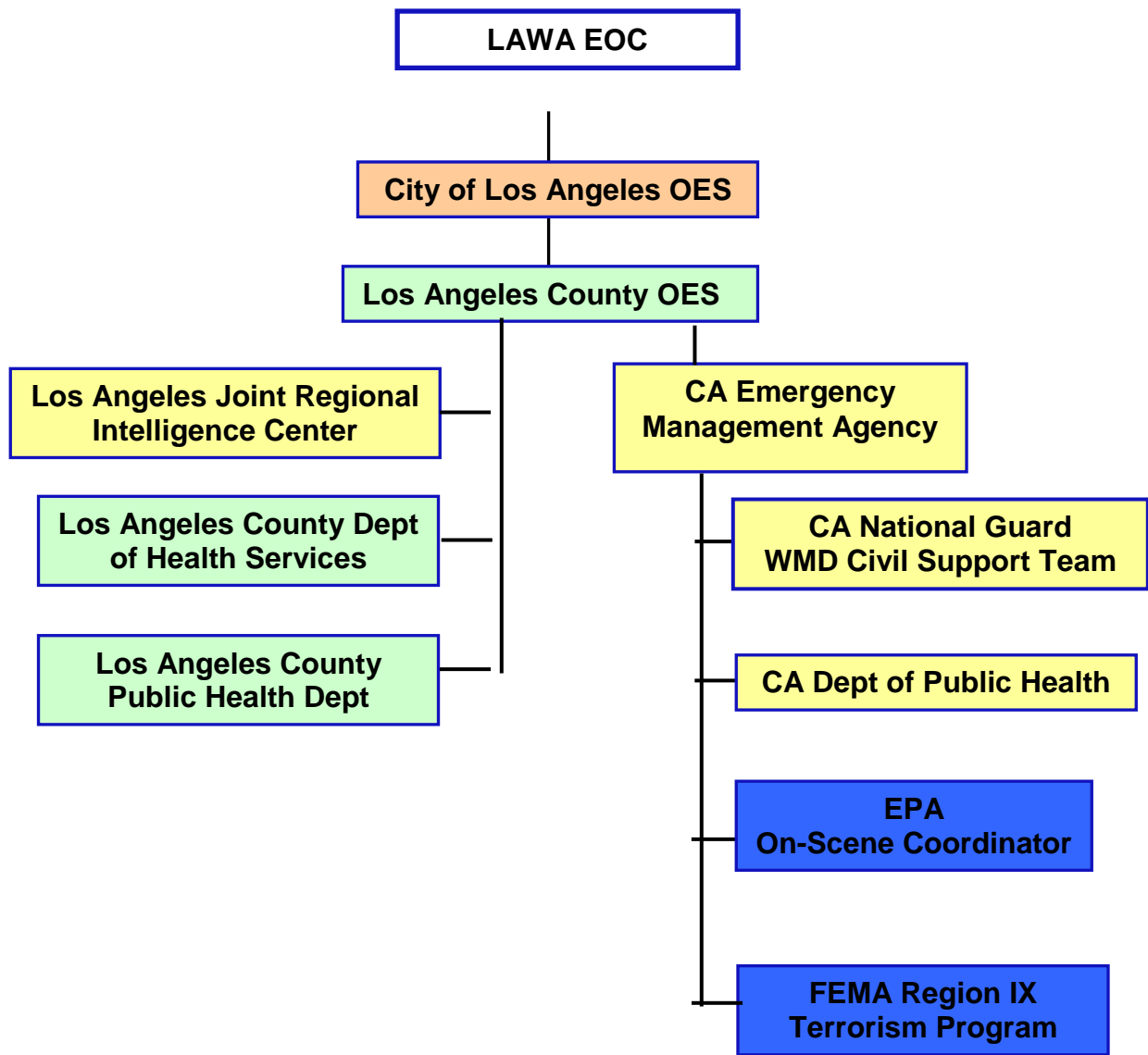


Figure A-2. Initial notification of secondary responders from city, county, state, and Federal agencies.

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A.1. Process Incoming Reports

The initial identification of a CWA or TIC incident at LAX could be made as a function of verbal reports, including direct communication from LAWA personnel or eyewitnesses; monitoring information; or observation from surveillance cameras. To the extent possible, the following details should be recorded from incoming reports:

- Name and telephone number of the reporting individual.
- Title of reporting individual (e.g., physician, FBI agent, or citizen witness).
- Date and time of the verbal report.
- Time and location of the incident (for example, place within an airport terminal or nearest gate within a boarding area).
- Visual observations concerning the release, signs and symptoms of any victims, or other pertinent information.
- Extent of injuries and estimated number of victims.
- Demeanor of victims (for example, panicked).
- Nature of any immediate actions taken.

A.2. Classify the Incident

Classification criteria should be established before an incident so that situations can be identified as either a threat or an indefinite, definite, or confirmed attack. The classification scheme should apply the following parameters:

- **Threat.** A verbal or written message indicates that a potential CWA or TIC incident will occur. Recent incidents at other, similar facility may have already occurred.
- **Indefinite incident.** An unknown material or device (e.g., an unidentified liquid or an aerosol device) has been discovered; however, people in the vicinity do not exhibit symptoms of CWA or TIC exposure.
- **Definite incident.** An unknown material or device (e.g., an unidentified liquid or an aerosol device) has been discovered, and people in the vicinity exhibit symptoms of CWA or TIC exposure.
- **Confirmed incident.** Analytical confirmation of a released CWA or TIC has been obtained.

At LAX for example, initial reports from first responders regarding the immediate physical effects on exposed persons, such as coughing, tearing, and vomiting, would result in a preliminary determination that a “definite” CWA or TIC incident has occurred. To confirm or revise a preliminary classification, it is critical that first responders relay all initial assessments related to the incident to the Airport Police Dispatch Center so that the information can be

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transmitted to the Los Angeles County Health Hazardous Materials Division's Emergency Response Unit, which has subject matter experts available to confirm the preliminary classification.

Once onsite, Los Angeles City Fire Department personnel have portable meters that can detect a CWA or TIC. The LA County Health Hazardous Materials Division staff can take initial air samples and send them either to the South Coast Air Quality Management Board or to a Federal analytical laboratory. In addition, initial samples of any suspect liquid(s) can be sent to county analytical laboratories (e.g., the Los Angeles County Department of Agricultural Commissioners Weights & Measures' environmental toxicology laboratory), the county's contract analytical laboratories, or Federal analytical laboratories.

A.3. Notify Appropriate Agencies

Timely notification of first responders, community officials, regulatory personnel, and facility restoration organizations is vital during the Notification Phase. When a CWA or TIC release by a terrorist could threaten human health and safety or the environment, the first response agencies listed in Table A-2 must be verbally notified first. Then the support agencies identified in Table A-3 are notified. Support organizations can provide additional response resources.

Essential information must be provided to responders to ensure their safety. The on-scene FBI representative may alert the FBI Joint Terrorism Task Force (JTTF), which can bring additional Federal emergency resources to the scene. The on-scene FBI representative will also notify the FBI Strategic Information and Operations Center (SIOC). The FBI SIOC immediately reports a terrorist threat (if the FBI deems the threat to be credible) or an actual incident to the Homeland Security Operations Center (HSOC) and to the National Counterterrorism Center (NCTC). The HSOC serves as a national-level, multi-agency, situational awareness and operational coordination center. In addition, confirmed incidents, regardless of whether or not there is a terrorist nexus, are reported immediately to the HSOC by appropriate governmental and nongovernmental entities.

Annex A**Table A-1. Primary agencies to be immediately notified if a CWA or TIC release threatens health, safety, or the environment.**

Agency to notify
LAWA local
LAX Fire Department
LAX Police Department
Federal Bureau of Investigation (FBI), LAX Office
Airport Operation Center
Airfield Operations
Terminal Operations
Los Angeles City Police Department
TSA Operations
Public Relations
Immigration
FAA tower
FAA CASFO
LAX Environmental Management
LAX Maintenance
Public Health
LAX Risk Management
Traffic Supervisor
Coroner
Southern California Gas
U.S. Customs and Border Protection Service
Building evacuation contact for each terminal

Annex A**Table A-3. Secondary contact agencies to notify if a CWA or TIC release threatens health, safety, or the environment.**

Agency to Notify
Regional, State, and Federal
California National Guard 9 th WMD Civil Support Team
California Department of Public Health
California Emergency Management Agency (EMA)
FEMA Region IX
LA City Emergency Operations Center
LA County Department of Health Services
LA County Department of Public Health, Acute Communicable Disease Section's Administrator of the Day
LA Joint Regional Intelligence Center (JRIC), a State of California Regional Terrorism Threat Assessment Center
Environmental Protection Agency On-Scene Coordinator

The Los Angeles Joint Regional Intelligence Center (LA JRIC) was created to prevent terrorist attacks. This state coordinating agency has staff on loan from law enforcement agencies, including Joint Terrorism Task Force officers from the Los Angeles Police Department, the Los Angeles County Sheriff's Department, and the FBI. The LA JRIC staff includes several dozen full-time analysts whose specialties range from epidemiology and public health to emergency operations and hazardous materials. The LA JRIC, as one of the four State Terrorism Threat Assessment Centers (STTAC), is a conduit to the California Department of Justice, the California Highway Patrol, and the California Office of Homeland Security (OHS).

Beyond the ICP, local and state EOCs would be activated or created, if necessary, in addition to the Joint Field Office (JFO) that coordinates Federal assistance and supports incident management activities. The JFO communicates directly with the HSOC.

A.4. Take Initial Actions at the Scene

Airport personnel who witness a CWA or TIC release, or individuals who exhibit signs or symptoms of exposure, should:

- Protect themselves by moving a safe distance away (upwind) from a suspected source.
- Dial 911 when it is safe to do so.
- Inform first responders of all information known about the incident.

Annex A**A.5. Summary of Actions Related to the Notification Phase**

Table A-1 summarizes actions to be taken before and during the Notification Phase.

Table A-2. Summary of Notification Phase actions.

Personnel	Action
Airport management	Complete the following pre-planning actions: Develop the notification protocol (such as a phone tree, notification matrix with predetermined incident classification criteria, and prepared text messages) for all responders and agencies (Federal, state, and local) tailored to each stage of a developing incident. Develop a policy statement specifying the criteria for airport closure or suspension of operations after a CWA or TIC attack.
Airport personnel or witnesses present at the scene	Protect yourself, and move away from the source of exposure to a holding area. Notify emergency dispatch (e.g., 911) when it is safe to do so. Remain in the area to provide information to first responders.
Airport Police Dispatch Center	Evaluate reports and determine if the incident meets criteria for a CWA or TIC incident. Notify key emergency response organizations.
Incident Command Post personnel	Gather all pertinent information from verbal reports. Evaluate all reports, data, and intelligence information. Confirm or revise incident classification as a CWA or TIC incident. Update Airport Police Dispatch Center and the LAWA EOC.

A.6. Annex A References

DHS (January 2008), Department of Homeland Security, *National Response Framework*; available at <<http://www.fema.gov/emergency/nrf/>>.

NIMS (December 2008), *National Incident Management System*, available at <<http://www.fema.gov/emergency/nims/index.shtm>>.

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Annex B

Annex B. Considerations for the First-Response Phase

This Annex uses Los Angeles International Airport (LAX) as the model airport for identifying relevant actions to implement during the First-Response Phase. For more information on topics related to first response, refer to the *National Response Framework* (NRF; see DHS, 2008) and the National Incident Management System (NIMS, 2008).

During the initial phases of response to an incident involving a release of chemical warfare agent (CWA) or toxic industrial chemical (TIC), emergency activities are focused on saving human life and on securing and stabilizing the incident scene. The First-Response Phase consists of the following actions on the part of airport personnel, including the Los Angeles World Airport Police Department (LAWA PD), the Los Angeles City Fire Department (LAFD) battalion stationed at the airport, and other first responders who are present at the scene:

- LAFD establishes a Unified Command (UC) at an Incident Command Post in a safe location near the incident scene.
- LAFD and LAWA PD shelter-in-place or safely evacuate potentially exposed people, and they care for affected individuals.
- LAFD conducts a rapid assessment of the affected area(s) and identifies the agent(s) to the extent possible using equipment at hand.
- LAFD contains the contamination to the extent possible and works to mitigate immediate threats to human health.
- LAWA PD shuts down traffic into the central terminal area
- The UC implements pre-planned risk communication.

The First-Response Phase can also include hazardous material (HazMat) and emergency actions, securing the area and making it safe for response personnel, forensic investigation, public health actions, and screening sampling to initially characterize and prioritize affected area(s). The initial assessment and results of actions by the IC or UC, in consultation with the Airport Operations Duty Officer and FAA control tower, provide the basis for determining whether or not airport operations should be curtailed or shut down. The typical command structure for the UC during the First-Response Phase is shown in Figure B-1. Agencies specific to LAX that would be part of the UC during the First-Response Phase and their role(s) are identified in Table B-1.

Immediately following a terrorist incident, airport personnel and tenants who are at the scene may need to function without outside resources for a time. Such personnel can perform several critical tasks if they are properly trained and instructed. Examples include organizing an evacuation of a terminal or airport, shutting down terminal or airfield operations, attending to casualties, and supporting medical response teams.

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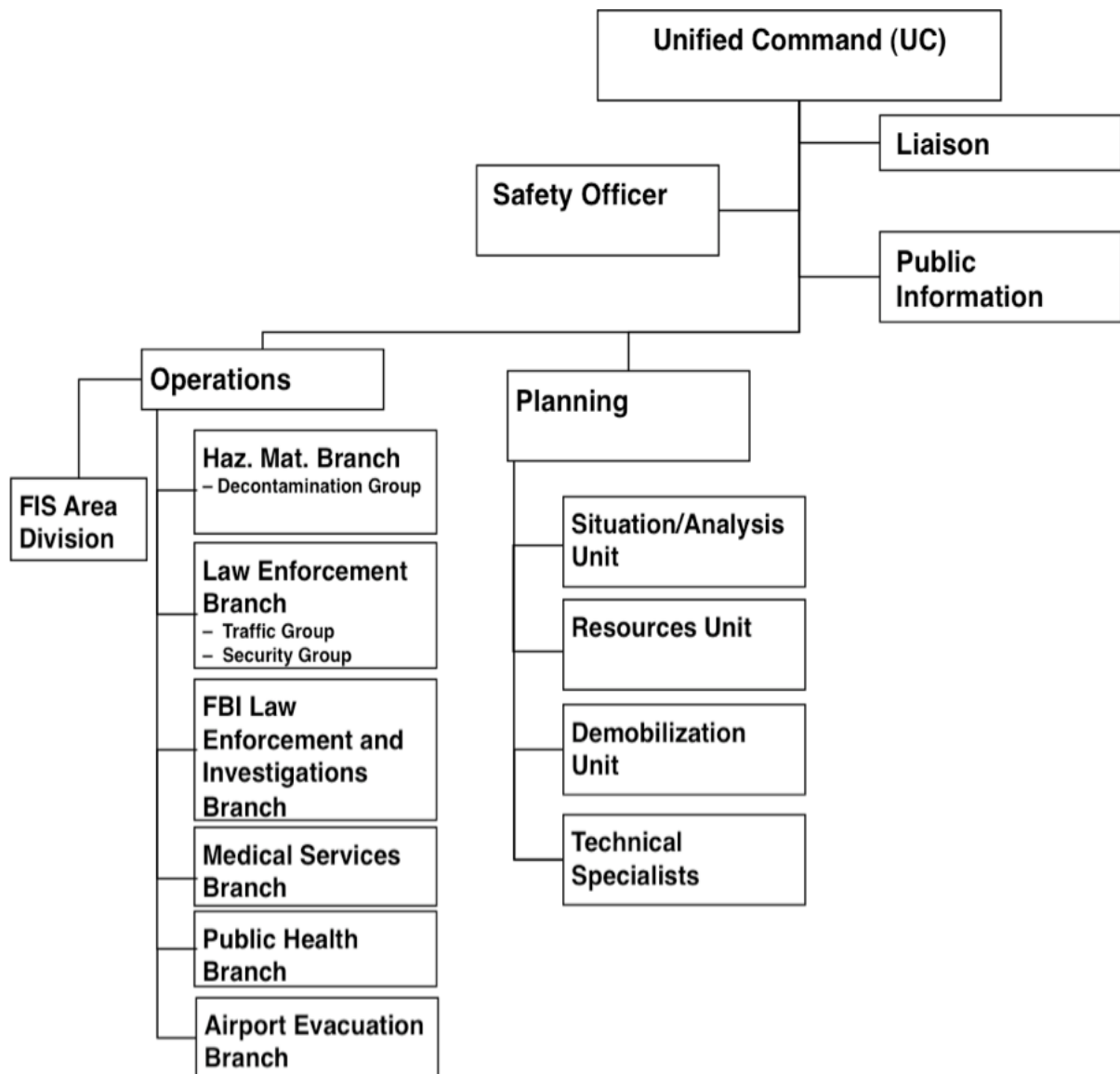


Figure B-1. Typical Unified Command structure for first response.

Annex B**Table B-1. Unified Command functions and related emergency response agencies at LAX during the First-Response Phase.**

Function	Agency
Unified Command	FBI WMD Coordinator LAFD LAWA Police Transportation Security Administration (TSA) U.S. Customs and Border Protection (CBP)
Operations Section	
Fire and HazMat Branch	LAFD LA County Fire Department LA County Health HazMat Division CA National Guard Civil Support Team
Law Enforcement Branch	LAWA Police LA City Police Department LA County Sheriff
FBI Law Enforcement and Investigations Branch	FBI
Medical Services Branch	LA County Health Services Department LA County Coroner Department
Public Health Branch	LA County Public Health Department LA County Health HazMat Division
Federal Inspection Service Area Division	U.S. CBP
Planning Section	
Technical Specialists	LA County Health HazMat Division FBI Hazardous Material Response Unit LA County Public Health Emergency Response Team
Resources Unit	LAFD LAWA PD LA City PD
Situation and Analysis Unit	LAFD LAWA Operations LAWA Terminal Operations TSA DTSC

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Additional support and coordination components include local, state, and Federal resources accessed through coordination centers and emergency operations centers (EOCs), as shown in Figure B-2 and Table B-2.

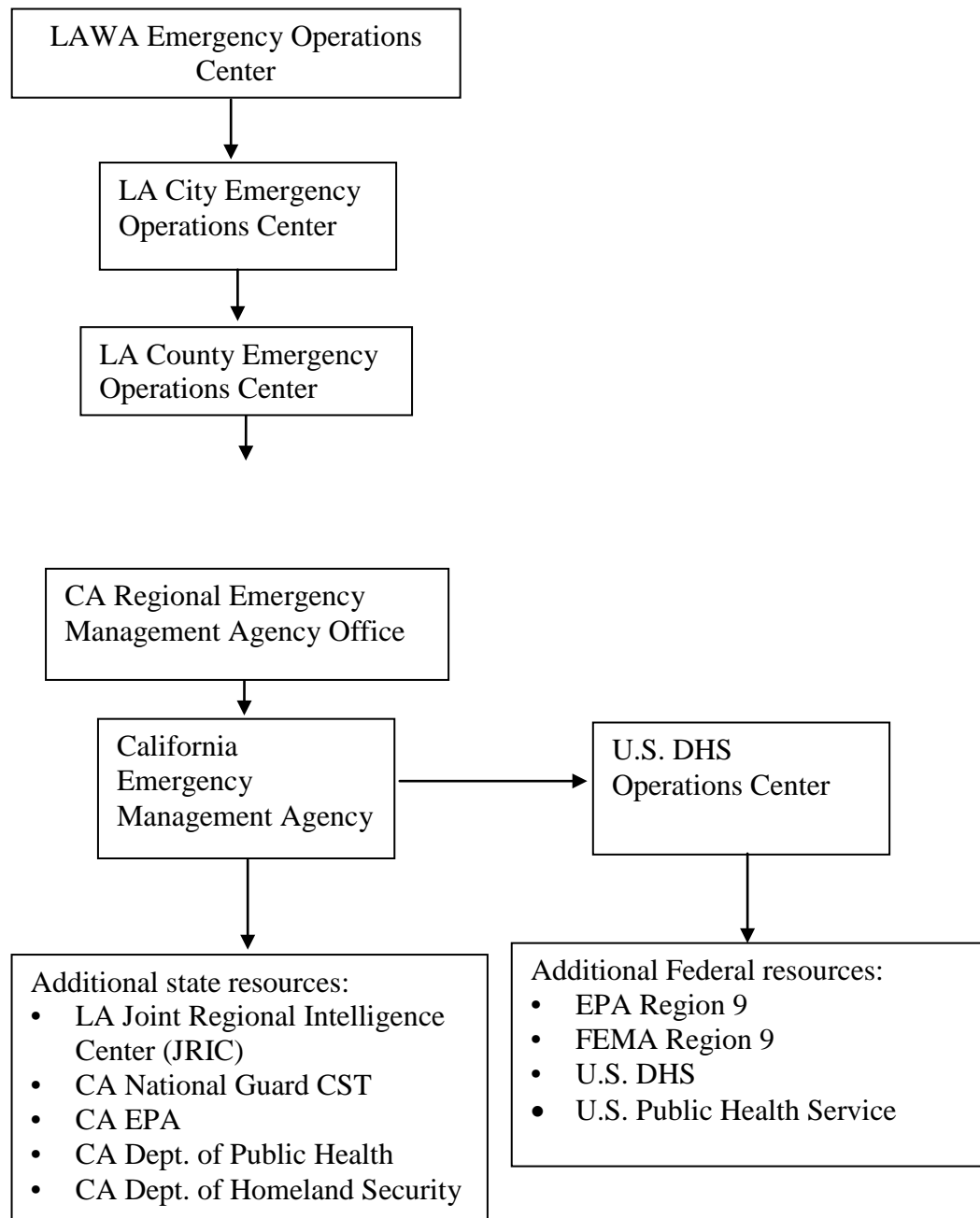


Figure B-2. Additional support organization available during the First-Response Phase.

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Table B-2. Resources and services available from additional organizations supporting LAX during the First-Response Phase.

Organization	Additional Support and Resources
LAX Emergency Operation Center	Coordinates LAX support organizations and gathers facility information to support the UC.
LA City Emergency Operations Center	Notifies city organizations and deploys resources. Resources: site security personnel and traffic control, social services staff, public works, and HVAC-knowledgeable staff.
LA County Emergency Operations Center	Notifies county organizations and deploys resources. Resources: analytical laboratory and support for TIC identification, public health experts, pesticide and insecticide subject matter experts.
California Regional Office of Emergency Management Agency	Notifies California EMA to request state assistance.
California Emergency Management Agency	Notifies state organizations and deploys resources. Resources: subject matter experts within JRIC: analytical and decontamination support, toxicologist support, public health subject matter experts; traffic management via CA Highway Patrol; CA National Guard Civil Support Team.
U.S. DHS Operations Center	Notifies Federal organizations and deploys resources. Resources: FEMA staff; EPA staff, including subject matter experts in sample collection and analyses; analytical laboratories; access to DOE and DOD subject matter experts in WMD, explosives, forensics, atmospheric modeling, fate and transport, risk assessment, and surveillance.
EPA Region 9 Response Center	Provides access to EPA Emergency Response Resources. Resources: Regional and National Response Team, OSCs, Regional Response Corp, contractors, U.S. Coast Guard National Strike Force.

B.1. Preplanning Activities**B.1.1. Develop Evacuation Plans**

Preplanning activities include developing evacuation procedures and identifying evacuation routes and locations suitable for holding evacuated individuals. The locations may include suitable internal or external shelter-in-place areas. Factors that should be considered while identifying evacuation routes and holding locations include:

- Location of the release(s) within the facility.
- Material and physical state of the CWA or TIC involved in the release.

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- Maintaining a safe distance from affected area(s).
- Minimizing the spread of contamination to other areas and people.
- Ventilating an area to prevent contaminant from entering other areas (e.g., HVAC for a shelter-in-place location separate from holding area) or to remove contaminant from an area (e.g., unenclosed outdoor area with no surrounding buildings affecting air movement).
- Ability of Airport Police to secure the containment area.
- Providing access for emergency response and decontamination equipment.
- Minimizing impacts on the continuity of airport operations at other locations.
- Traffic plans to minimize congestion and control vehicular flow.

Evacuation plans must include maps showing evacuation routes and holding areas. Criteria for choosing an evacuation route or holding area should be specified on the maps. The maps should be available to all airport and emergency response personnel that would play a role in implementing the evacuation plan. The evacuation procedure also needs to specify what messages will be used to initiate the procedure and how any messages are to be communicated throughout the airport facilities or elsewhere.

B.1.2. Specify How to Decontaminate Victims

It may be necessary to decontaminate victims before their removal from a hot zone and to prevent the spread of contamination to an offsite medical facility. Decontamination procedures should be developed that will effectively remove contaminants using readily available materials.

Primary decontamination can be accomplished by removing clothing, then using dry wiping techniques to remove visible contamination followed with a soapy water rinse. Although a rinse solution consisting of dilute hypochlorite or peroxide will deactivate a CWA or TIC, adverse reactions to hypochlorite or peroxide chemicals are possible. Thus, an initial rinse using large amounts of water to flush contaminants away should be the first course of action for decontamination. Provisions must be made to provide replacement garments for victims who have been decontaminated.

Appropriate containers must be available to collect and contain contaminated clothing. Spent decontamination solutions and rinse water should be collected for treatment using household bleach and then properly disposed. The decontamination procedure should incorporate effective preventive measures that eliminate or minimize releases of CWA- or TIC-contaminated material to the environment. Decontamination solutions must be contained to prevent the creation of a second contamination zone and the necessity of additional remediation activities. The local health department and fire department may have existing decontamination procedures or requirements that need to be incorporated.

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B.1.3. Decide How to Contain the Affected Area

Airport facility management and first responders need to identify containment options for minimizing or stopping the spread of contamination. Possible avenues for transport include air movement and physical contact with people or objects moving through the contaminated area. Air movement can be caused or exacerbated by the HVAC system and exhaust systems in a facility, opening of exterior doors, and the movement of people or equipment. Steps that can be implemented to minimize or eliminate air movement include sealing exit doors, deactivating automatic door sensors, shutting down HVAC systems, closing dampers in an HVAC system, closing fire doors, and shutting off exhaust fans in food-preparation areas, bathrooms, and other areas. Controlling the number of emergency response personnel who enter an affected area, as well as restricting entry and exit routes used by emergency response personnel, can help to limit the spread of contamination.

The method for implementing containment options (e.g., control switches versus manual closure) must be specified as part of the preplanning procedures. The location of control switches and how to access controls must also be identified.

B.1.4. Complete Personnel Training Prior to an Emergency

Airport facility management should identify the roles and responsibilities of all facility personnel who may be called upon to assist at the scene. Designated emergency response personnel need to be trained to the appropriate classification level specified by the Occupational Safety and Health Administration (OSHA) in 29 CFR 1910.120(q) or in a corresponding state regulation. OSHA identifies the following emergency responder categories: on-scene incident commander, hazardous materials specialist, hazardous materials technician, first-responder operations level, first-responder awareness level, specialist employees, and skilled support personnel. If tenant personnel are responsible for making notifications or initiating response actions, tenant management should identify the roles and responsibilities for those employees who could be involved in an emergency. Such information will allow airport facility management or tenant management to assign an emergency responder category to each employee in accordance with corresponding training requirements. Airport personnel who could respond to the Incident Command Post or airport facility EOC should be trained in the Incident Command System according to NIMS.

Personnel responsible for notifying proper authorities of a release or for initiating or assisting during an evacuation are considered part of the emergency response. Such personnel must be trained regarding appropriate procedures for making notifications and initiating or implementing any response actions.

B.1.5. Explain How to Perform Risk Communication

Protocols for disseminating official information regarding a potential CWA or TIC incident should be coordinated in advance with the Public Information Office. Tasks include identifying possible types of scenarios, addressing key “talking points” for each scenario that would be expected to be covered during a press release, designating official spokesperson(s), identifying

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required logistics, stipulating the anticipated frequency of communication, and specifying communication guidelines for airport staff.

B.1.6. Consider Family Services and Reunification

The protocol for disseminating official information regarding the status of staff members and other persons potentially affected by a CWA or TIC incident should be planned in advance. If no mechanism is available for individuals to obtain information on family and friends, the public may arrive on-scene and potentially interfere with a coordinated response. Furthermore, because airport staff members and first responders will be able to concentrate more effectively on their roles and responsibilities if a clear mechanism is in place for contacting family members and others of concern, contact numbers together with the names of persons or agencies to be contacted should be identified in advance.

The airport facility EOC can work with the city EOC to pre-identify locations near the airport where members of the public can be directed to await reunification with passengers as they are released from the airport. Preplanning should take into account how passengers will be transported from the airport to all offsite reunification locations.

B.2. First-Response Actions

B.2.1. Evacuate Exposed Individuals and Gather Initial Information

Initial response actions focus on evacuating affected individuals to a safe location and providing medical attention, as necessary. Airport first responders at the scene should evacuate individuals from affected areas using established evacuation plans. Victims who show signs of exposure need to be separated from unexposed individuals to prevent contamination of additional people and to provide prompt medical evaluation and treatment, when necessary.

Airport police or an equivalent security force must dispatch personnel to the evacuee holding area to ensure that evacuated individuals do not leave the area and that spectators do not interfere with first responder activities. Rerouting of vehicle and foot traffic may be required to facilitate first responder activities and prevent entry into contaminated area. Support agencies and organizations may need to send responders to hospitals where victims are to be treated and to assist with decontamination efforts aimed at preventing or minimizing contamination of those facilities.

Airport personnel should prepare a list of eyewitnesses and directly affected individuals, gathering critical information necessary to aid first response decision-making and any subsequent criminal investigation. Recorded information would include the location of individuals when the incident occurred, descriptions of potential suspects, type of release (e.g., gas, powder, or liquid), an estimate of the amount of material released, if possible, a description of the release mechanism (e.g., a gas cylinder), any exposure symptoms, and any other available information deemed pertinent. Coordination with law enforcement personnel and prompt communication of information regarding the incident to the IC or UC and airport EOC should be a priority.

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B.2.2. Coordinate with Off-Airport First Responders

Support agencies and organizations can assist with rescue operations, mitigating any life-threatening or hazardous conditions (e.g., fire or explosion), securing the scene, decontaminating victims and exposed personnel, treating exposed people, collecting evidence, and conducting preliminary tests to identify the CWA or TIC involved. Some organizations can provide additional expertise, resources, decontamination equipment, and equipment to assess hazards and implement mitigation measures as needed.

The exact configuration of potential support agencies will vary from airport to airport. For LAX, off-airport support can include the LA County Health Department, the LA Regional Intelligence Center (LA JRIC), LA City Police, the FBI, and others such as the California National Guard 9th Civil Support Team.

B.2.3. Stabilize the Emergency

Any actions tailored to address the hazards of a particular CWA or TIC should be performed with the objective of containing and stabilizing the emergency if the agent is known. General hazardous-material emergency-response actions that should be considered for all CWA or TIC incidents include:

- Rescuing, decontaminating, triage, and transportation of victims.
- Putting into place containment measures to minimize the spread of CWA or TIC, when possible.
- Shutting down or curtailing affected airport operations, as necessary.
- Notifying additional workers or relevant agencies, as necessary.
- Securing the scene for forensic investigation and remediation activities

The Incident Commander, in consultation with representatives from airport terminal operations and airport police, evaluates how to enter the affected facility to check for injured, trapped, or sheltered-in-place people. Access routes should be selected not only to facilitate the prompt and efficient removal of potentially exposed victims but also to minimize response personnel from crossing through potentially contaminated areas, thereby minimizing the spread of contamination. Limiting the number of personnel, access and egress points, and frequency of entry can further minimize the spread of contamination. For example, frequent opening and closing of doors can increase air movement and the potential for contaminating additional areas.

The IC or UC, working with airport terminal operations and airport police representatives, should review predetermined contaminant containment options for the affected facility and select the best options according to the details of a situation. Airport police, airport construction and maintenance personnel, and terminal operations personnel may be able to assist in implementing the selected containment options.

Communication among the IC or UC, airfield and terminal operations, and the airport EOC is critical for assessing initial impacts on airport operations and the potential need to curtail or shut

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down operations. The location of the release, all physical connections with adjacent terminals or other buildings, and shared HVAC systems must be evaluated when determining whether additional terminals or facilities need to be evacuated or shut down. Preplanned scenarios and expected impacts on airport operations will facilitate timely decision-making.

Following an initial assessment of the incident by first responders and an evaluation of projected impacts on airport operations, additional workers and agency personnel are notified, as appropriate. Notifications should make use of pre-scripted messages tailored to the intended audience, including directions for evacuation and instructions for responding to the incident.

Appropriate contamination control points must be established to ensure that responders are adequately decontaminated before exiting the hot zones. Personnel can be decontaminated using dry-wiping techniques to remove visible contamination followed with a hypochlorite, peroxide, or soapy water rinse. A final rinse should be done using large amounts of water to flush any remaining contaminant away. For most CWAs and TICs, nondisposable equipment can be decontaminated with dilute hypochlorite solution followed by a water rinse. Spent decontamination solution and rinse water should be collected for treatment and proper disposal.

Once emergency HazMat actions are completed and the immediate emergency is stabilized to the extent possible, airport police maintain security of the affected area to prevent entry and preserve the area as a crime scene.

B.2.4. Evaluate and Perform Public Health Actions

During the First-Response Phase, personnel from the responsible public health agencies will promptly assess the situation and commence those public health actions deemed appropriate to the situation. Such actions can include treating and decontaminating potentially exposed individuals, performing medical examinations, notifying associated agencies, and taking any other required intervention or treatment options related to public health. The Los Angeles County Health Hazardous Materials Division is the primary public health point-of-contact for LAX. This entity also provides guidance on how to appropriately decontaminate emergency responders exiting the incident scene. After the immediate emergency has been stabilized, the Public Health Officer provides further guidance on what areas of the airport should be isolated or otherwise controlled, whether adjacent terminals can remain open or should be closed, and whether or not holding areas for evacuees can be returned to normal use.

B.2.5. Perform Environmental Field Testing and Sampling

Environmental sampling by first responders is typically done to identify the CWA or TIC (or at least its type) promptly and to help locate the release point if not already known. Such information is useful in identifying appropriate medical treatment(s) for victims and establishing HazMat exclusion, contamination-reduction, and support zones. Sampling activities continue in more depth during the Characterization Phase. In addition to first responders who are at the scene, other local, regional, state, or Federal resources may respond quickly to provide

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field sampling and analytical capabilities. Such entities include public health agencies, the FBI, National Guard Civil Support Teams, and EPA regional resources.

The ability to identify a given CWA or TIC depends on its physical state (gas or liquid), physical properties (such as volatility), and chemical interactions with various surfaces within a facility. Degradation byproducts created through chemical reactions of an agent with the environment (e.g., water moisture or concrete) can also be used to deduce the identity of a CWA or TIC.

If preliminary tests indicate the presence of a CWA or TIC, the FBI will likely commence a forensic investigation to confirm the agent, determine its specific physical and chemical properties, search for other types of evidence, establish a possible source of contamination, and determine the responsible party.

B.2.6. Coordinate Public Affairs and Risk Communication Efforts

A Joint Information Center (JIC) should be established immediately to coordinate all public-affairs activities and media releases regarding the incident. A Public Information Officer (PIO) who reports to the IC or UC should be appointed to develop and release information about the incident to the media and to all other agencies and organizations involved. Targeted communication must evolve in synchrony with the phases of response and must be directed toward phase-specific activities. The operational requirements of each phase will vary according to the nature and longevity of a specific incident. JIC staff should be familiar with the basic tenets of emergency risk communication and with the unique information requirements of each phase. At LAX, the JIC is also responsible for coordinating responses to large-scale CWA or TIC incidents with the LA City EOC.

B.2.7. Take Necessary Law Enforcement Actions

Several different law enforcement agencies could be responsible for implementing actions during the First-Response Phase. The law enforcement agencies can include the airport police department, city police department, highway patrol, FBI, and Customs and Border Protection. These agencies should be incorporated into the UC to ensure that their response actions are integrated. The types of law enforcement actions to be implemented can include:

- Stopping vehicular traffic to the airport and around terminal areas.
- Implementing shelter-in-place or evacuation of passengers and public in other terminals.
- Controlling vehicular traffic on city streets and highways near the airport.
- Controlling access to the incident scene.
- Controlling and holding international passengers who have not cleared customs.
- Interviewing witnesses and other personnel at the airport.
- Inspecting parking structures, buildings, and other structures at the airport.
- Collecting evidence at the scene.

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Some law enforcement actions can continue beyond the First-Response Phase; if so, such actions would be transitioned appropriately as part of remediation phase activities.

B.3. Summary of First-Response Actions

Table B-3 summarizes the actions that should be taken during the First-Response Phase by airport personnel (including airport first responders) and outside support agencies and organizations. Airport first responders include those individuals resident at or proximal to the airport facility and the first to arrive at the scene (such as airport police, fire department personnel, airport operations personnel, and others).

Table B-3. Summary of actions to be taken during the First-Response Phase.

Personnel	Action
Airport first responders	<p>Safely evacuate the affected area, and provide immediate care for victims. Report any symptoms (e.g., possibly associated with chemical exposure) to responders and the Incident Command Post (ICP).</p> <ul style="list-style-type: none"> • Maintain a safe distance from the source of CWA or TIC exposure by remaining or moving upwind. • Segregate potentially exposed people (e.g., those whose symptoms indicate exposure) from nonexposed people. • Initiate information gathering from witnesses. • Reroute vehicular and personnel traffic from the affected area. <p>Inform first responders of available information to assist in identifying the nature of the incident.</p> <p>Don pre-identified personal protective equipment (PPE) before attempting rescue or decontamination of victims.</p> <p>Contain the affected area (e.g., shut down HVAC systems; establish hot, warm, and cold zones).</p> <p>Secure the scene to preserve evidence.</p> <p>In consultation with the UC or IC, determine if the terminal should be shut down and whether airport operations should be curtailed.</p> <p>Evaluate potential spill or releases to the airport's storm drain or sanitary sewer system, unpaved areas, or offsite areas.</p> <p>Determine whether re-entry can be allowed and operations can resume.</p>
Support agencies and organizations (e.g., public health, FBI, EPA, and others)	<p>Assist in evaluating HazMat actions required to stabilize the situation.</p> <p>Assist in decontaminating affected personnel and victims.</p> <p>Assist in implementing all other appropriate public health measures.</p> <p>Assist in identifying and prioritizing contaminated areas and operations.</p> <p>Assist in identifying the CWA or TIC through field testing and sampling.</p> <p>Assist in the forensic investigation.</p> <p>Assist in determining whether the immediate threat is abated or continuing.</p>

Annex B**B.4. Annex B References**

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EPA (August 2007), U.S. Environmental Protection Agency, *Risk Communication in Action—The Tools of Message Mapping*, EPA/625/R-06/012.

NIMS (2008), *National Incident Management System*, document available at: <http://www.fema.gov/pdf/emergency/nims/NIMS_core.pdf>.

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Remediation Guidance for Major Airports After a Chemical Attack Annex C

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Annex C**Annex C. Considerations for Sampling Design**

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This Annex describes general considerations for sampling designs applicable to airports and to both characterization and clearance sampling. Specific details of any characterization or clearance sampling design (for example, how many samples to take and where to take them) would be developed in the context of the issues discussed here.

Sampling takes place in all phases of remediation after a terrorist attack involving a chemical warfare agent (CWA) or toxic industrial chemical (TIC). The phases shown in Figure C-1 match those in Figure 1-1 of the main text, but the elements shown here are focused on sampling. The phases proceed approximately in the following order:

- Notification and first response, which includes screening sampling.
- Characterization, which includes both an initial assessment of contamination and further detailed sampling to gather information on the extent of contamination for use in later phases and on identity of the chemical(s) of concern, if still necessary.
- Decontamination activities, including measures to monitor the decontamination process as it takes place and to verify that decontamination is done as designed.
- Clearance, which is a formal demonstration of cleanliness to the level of clearance goals as a necessary condition for releasing an area for refurbishment and reoccupancy.
- Long-term monitoring, if necessary, to ensure that no long-term health risk exists to the public or employees once a building is reoccupied.

First responders and law enforcement agencies may conduct initial sampling activities. Sampling has an especially prominent role during characterization and clearance. Early coordination with the qualified and certified laboratories that will be used for sample analysis is essential to determine their capabilities and the analytical processes they use. Such coordination ensures that samples will be collected and prepared in a way acceptable to the laboratories.

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Notification and First Response

- Perform initial sampling by HazMat and FBI.
- Determine CWA or TIC type(s).
- Identify suspect release site(s).

Characterization Phase

- Review pre-planned zones (define zones if necessary).
- Classify zones relative to contamination likelihood.
 - Determine information needed in each zone.
- Perform additional ad hoc sampling if needed.
- Identify types of surfaces and objects in each zone, and appropriate sampling methods.
 - Develop Characterization Sampling and Analysis Plan (SAP) for each zone.
 - Conduct sampling.
- Review results: Is decontamination needed? Enough information to design decontamination?

Decontamination Phase

- Select clearance goals if not done earlier.
- Select clearance criteria to determine if goals are met.
- Plan and conduct any necessary decontamination.
- Perform sampling as necessary to monitor progress of decontamination.
- Perform sampling of waste residues, as necessary, to establish residual CWA or TIC levels or to characterize waste in preparation for disposal.

Clearance Phase

- In each zone, identify sampling strategy that will test clearance criteria.
- Write Clearance Sampling and Analysis Plan (SAP), and obtain approval.
 - Conduct sampling.
 - Decide whether clearance criteria have been met.

Restoration Phase

- Plan and conduct long-term monitoring if needed.

Figure C-1. Response and recovery activities related to sampling.

Although Figure C-1 suggests that the sampling process is linear, in reality, efficient remediation requires that many activities occur simultaneously. The processes should be adaptive, not strictly step-by-step. Sampling and decontamination activities can occur simultaneously in different parts of a facility. It is possible in certain situations that some decontamination activities might

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precede characterization sampling. For example, visually obvious contamination, such as freestanding liquid CWA or TIC, could be immediately decontaminated without the need for characterization sampling. However, if the possibility of secondary vapor contamination cannot be ruled out, then characterization sampling would follow to assess the extent of secondary contamination. The remediation process is dynamic, and the use of sampling to support the process should adapt to changing conditions and new information.

C.1. Purposes of Sampling

Because 100 percent of surfaces or air cannot be characterized, sampling is necessary. Within each phase of response, the decisions and sampling objectives may be unique. During the First-Response Phase, samples are obtained to quickly identify the CWA or TIC and to support immediate actions. The major sampling efforts will probably be performed during the Characterization and Clearance Phases. During the Characterization Phase, sampling provides information about the extent of contamination; in the Clearance Phase, sampling assesses the success of decontamination. Sampling may also be used during the decontamination process(es) and during long-term monitoring.

C.2. Pre-Planning

Because an airport is a complex physical environment, it will be helpful to plan ahead for the kinds of sampling that will be done in the event of a CWA or TIC attack. Much of the planning can be done according to the physical structure of the airport, and the pre-planning should be incorporated into the Facility Emergency Response plan. The templates in Annexes H and J are intended to help with the process.

It is imperative that the person responsible for planning any sampling visit the facility and fully evaluate the physical nature of areas to be sampled before designing a sampling plan. Such a visit will reduce the possibility of producing a sampling plan that may have potentially dangerous consequences or be impractical to implement.

C.2.1. Physical Structure

From the perspective of sampling for CWAs or TICs, airports present a large and complex physical environment. In addition to a superstructure (including floors, walls, and ceilings) and environmental controls [heating, ventilation, and air conditioning (HVAC) systems], there are many structures of widely varying sizes and shapes. Examples include ticket counters, shops, restaurants, flight arrival and departure monitors, informational signs, escalators, seats, conveyor belts, metal detectors, scales, artwork, kiosks, and others. Many of the objects are semi-permeable to room air (e.g., cabinets, drawers, electrical equipment, and escalators). Moreover, contaminated surfaces can range from smooth (seamless linoleum) to rough (textured surfaces, seams, and fabrics), the latter of which are not easily sampled for contamination. Many critical items may need to be quickly released before the area is decontaminated (e.g., computers and survey equipment). All such considerations can complicate sampling. To manage the sampling of

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such a complex environment, an airport can be hierarchically partitioned into sampling zones and sampling units.

C.2.2. Sampling Zones

To facilitate development of sampling schemes within an airport, a useful way to view an airport's physical structure is in terms of areas or zones. Identifying zones that could easily be partitioned from each other, so that different decontamination decisions for each zone are feasible, can facilitate the approach to sampling design. At the Tom Bradley International Terminal (TBIT) at LAX, for example, the northern boarding area is connected to the central building by a short, small corridor. The corridor is a natural location to construct barriers that would allow opposite sides to be decontaminated separately. Alternatively, one side could be decontaminated and the other side not decontaminated if decision-makers were to become sufficiently confident that one side is not contaminated. Because each such zone represents an area that can be separately decontaminated, it is natural to make the decision, "to decontaminate or not to decontaminate," separately for each (see Section 3.1.3).

Partitioning an airport into sampling zones depends on several factors. Some factors—such as physical structure and layout of an airport, airflow patterns, and life-safety zones—should be identified and defined before an incident. Other factors specific to the incident itself will be either known (if, for example, the release was witnessed or caught on monitors) or inferred (for example, epidemiological results implicating a certain boarding area, or models of the spread of contamination). In addition, the designation of sampling zones should take into account areas with the greatest potential exposure (even if expected concentrations are low), and areas of the greatest expected concentration (even if exposure potential is low). These two types of areas may or may not coincide.

A general approach for designating sampling zones is to start with the largest scale, the entire airport, and to successively break it down into smaller and smaller areas until manageable and sensible sampling zones are defined. The first partitioning should be done according to the physical structure of the airport and should be completed in advance of an incident. For example, at LAX, the first step would be to partition the entire airport into nine sections: the TBIT and the eight other terminals. Each section would be further partitioned into the respective terminal buildings and one or more boarding areas. The next step could be to consider each floor separately. Where applicable within the floors, life safety zones (defined by the HVAC system and fire-safety design of the facility) could provide the next level of partitioning. Zones are not equivalent to rooms. A single zone can include several rooms, especially if rooms are small and physically grouped. If a zone combines rooms, the rooms should be similar in potential for the presence of contamination. For example, they might share a common corridor and be served by the same air-handling unit. To the extent possible, partitioning should be completed in advance of an incident.

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Because the decision, “to decontaminate or not to decontaminate,” is made for each zone, the use of zones is also an organizational tool. That is, zones help keep track of what work has been done, where the work has been done, and what the outcome was.

C.2.3. Sampling Units

Sampling units are surfaces, objects, or sets of objects, within a sampling zone that might be sampled. CWAs and TICs interact differently with different materials, so another natural organization of sampling units is by material. For example, glass, concrete, and caulking materials would be different sampling units because the chemicals of concern interact differently with each. As a rule, each sampling unit should be a physically homogenous area, object, or set of objects for which it makes sense to make a single, collective assessment or decision. For example, the set of ticket counters in the TBIT is homogenous in the sense that they are all ticket counters, and most are built the same way. As a set, they can be considered a single sampling unit if it is sensible to make a single decision about all of them collectively. It would not make sense to make a single collective decision about the ticket counters together with the nearby CTX machines whose purpose is screening oversized baggage. Thus, ticket counters and baggage screening units would be considered as separate from the point of view of sampling design. Sampling units may also be defined with regard to how they contribute to decontamination decisions. For example, sampling glass windows is less likely to help decide whether a zone needs decontamination than a nearby permeable material because glass may not indicate whether airborne contamination had previously been present, whereas the permeable material may. For clearance sampling, sampling units can be defined in terms of their potential for being a source of human exposure. For example, floors should probably be considered separately from walls because (1) concentrations on vertical surfaces tend to be lower than on horizontal surfaces, and (2) the frequency with which humans touch them is different.

If pre-incident planning identified potential sampling units, then they are reviewed and adjusted from information available for a specific incident. For example, if the location of a release is known, that information combined with known airflow patterns might indicate that some regions of the floor are more likely to have contamination than others. The floor could be partitioned into sub-units on that basis. However, if the floor space were small such that if any part of the floor is contaminated, the whole floor area would be decontaminated, then partitioning the floor into sub-units would not be appropriate. If chemical dispersion modeling indicates a region of highest expected concentration, that region would likely be a sampling unit. Any information about ways in which decontamination tends to fail should be incorporated in the clearance sampling design. For example, if gas or vapor decontamination tends to be poor in the corners where floors meet walls, then corners could be defined as a separate sampling unit. Such partitioning should continue until the sampling design team decides that reasonable and manageable sampling units are defined. Because a single decision is to be made for each sampling zone (i.e., at the smallest, non-overlapping segmentation level), sampling units should be contained entirely within sampling zones. Sampling units can also form the basis for stratified sampling.

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C.3. Characterization Sampling

Initial strategies for characterization environmental sampling after a release are, in large part, developed from information obtained from emergency responders and law enforcement agencies during first-response activities. Important information includes:

- Whether people were hurt or are sick (indicating greater contamination concentrations).
- Indications of the release location(s).
- Survey results from emergency responders, if any.
- Survey results of clothing or shoes from victims or responders.
- Nature of the contamination, such as the chemical(s) used in the attack and their form (i.e., gas, liquid, or solid).

The information can be used to guide the development of a sampling strategy and determine required levels of personal protective equipment (PPE) needed for the sampling team.

C.3.1. Preliminary Assessment

The main goal of preliminary assessment is to estimate quickly the extent and nature of contamination (see Section 2.2 of the main text of this *Remediation Guidance* document). Important and basic information may have been developed during first-response activities. Specifically, the chemical(s) and their form(s) (gas, liquid, or solid) should have been identified, the release point(s) determined, and perhaps the general spread of contamination estimated. As characterization commences, such information together with information about the design of the building, human traffic patterns, details of the ventilation systems, and other facts are used to develop a preliminary assessment of the likelihood of contamination in the pre-defined zones, if they exist. Zone definitions can be re-assessed. If zones were not identified during preplanning, then rooms or areas within rooms should be organized into zones and their likelihood of being contaminated should be estimated. Section 2.2.9.1 suggests an approach that incorporates the design of the air-handling system to categorize zones into the four different classes shown in Figure C-2. Information from the preliminary assessment is then used to decide what degree of characterization is necessary in each zone, and especially to decide whether a more quantitative assessment of contamination using statistically based sampling strategies is needed. Figure C-2 is a flowchart summarizing the process. If available information is insufficient to categorize areas of a facility into one of the four classes shown in Figure C-2 with confidence, then a conservative approach would be used to categorize those areas into the most plausible of the four classes.

The judgmental sampling indicated in Figure C-2 (see the diamond under “B”) is centered on those locations believed to have a high likelihood of CWA or TIC, if present in a zone. Potential sampling approaches include grab samples of room or exhaust air and large-area wipes of likely places of deposition. Potential sampling locations include floors and other horizontal surfaces, ventilation exhaust grills and ducts, computer screens and fans, and high-traffic areas. Large-area surveys for surface contamination could also include surveys of booties while surveyors move through rooms.

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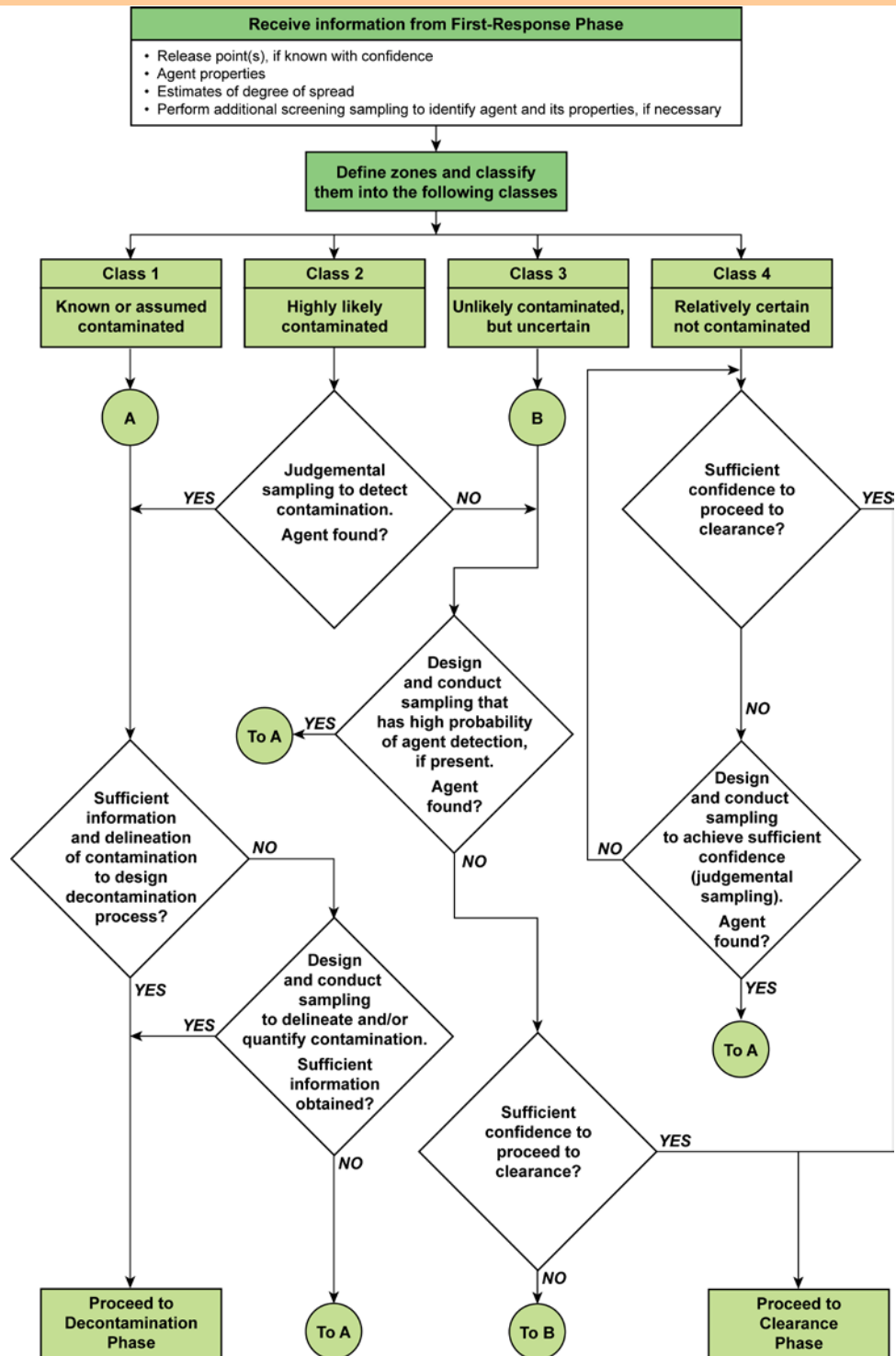


Figure C-2. The characterization process, following a preliminary assessment of the degree of contamination in each zone.

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The process shown in Figure C-2 is intended to:

- Find contamination and document its location
- Find areas with the greatest levels of contamination.
- Suggest the likely absence of chemical(s) of concern in some rooms.
- Assess the spatial extent of contamination.

Such information can also help establish access controls to contaminated areas.

In some cases, building personnel may want equipment immediately, such as computers containing critical information. A quantitative assessment of contamination levels on inner and outer surfaces of critical equipment could be done and the findings documented. If all inner surfaces cannot be accessed, items may have to be decontaminated and discarded as waste.

Sampling must be documented. Important information includes the survey location, surface type, name of person collecting samples, time and date of samples, instrument used, instrument calibration due-date, results from instrument operability checks, and the amount of chemical collected. Air sampling results should include dates, locations time samplers were turned on and off, flow rate, collection media (e.g., filter paper or charcoal cartridge), and amount of chemical of concern collected.

Another important consideration is the temporal nature of a release: whether it is ongoing or has ended, and if ended, how long it lasted. Survey strategies and PPE requirements for surveyors could depend on knowing whether or not there is a continuously emitting source. Information on natural attenuation is also an important temporal consideration. Surveys over time, especially air sampling, are useful to assess temporal variations in air concentrations. Real-time air monitors can rapidly determine air concentrations and temporal variability. Although a release may have been acute, the assumption should not be made that initially high air concentrations associated with a release have declined. Some liquid chemicals can evaporate and produce dangerous gases; resuspension of chemicals or contaminated dusts from disturbed surfaces can also occur.

C.3.2. Formal Characterization

Formal characterization consists of making the measurements necessary to support a formal decision in each zone: to decontaminate or not to decontaminate. The decision is made on the basis of clearance goals for acceptable residual levels of contamination. Initial assessments and preliminary characterization, described above, may not be sufficient to formally compare each zone with the clearance goal. Zones exceeding clearance goals must be decontaminated, whereas other zones do not require decontamination. Figure C-3 identifies the possible rules for deciding that a zone does not need decontamination:

1. Demonstrating that the average concentration is below the clearance goal. See EPA (1989), *Risk Assessment Guidance for Superfund*, for methods to calculate the “average.”

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2. Demonstrating that a high proportion of possible measurements are below the clearance goal.
3. Demonstrating both 1 and 2, above.
4. Demonstrating that it is unlikely that the maximum concentration exceeds a clearance goal.

Quantitative methods for the three rules are included in Annex E.

If the decision is made to decontaminate, then there must be sufficient information to decide how and where to decontaminate. Quantitative characterization supplies such information if information from first-response activities and initial qualitative characterization is insufficient.

Briefly summarized, the suggested starting point for sampling (characterization and clearance) is to use a combined strategy that includes judgmental sampling, combined with random sampling when judgmental sampling does not detect the presence of the chemical of concern. Random sampling can include either or both of simple random sampling and grid-based random sampling (randomly placed grid). Confidence levels should be set at 95% or higher (though higher confidence will lead to larger numbers of samples). When using grid-based sampling, a suggested grid spacing is to use hot-spot detection methodology, with the hot-spot size set at 5% or less of the total surface area being covered by the sampling grid. For statistical analysis, a 95% or 99% coverage (i.e., for the 95th or 99th percentile), and a 95% or greater confidence upper tolerance limit (Mulhausen and Damiano 1998) can be compared with clearance goals.

C.4. Decontamination

Sampling is performed during decontamination to provide immediate feedback on the effectiveness of the decontamination method(s). The purpose of such sampling is not to clear an area formally for reoccupation. Rather, sampling focuses on answering the question: is the decontamination proceeding as intended? Surveys should be done in those areas recently decontaminated. Efficient decontamination requires rapid feedback to guide workers about which areas are clean and which remain contaminated. Sampling might also indicate that current techniques being used should be modified to improve the effectiveness of decontamination. In addition, during the Decontamination Phase, wastes residues might be sampled to establish residual CWA or TIC levels or to characterize wastes in preparation for disposal.

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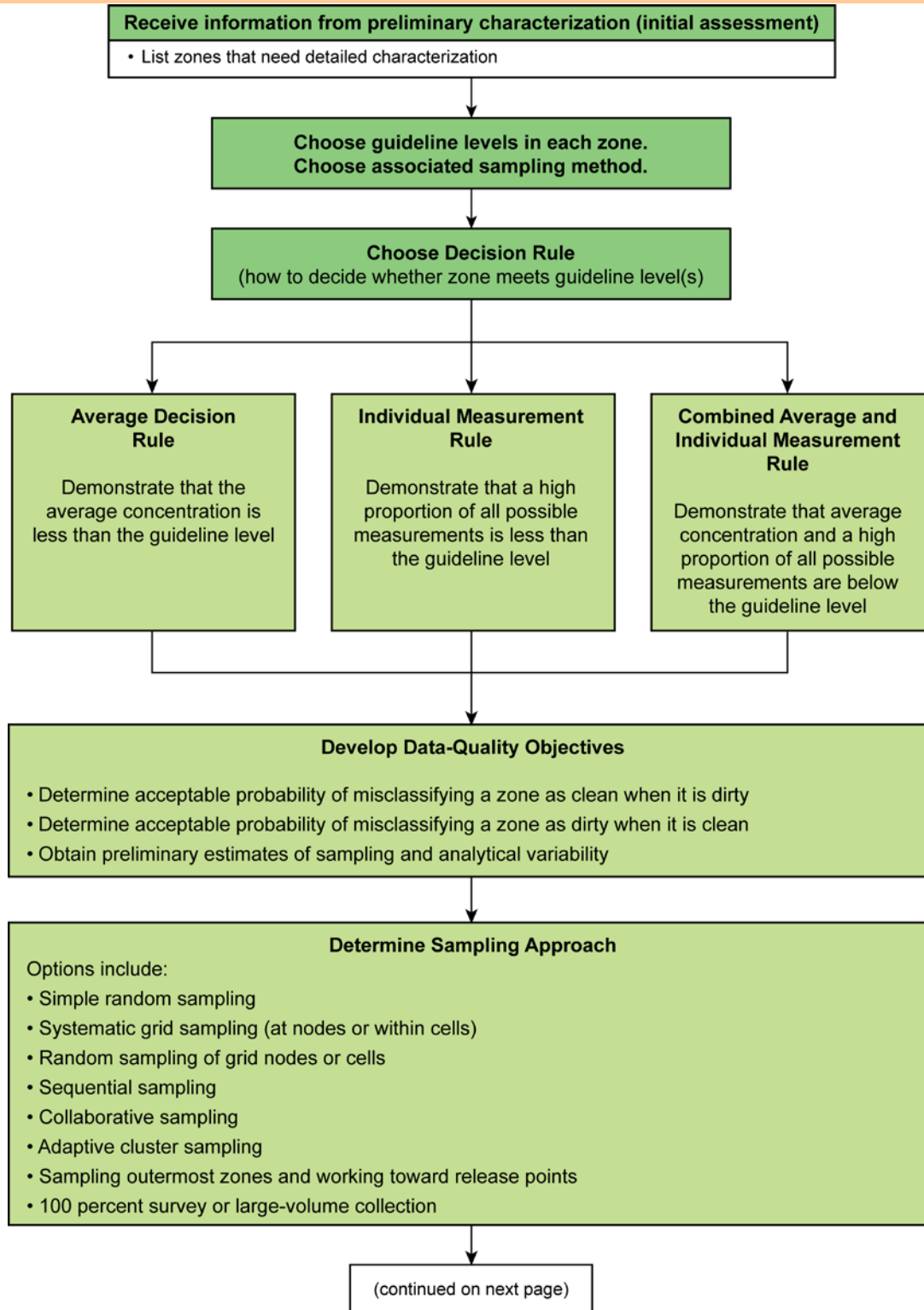
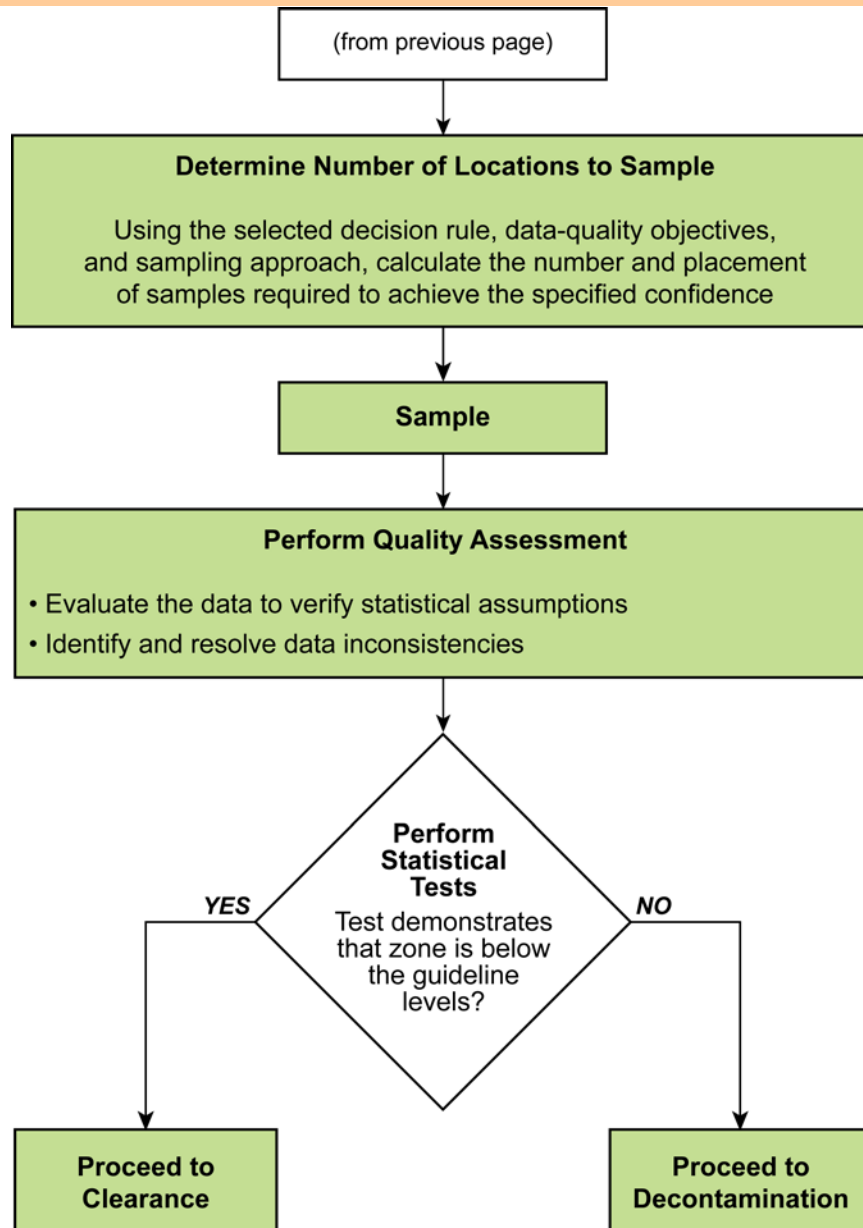


Figure C-3. Formal characterization is used to determine whether confirmed contamination is less than the clearance goal. See Annex E for sampling approaches.

Annex C**Figure C-3. Continued.****C.5. Clearance Sampling**

The purpose of post-decontamination clearance sampling (Figure C-4) is to determine whether or not the decontamination process reduced contamination below the clearance goal. Every sampling zone and unit (any area or object) that was decontaminated requires clearance sampling. The maximum acceptable level should have been defined before decontamination began. In fact, an approved post-decontamination sampling and analysis plan (SAP, also referred to as a Clearance Environmental SAP) is a prerequisite. When statistically designed sampling is used, the definition of the maximum acceptable level or clearance goal is an essential input to the statistical design.

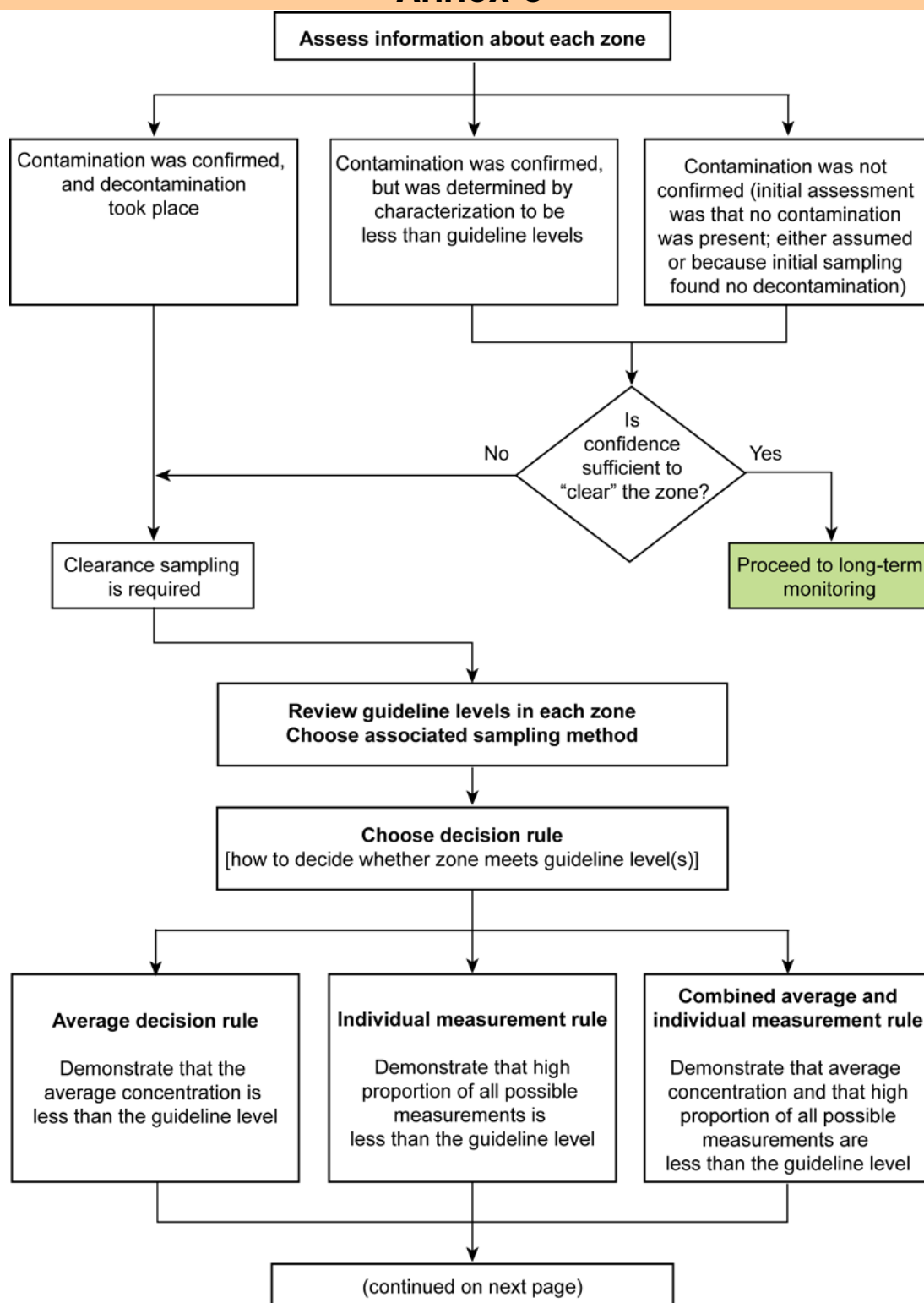
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Figure C-4. Clearance is used to determine whether zones may be released for refurbishment or re-occupancy.

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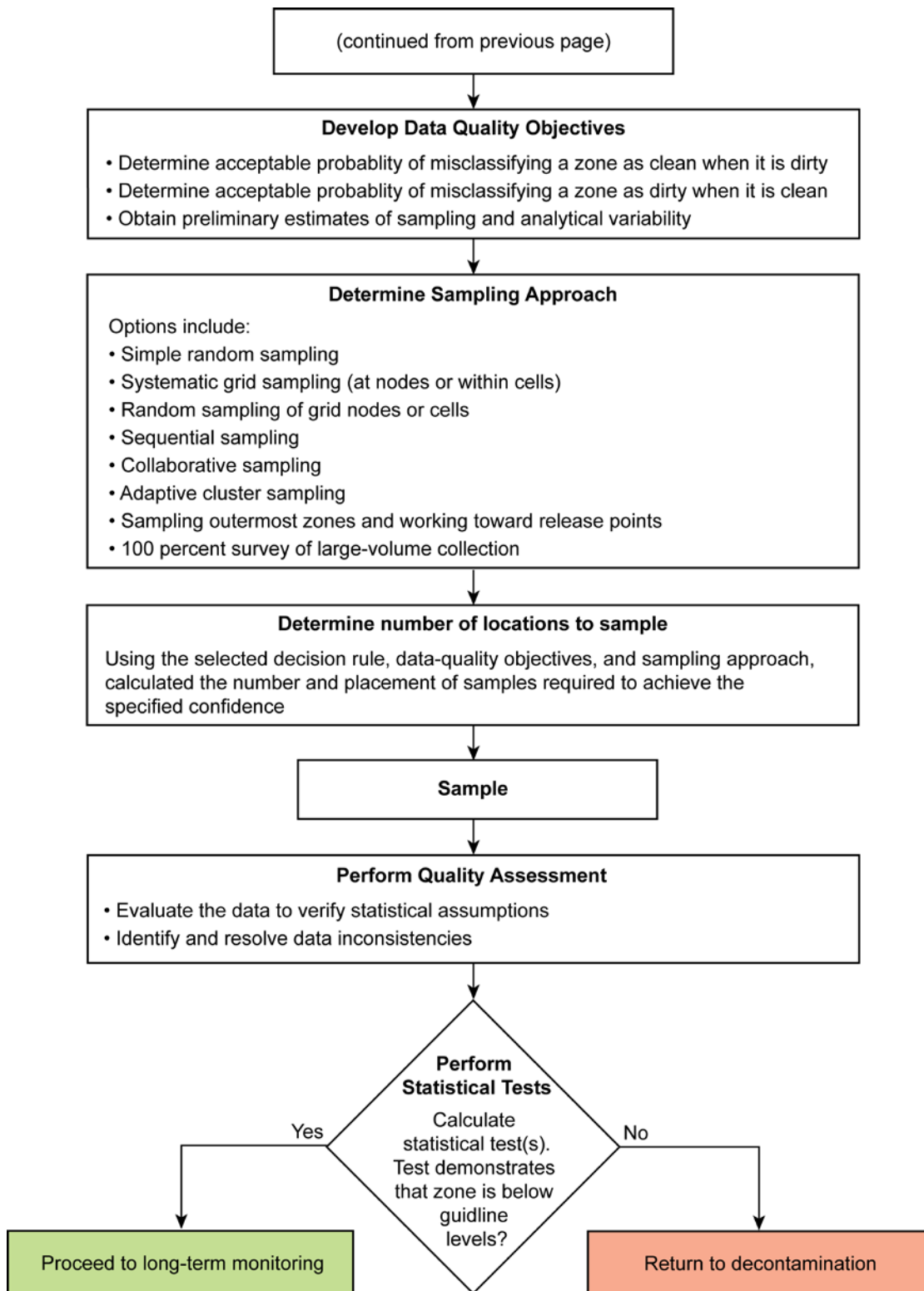


Figure C-4. Continued. See Annex E for descriptions of sampling approaches.

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To the extent possible, the same sampling units should be used during clearance as during characterization. It is possible that information gathered during characterization may cause the definitions of sampling units to be refined for clearance sampling. It would, however, be undesirable to completely redefine the sampling units because the change would make before-and-after comparisons difficult. Reasonable changes to sampling unit designations might consist of either subdividing sampling units (for example, when contamination was found, and a more detailed assessment is anticipated during clearance) or combining two or more sampling units into a single larger sampling unit (for example, when no contamination was found in any of the units during characterization). Similarly, it might be possible to combine sampling zones.

The number and locations of samples may change from characterization to clearance sampling, especially if statistical sampling is used. However, any judgmental sampling performed during characterization should be evaluated by repeated sampling during clearance, especially sampling in the areas of greatest exposure potential and greatest expected concentration.

C.5.1. Decision Uncertainty

The primary purpose of clearance sampling is to support a decision: should or should not the facility be cleared for reuse, and, if not, what is required to make the final decision? (Additional sampling might be required, or additional decontamination, or both.) Several factors contribute to uncertainty in making the decision to clear a facility for reuse. Suppose it has been agreed that a facility may be reopened when “no residual contamination is found in any clearance sample.” This statement is a surrogate for a more important criterion: that the facility is safe to use. To take an extreme and unrealistic example, a clearance decision based on a single sample would have no credibility whatsoever, because it would be far too easy for a single sample to miss residual contamination in locations that would make the facility unsafe to use.

As the number of samples increases, it becomes more likely that residual contamination, if any, will be found. However, unless every sample that possibly could be collected has been collected, there is always a possibility that some residual contamination is present at some unsampled location. To make matters worse, the smaller the area(s) of residual contamination, the less likely it is such area(s) will be found during clearance sampling.

Another factor that contributes to decision uncertainty is the fact that currently available sampling methods do not have 100% efficiency, that is, they do not necessarily pick up all of the chemical of concern that might be present. Thus, residual amounts could be present in a facility but not found in the sample, even when the sample was collected in a location where residual CWA or TIC is present. Thus, there is a possibility of false negatives, in other words, concluding that contamination is not present when it is. A recent literature survey (EPA 2007) found that data on surface sampling of CWAs was extremely limited, and most reports did not identify the type of surface sampled, a parameter that is expected to substantially affect the sampling efficiency. The highest recovery rate reported was for HD using a Q-tip wetted with ethyl acetate. The rate dropped from 44% after 5 minutes, to 2.4% after six hours, to 0.05% after 24 hours. Such data gaps are being addressed by experiments to measure sampling efficiencies on

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surfaces expected to be found indoors in an airport. Yet another factor is the limit of detection (LOD) of the analytical method used. Even when residual contamination is collected by the sampling material, the analytical method may not reveal its presence if the quantity of CWA or TIC is too small. For such reasons, some uncertainty is always associated with the decision to reopen a facility. Statistically designed sampling approaches allow uncertainty to be controlled to acceptable levels.

C.6. Considerations for Air Sampling

The most likely routes of exposure for the chemicals of concern in this document are direct vapor eye (ocular) contact and inhalation of vapor or aerosol (see Section 2.3 of the main text, Annex G, and Fitch et al. 2003). Therefore, it is critical to sample the air at every phase of remediation to characterize the threat to first responders, remediation personnel, employees, and the public. The specific technique used to sample air depends on the phase of response, from first response to final release of a facility for public use.

C.6.1. General Purposes for Sampling Air

Air sampling measures concentrations of one or more chemicals of concern in air. Measurements of air concentration specific to remediating a facility following a CWA or TIC attack are used to establish hazard levels for responders, characterize the nature of the airborne chemical and its dispersion in time and space, and may also help identify source locations, if unknown. Air sampling can be done during remediation activities to confirm initial results and monitor decontamination activities. Following decontamination, air sampling is critical to confirm that the levels of CWA or TIC remain below established clearance goals (see Annex D).

Air quality measurements can be critical to ensure the safety of individuals entering contaminated zones. Measured levels of a chemicals of concern in the air are used to determine necessary personal protective equipment (PPE), such as respiratory protection and protective clothing. The information is documented in the remediation Health and Safety Plan (HASP).

Concentration measurements are also used to establish boundaries of controlled areas and access locations for personnel entering the area. Boundaries of the controlled areas are positioned such that air concentrations in areas outside the boundaries should be at safe levels and not require respiratory protection. Air concentrations inside the controlled areas could be expected to be greater and may be sufficiently high to require respiratory protection. Physical activities in contaminated areas, such as walking or surveying, may cause resuspension of CWAs or TICs from surfaces and increase air concentrations, and those possibilities should be considered when establishing PPE requirements.

Depending on air concentration measurements, additional administrative (e.g., stay times) or engineering controls may need to be implemented to keep integrated exposures to elevated air concentrations at acceptable levels. Engineering controls, such as local exhaust or room-scale ventilation, may be necessary to minimize the migration of chemicals of concern through the air; air sampling can be used to confirm the effectiveness of engineering controls.

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Air sampling not only measures air concentrations but can also help characterize the chemical of concern (ACGIH 2001; Fitch et al. 2003). Common measurements made from air samples include chemical identification, material phase at room temperature (gas, liquid, or particle), particle size if liquid or particles are involved, and in some cases, solubility of the chemical material in lung fluid for biokinetic modeling. Information from each of these measurements is important for predicting air dispersion and toxicity of the chemical of concern, if inhaled.

C.6.2. Placement of Air Samplers

To meaningfully interpret sampling results, it is critical to understand the relation between temporal and spatial dispersion of an airborne chemical, and the sampling location of air samplers relative to general airflow patterns in affected rooms. A poorly positioned air sampler in a room may suggest that air concentrations in a room are low, when in fact air concentrations elsewhere in the room may be much higher. Such a result is possible if a sampler is sampling air outside the main bulk of the chemical airstream (Whicker et al. 1997).

Placement of samplers is often determined according to the purpose of the measurement. If, for example, the purpose of sampling is to estimate inhalation hazard to workers, then sampling for chemicals could take place in the breathing zone of workers (ACGIH 2001). Breathing-zone samplers generally consist of a battery-powered pump that is worn on a belt and draws air through the collection media (often a filter). The filter is supported inside an open-faced cassette. Cassettes vary in design and sampling capabilities (ACGIH 2001).

The response team often wants to know the general air concentrations in a room or area. Such information is useful to establish PPE requirements and control boundaries, and to assess the effectiveness of decontamination. Assessing the air quality in rooms is done using area air samplers placed in a stationary location within a room. Such air samplers usually sample at a higher airflow rate than breathing-zone samplers and thus have greater sensitivity.

Because the purpose of such samplers is to assess the general levels of an airborne CWA or TIC in a room, the number and placement of samplers is critical (Whicker et al. 1997). Optimizing the number and placement of samplers in rooms is possible if something is known about the ventilation-driven patterns of dispersion of the airborne material (Stoetzel et al. 1996; Whicker et al. 2003). Without knowledge of airflow patterns, area air samplers could be used to assess air quality by sampling at locations where occupation is likely or at room exhaust locations. Larger rooms, rooms with interior equipment, or those with low air-exchange rates (e.g., <5 room air exchanges per hour) justify more air samplers relative to smaller rooms or those with high room air-exchange rates. Air concentration measurements made by area air samplers do not necessarily represent the air actually breathed by survey personnel or facility workers once occupied following decontamination and can vary by several orders of magnitude. Concentration in the breathing zone is often greater than that measured by general room monitors (Marshall and Stevens, 1980).

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C.7. Annex C References

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Annex D

Annex D. Collection and Analysis of Samples for the Presence of a Chemical of Concern

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D.1. Purpose

This Annex describes procedures for collecting and analyzing samples of various matrices to determine the presence of chemical warfare agents (CWAs) and toxic industrial chemicals (TICs) in a civilian setting. The content is intended to provide sufficient information to make informed decisions about the sampling and analysis process and to suggest analytical strategies that might be used by scientists performing sampling and analysis. This Annex is not intended to be used as a standard operating procedure or to provide detailed instructions on how trained scientists should handle samples.

Table D-1 lists the CWAs and TICs considered in this Annex. In selecting sampling and analysis methods, this guidance considered procedures proposed by the Organisation for Prohibition of Chemical Weapons (OPCW), the EPA, and peer-reviewed scientific literature. EPA analytical methods are good resources describing issues of quality assurance with respect to chain-of-custody (COC), sample handling, and quality control requirements.

Table D-1. Selected properties of CWAs and TICs considered in this *Remediation Guidance*.

Class	Chemical of Concern	Symbol	Persistence of Bulk Contamination on Surface ^a	Onset of Symptoms of Adverse Health Effects
Nerve	Tabun	GA	High	Very rapid
	Sarin	GB	Low	Very rapid
	Soman	GD	Moderate	Very rapid
	Cyclosarin	GF	High	Very rapid
	VX	VX	Very high	Rapid
Blister	Sulfur mustard	H, HD	High	Delayed
Choking	Phosgene	CG	Low	Delayed
Blood	Hydrogen cyanide	AC or HCN	Low	Rapid
	Cyanogen chloride	CK	Low	Rapid

^a Persistence of a bulk CWA or TIC deposited on a surface depends, to a first approximation, on its vapor pressure. “Low” persistence = vapor pressure greater than 1 mm Hg. “Moderate” = vapor pressure of 0.1 to 1 mm Hg. “High” = vapor pressure of 0.01 to 0.1 mm Hg. “Very high” = vapor pressure of less than 0.01 mm Hg.

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D.2. Sampling Plan

A sampling event begins with the creation of a sampling plan, which defines what problem is to be solved and the information required. Under ideal circumstances, the Unified Command (or their designees), samplers, and technical representatives from the analysis laboratory collaborate on the design of the sampling plan to ensure that all methods, procedures, preservatives, and documentation meet the study objectives and match the laboratory requirements. The complexity and formality of the sampling plan depends on the question(s) being addressed and the information sought from analyses of the samples. For example, to answer the question of “what chemical of concern is present?” a sampling plan could be as simple as deciding to collect a sample of the suspicious liquid for chemical analysis. In contrast, when required to prove, with unambiguous, defensible data, that concentrations of a chemical of concern remaining in an airport after decontamination are sufficiently low that they will not harm human health, a detailed, peer-reviewed sampling plan is needed. Such a sampling plan needs to consider the numbers and locations of samples to be collected and analyzed so that resulting quantitative data support statistically meaningful decisions. In both cases, a good sampling plan typically documents the following information (EPA 1997):

- Project objectives.
- Data-quality objectives.
- Sample collection requirements.
- Analysis and testing requirements.
- Quality control (QC) requirements.
- Required project documentation.
- Identification of organizations conducting laboratory and field operations.

In the former example of simply identifying a chemical of concern, the information might be entered into a laboratory notebook. In the later example, the information would be written as a formal sampling plan document. In both examples, it is critical to develop and adhere to a thorough sampling plan so that the data generated are scientifically defensible and so that analytical results are readily accepted by various stakeholders. More detailed information regarding the creation of a sampling plan can be found in Annexes E and H. Communication and coordination with analytical laboratories is an essential part of developing a sampling plan.

The EPA offers a good example of the development of a comprehensive project plan. The EPA uses a quality assurance project plan (QAPP) to document results of a project’s technical planning process and provide in one place a clear, concise, and complete plan for environmental data operation and its quality objectives (EPA December 2002). A detailed QAPP provides not only information of a technical nature, but also lists key personnel, including project management, and defines their responsibilities and required training. Documentation, including COC and data management, are included in the QAPP. An

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important part of the QAPP is the identification of data quality objectives (DQOs), which define the performance or acceptance criteria that are developed for the collection, evaluation, or use of data (EPA 2006). Considerable effort should be taken when creating a sampling plan; without such planning, useless data might be produced and money, time, and effort wasted. The EPA has considerable experience in analyzing environmental samples, and it offers many good reference documents describing quality assurance (QA) and quality control (QC). Several such documents are available at http://www.epa.gov/quality/qa_docs.html#guidance.

D.2.1. Sample Control and Documentation

It is necessary to record and document sample collection and to maintain sample control so that scientifically defensible data are produced. The purpose of sample control is to unambiguously connect the origin, history, and analytical test results of each sample. Various procedures for sample control have been discussed for environmental (EPA 1997) and Chemical Weapons Convention treaty verification (Rautio 1993) applications.

Sample control is done by assigning a unique identifier, most often a number or bar code, to each sample. The sample identifier is placed on sample bottles, written in field and laboratory notebooks, and recorded in reports of test results. Field and laboratory notebooks are also controlled and have their own unique names and numbers so they can be unambiguously identified. Notebooks may be either bound pages or electronic records. Logbook entries or other records should show the sampling event as accurately as possible and include the type of sampling; location, date, and time of sampling; method of sample collection, including instruments used; condition of the site relevant to sample validity, when applicable; results of associated field measurements, such as onsite meteorological data; calibration information pertaining to the field instruments used; and name of field personnel performing the work. Table D-2 lists information that should be documented from a field survey, including instruments, operating parameters, results in proper units, and any exposure information for the surveyors.

A documented COC, or historical record, is established and follows each sample through collection, transport, analysis, and final data reporting. In addition to a sample's unique identifier, information provided on the COC might include the identifier of the field logbook that documents the sampling event, date and time of sample collection, sample matrix and container, sampler's name, project name, name of the analytical laboratory providing services, required laboratory tests and turnaround times, and any additional instructions to the laboratory. The date and time the sample is relinquished, and by whom, and the date and time it is received by the carrier or analyst is noted on the COC. At all times, samples must be under the direct control of the individual signing for samples on the COC form. Such control includes storing samples in a locked, secure facility under the control of the COC signatory.

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Table D-2. Types of sampling information recorded from a field survey to document its proper conduct and ensure credible results.

Types of Records	Specific examples
Type of survey	Small-area survey (e.g., 100 cm ²) Large-area survey (e.g., >1m ²) Air sample Exhaust sampling Room air sampling Direct surface reading Survey of equipment for release from contaminated areas Sample ID numbers for all collected samples
Survey instrument	Type of instrument Instrument ID number Calibration date Initials of person who calibrated the instrument Air flow rates for air sampling
Time and location of each sample	Date and general time of the survey General location, building, and room Specific location on map Type of surface (table top, chair, carpet)
Results of survey	Measurement values Units Calculations Field corrections, if used
Identity of surveyors and reviewers	Names and signatures of personnel who performed the survey and those who reviewed the results
Access records	Names of people in the controlled survey areas Any measurement results from assessments of chemical uptakes or exposures to survey personnel should be documented for each entry and/or collectively over the course of survey activities Unexpected skin contaminations, if important to safety

D.2.2. Transporting Samples

As described in Section D.3, many samples of several different kinds are likely to be collected during the decontamination and clearance phases after a chemical attack. This section describes the precautions necessary to protect the health of individuals potentially exposed to samples during transport and preservation of samples during transport.

Before a sample is shipped, a determination must be made about the level of hazard associated with it. For example, if it is known, or suspected with a high degree of probability, that the

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sample contains a chemical of concern at concentrations that could harm humans, then that sample must be collected and shipped as a hazardous material. Such a scenario might apply to samples collected before any decontamination procedures were performed. In contrast, samples collected to support long-term monitoring after successful decontamination of an area had been demonstrated would not be expected to contain hazardous levels of chemicals. It might be possible to ship such samples as nonhazardous, environmental samples. The following discussion assumes that samples to be shipped are hazardous and outlines procedures necessary to protect human health.

Samples collected at the site of a chemical attack may themselves present a health hazard, and their transport should be treated as transport of a hazardous material. Samples will either be transported to an onsite location for analysis or be taken to an offsite laboratory specializing in the detection of trace concentrations of CWAs or TICs. Transport of samples within the response site boundaries should follow all site requirements for contamination control. For example, contamination control may require additional external packaging at the boundaries of designated contamination zones. Procedures and facilities for additional packaging should be in place prior to the transport of samples. Packing materials should be selected so that the materials form a barrier to permeation of chemicals of concern and their vapors. The outside of packages containing samples should be screened for contamination by portable field monitors. For example, ion-mobility spectrometers (e.g., APD2000 from Smiths Detection) or flame photometric detectors (e.g., AP2C from Proengin) can be used to detect the presence of organophosphate chemicals.

Samples destined for offsite laboratories for analysis may fall under hazardous material transportation regulations. Only a few laboratories in the U.S. are capable of conducting analyses of CWAs. Within the U.S., samples can be transported by highway, air, rail, or water. The transport of hazardous materials and environmental samples is governed by regulations according to the mode of sample transport. For example, highway, rail, and water transportation of hazardous materials within the U.S. is governed by Department of Transportation (DOT) 49 Code of Federal Regulations (CFR); civilian air transport is governed by International Air Transport Association (IATA) and International Civil Air Organization (ICAO) Technical Instructions; military air transport is governed by Air Force Joint Manual 24-404 (AFJM 24-404); and water transportation is governed by International Maritime Dangerous Goods (IMDG) Code. Sample packaging and labeling must conform to the regulations under which the shipping company operates. However, in a Federally declared state of emergency, there is precedent for the U.S. Secretary of Transportation to waive some regulatory requirements. In addition, both the military and the U.S. Federal Bureau of Investigation (FBI) have special authority and provisions for shipping hazardous materials.

Shipping samples that are considered to be neat CWA (that is, 100% chemically pure) will be difficult, if not impossible. If samples can be designated as environmental samples, which typically have low or negligible concentrations of hazardous constituents (as would be the case after decontamination procedures have been applied), sample shipping is considerably easier.

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The previously described regulations (see DOT, above) will specify appropriate sample shipping and packaging protocols. There are also recommended procedures for packaging samples collected by the OPCW to verify the Chemical Weapons Convention treaty (Rautio 1993), and sample-handling methods are discussed by the EPA (2011). Neat samples and potentially highly contaminated materials are packaged in a sampling container; placed in a stainless-steel secondary container with absorbent material; and placed in a tertiary stainless-steel, pressure-tight container (lid sealed with nuts and bolts) before being placed in a shipping crate (Rautio 1993, *Recommended Operating Procedure GS 2*). All containers are sealed with tamper-indicating tape or seals. Environmental samples are packaged in a comparable manner, with the exception that, because the concentration of CWA residues is expected to be less than those associated with extremely adverse health effects, tertiary containment is not necessary (Rautio 1993, *Recommended Operating Procedure GS 3*). Once packaged, the outside of a sample container could be checked for contamination, as previously described. During transport, samples must be accompanied by a shipping document (i.e., a bill of lading, declaration for dangerous goods, air bill, or manifest) completed and signed by a properly trained (per Defense Transportation Regulations, DOD 4500.9) individual.

Actions should be taken to ensure that collected samples accurately reflect conditions at the location and time they were obtained in the contamination zone. Preserving the integrity of samples requires actions to prevent loss of material from the sample and to prevent contamination of the sample. Loss of material from the sample can occur through direct contact with packing materials or through outgassing of vapors from the sample. Often, environmental samples are shipped in coolers packed with ice to keep the temperature of the sample sufficiently low (4 to 7°C; 39 to 45°F) to minimize volatilization of analytes. The receiving laboratory should provide instructions explaining how to preserve (if necessary) and ship a sample. If no information is provided, the best course of action is to add no preservatives to a sample and ship it on ice.

D.3. Sample Collection

Many different types of samples are needed for characterization activities, to confirm success of decontamination, and to clear facilities for reuse. The reason is that many different media may be contaminated, and no single method detects all CWAs. The type of sample collected is determined by the matrices or media to be sampled and analytical methods to be used to assess the sample. This section describes sample collection methods for air, surfaces, solids (including chips, bulk materials, and soils), vegetation, and liquids. Distinct advantages and disadvantages in the types of media sampling need to be considered when selecting sample methods. Table D-3 summarizes the advantages and disadvantages of collecting various sample types.

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Table D-3. Types of samples that can be analyzed for the presence of CWAs.

Sample Type	Advantages	Disadvantages
Air	<ul style="list-style-type: none"> • Can detect airborne CWA in a large area • Provides direct information on inhalation hazard • Can obtain real-time results with appropriate instruments 	<ul style="list-style-type: none"> • Difficult to pinpoint precise areas requiring decontamination or repeated decontamination • Results will not provide information on contact or ingestion hazards
Surface samples and wipes	<ul style="list-style-type: none"> • Used to rapidly and easily sample surfaces • Can collect many samples • Provides information for contact hazard analysis 	<ul style="list-style-type: none"> • Sorbed CWA not always readily detected (especially on porous surfaces) • Results cannot be used to predict inhalation hazard
Chips and bulk sample	<ul style="list-style-type: none"> • Can detect presence of sorbed CWA • Provides more definitive proof of presence or absence of CWA 	<ul style="list-style-type: none"> • Destructive analysis, requires partial destruction of surface being sampled • Complex extraction procedures, with potential for multiple interferences • Limited number of samples can be collected • Results cannot be used to predict inhalation hazard
Environmental (water, soil, vegetation, and liquids)	<ul style="list-style-type: none"> • Can collect many samples • Can detect presence of sorbed CWA • Can use results to provide contact and ingestion hazard analysis • Can use results to delineate extent of contamination in outdoor scenarios 	<ul style="list-style-type: none"> • Complex extraction procedures, with potential for multiple interferences • Results cannot be used to predict inhalation hazard

Several publications describe sample-collection methods that serve as examples to detect chemicals of concern (EPA 2002; ASTM 2004). Although they are excellent references, they focus on collecting large samples in outdoor settings for purposes dissimilar to decontamination and reuse of facilities. Despite the differences in analytical objectives, the references provide some useful sampling guidelines. For example, in any sampling activity, care should be taken to ensure collection equipment is clean between samples to avoid cross-contamination of samples. Similarly, identification of the sample location and markings on sample containers need to be complete and easy-to-interpret to support COC requirements. In all situations, samples should be collected using procedures and locations specified in the approved sampling plan and QAPP.

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D.3.1. Collecting Air Samples

Air sampling of the general environment and of potentially degassing surfaces provides the most direct evidence of the presence of an airborne chemical of concern. In addition, air is the pathway of greatest concern with respect to human exposure and provides the best quantitative way to determine risk to humans. However, the results of air samples do not provide information on contact or ingestion hazards. Air sampling is also less useful for determining the precise location of chemical contamination to guide decontamination activities.

Air sampling requires collecting airborne material onto appropriate collection media, then analyzing the media to determine the amount of chemical of interest. The collection media can be analyzed continuously for the chemical to provide concentration measurements in near real time, or the collection media can be taken to a laboratory for retrospective assessment of the amount of chemical collected.

Techniques fall into two general categories: active air sampling and passive sampling. Active air sampling requires a vacuum pump to draw air through the collection media, whereas passive sampling relies on molecular diffusion to transport the chemical into contact with the collection media. Pumps used for active air sampling generally require electricity from wall AC outlets, but some pumps are driven by batteries. Battery-powered pumps are portable, and most attach to the belts of workers. AC-powered pumps are limited to locations with power outlets, which may be compromised following an attack.

High-volume air samplers and chemical agent monitors (CAMs) are the most common onsite sampling tools. High-volume air samplers can sample over a large area to determine the presence of CWA, but they cannot determine the specific location of contamination. High-volume air samplers can collect analytes from a large volume of air; the samples can be extracted and analyzed to determine low concentrations of airborne CWAs. Small, handheld CAMs can rapidly monitor smaller areas; however, the detection limits for CWAs by CAMs are not as low (i.e., are not as good) as those obtained by high-volume air sampling.

D.3.2. Collecting Surface Samples

Surface samples are used to determine the presence of chemicals of concern that might outgas from that surface over time and to evaluate contact hazard. Surface samples can be used to rapidly determine the contamination extent and decontamination efficacy; however, surface sampling may not detect low concentrations of sorbed chemicals of concern that may still present an inhalation hazard. In addition, analytical results provided by surface sampling cannot be used to directly determine the inhalation hazard posed by chemicals of concern present on surfaces.

A wipe sample is one type of sample that is commonly collected from a contaminated surface. A wipe sample is collected with a material that is moistened with a solvent (e.g., methylene chloride or acetonitrile) and then wiped over the area of interest to remove a chemical of concern. Wipe samples can be collected by a variety of media, including cotton swabs, cotton pads, wipers, and glass wool. Forceps or a hemostat can be used to hold the wipe to prevent

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direct contact by the worker and to reduce contamination of the worker's protective clothing (e.g., glove). One unusual method for wipe sample collection is for workers to use their booties (shoe coverings) as wipes along the floor to help determine the presence of contamination on floors. The wipe is placed in a clean glass container and sealed for transport to an analytical laboratory.

D.3.3. Collecting Solid Samples (Chip or Bulk Sampling)

Collection and analysis of pieces of solid materials (e.g., pieces of walls, floors, carpeting, or personal protective equipment) allow for the detection of sorbed CWA and can provide evidence that the decontamination process has been successful. Whereas wipe samples also provide some information about solids, wipe samples are different than bulk samples in several aspects. First, wipes only sample chemicals of concern that can be removed easily from a solid surface, and with an efficiency that may be much less than 100%. In contrast, bulk samples include CWAs that reside on and below the surface of a material. Second, wipe sampling extracts chemicals of concern from surfaces in the field. The CWA, which has been transferred to the wipe material, is then removed from the wipe and detected after its arrival at the analytical laboratory. In bulk samples, the sample itself is transported to the laboratory for extraction and analysis to ensure that the best possible sample-extraction procedures can be used to remove minute traces of CWA from the matrix of the bulk sample. Because methods used in the laboratory to extract chemicals from solid or bulk materials can be optimized (i.e., yielding higher analyte recoveries than are possible with wipe sampling), bulk samples can be used to more definitively determine the presence of CWAs than can wipe samples. However, in interpreting the results of bulk sampling, it is important to understand that the CWA distribution in the bulk material is not homogeneous, as is the bulk material itself, and that the characteristics of the material will affect the results of chemical analysis. Bulk sampling is reliable, but because of inhomogeneities, care must be exercised in interpreting the data. For example, concrete is an alkaline matrix that promotes rapid degradation of most chemicals of concern. Analytical results obtained for bulk samples do not provide a direct measure of contact or inhalation hazards posed by a CWA.

To collect solid samples, pieces of a contaminated surface are chipped or cut, removed, sealed in clean glass containers, and transported to a laboratory for analysis. In the laboratory, the sample is further ground, homogenized, and extracted with an appropriate solvent, and the resulting extract is analyzed for the presence of contamination. The destructive sample collection and lengthy laboratory extraction processes limit the number of samples that can be collected and analyzed with reasonable time and resources. Material contaminated with residual levels of CWA or TIC would not likely be considered a hazardous waste under Federal regulations. When costs of analyzing bulk samples exceed the replacement costs of any items, disposal rather than clearance sampling would be prudent. Pertinent state regulations should be consulted to ensure that such requirements do not impose more stringent requirements on waste disposal.

D.3.4. Collecting Environmental (Water, Soil, Vegetation, and Liquid) Samples

Water, soil, vegetation, and liquid are special types of solid samples that are relatively easy to collect. Like other types of bulk samples, the potential for signal interference is great (because of

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the hundreds of other compounds in the sample matrix), and laboratory sample handling (extraction and analysis) is slow. In addition, it is not possible to translate the results of analysis into an inhalation or contact hazard.

Soil samples can be collected using scoops (spatulas, shovels, or pans), coring devices, or sweeping devices. A soil sample should be placed in a clean glass bottle. At the laboratory, the sample should be thoroughly mixed (homogenized) to ensure the sample is not fractionated with respect to soil particle size or texture.

Vegetation can be clipped using shears or vegetation cutters. Both woody material and leaf material should be collected; sorption by CWAs will likely be different because of orientation of surfaces and differences in permeability. Water and other liquid samples can be collected using vials, syringes, Teflon tubing, bailers, dippers, and other devices (EPA 2002). The choice of sampling equipment depends on the environment in which the sample is being collected. Syringes may be most appropriate for small puddles, whereas bailers or pumps with Teflon tubing may be best for deeper water sources.

D.4. Real-Time Air Monitoring for Initial Phase of Decontamination

Instrumentation for detecting CWAs and TICs during decontamination should be able to make real-time measurements and be portable. The Supplement to Annex D contains more detailed information on available technologies for detecting chemicals of concern. The ideal instrument should be able to detect the chemical(s) of concern at levels below both Short-Term Exposure Limits (STELs) and Acute Exposure Guidelines Levels (AEGLs). These and other health-based exposure guidelines are summarized in Annex G of this *Remediation Guidance*. From those listed guidelines, and the fact that the instruments provide sensitive and selective detection of CWAs, the best instruments for real-time CWA detection during decontamination are the flame photometric detector (FPD), ion mobility spectrometer (IMS), and mass spectrometer (MS), as identified in Table D-4.

The recommended detectors respond to low concentrations of CWAs; however, all the instrumentation can also respond to other environmental contaminants, which can result in false positive detection of a CWA. IMS yields false positive responses from interferents such as cleaning compounds containing ammonia, N,N-diethylaminoethanol, and latex paint fumes. FPD gives false positives from any nonCWA containing phosphorus or sulfur, gasoline vapors in >1% concentrations, and smokes. Because of its mass specificity, MS is prone to less interference than

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Table D-4. Recommended instrumentation for real-time detection of CWAs.

Instrumentation	Advantages	Limitations	Sample Matrices
Flame photometric detector (FPD)	Portable, low limits of detection	Some false positives. Compound identification not as definitive as by mass spectrometry. Sample preparation may require derivatization.	Liquid, ^a gas
Ion mobility spectrometer (IMS)	Portable, low limits of detection, rapid analysis	Some false positives. Compound identification not as definitive as by mass spectrometry.	Solid, ^b gas
Mass spectrometer (MS)	Specific identification, low limits of detection, rapid analysis	Large footprint, usually in fixed-base or mobile laboratories	Solid, liquid, ^a and gas ^c

^a Liquid samples may include solvent extracts of surface wipes.

^b Solid samples in IMS are generally surface wipes (can include liquids from surfaces) from which the compound vapors are extracted and analyzed.

^c Gas samples may include preconcentration on sorbent materials and subsequent desorption.

FPD and IMS detectors. IMS, FPD, and MS detection technologies can be combined with an orthogonal technique, such as gas chromatography (GC), to minimize or eliminate the interference problems. GC/FPD and GC/MS are standard commercial technologies. GC/IMS has been demonstrated and sold by specialty manufacturers; however, we know of no vendors who currently produce off-the-shelf GC/IMS instruments for general or CWA-specific applications. MS is the most reliable detector for chemicals of concern, both quantitatively and qualitatively. MS hardware is generally considered to be fixed-base instrumentation; however, several portable mass spectrometers are commercially available. Table D-5 shows manufacturers of technologies recommended for CWA detection during decontamination. Details on instrumentation from the representative manufacturers are in the Annex D Supplement, Tables Da-3 and Da-4.

Several technologies previously discussed can provide real-time detection of CWAs at low concentrations. Additional technologies are being developed; for example, the EPA is developing triple-quadrupole mass spectrometry and Fourier Transform infrared spectroscopy (FTIR) for real-time detection of chemicals. Ultraviolet Raman spectroscopy is being developed for detection of analytes of interest on surfaces; such technology has the advantage of providing stand-off detection of analytes at distances up to 3 m from a surface. Before such technologies are used in decontamination situations, they must be checked for false-positive responses against the decontamination reagents and any other common chemicals used in the decontamination process(es) and areas.

Annex D**Table D-5. Vendors of portable FPD, IMS, and MS systems.**

Detector	Vendor
FPD	Proengin
Portable GC/FPD	OI Analytical
IMS	Bruker-Daltonics Dräger EnviroNics General Dynamics Smith's Detection
Portable MS and GC/MS	Bruker-Daltonics Constellation Technologies Corp. ICX™ Technologies Inficon

D.5. Laboratory Analysis Methods for Decontamination and Clearance

Analysis of collected samples can be the bottleneck of a remediation process. The laboratory-based analysis of samples is time-consuming because of the numerous samples that will require analysis and the amount of time needed to prepare samples so that trace amounts of analytes can be measured in the presence of matrix interferences. For the chemicals identified as a CWA (i.e., a compound listed under Schedule 1A of the Chemical Weapons Convention), only half a dozen laboratories in the U.S. can analyze samples and work with authentic standards of the CWA. Examples of such laboratories include the two U.S. laboratories that have been designated by the Organisation for the Prohibition of Chemical Weapons (Lawrence Livermore National Laboratory, Livermore, CA, and Edgewood Chemical Biological Center, Edgewood, MD) and commercial laboratories, such as Battelle Memorial Institute, Columbus, OH; GEOMET Technologies, LLC, MD; Midwest Research Institute, MO; Southwest Research Institute, TX; and CUBRC, NY. In response to Homeland Security Presidential Directive 9, a network of Federal and state laboratories will soon be granted access to dilute solutions of CWAs and will be able to provide analytical assistance in response to homeland security incidents. These laboratories are referred to as Environmental Response Laboratory Network (ERLN) laboratories and the will include several regional EPA laboratories.

In addition, there are no standardized, validated methods for the quantitative determination of trace (part-per-billion or lesser concentrations) CWAs in environmental matrices. During the clearance phase of remediation, it will be important to be able to accurately determine such low concentrations of analytes. Whereas the OPCW mission is to implement provisions of the Chemical Weapons Convention, and that organization promotes methods for determining CWAs and related compounds, the methods are targeted at detecting the presence of analytes at concentrations greater than a part-per-million in various matrices. OPCW methods are only

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qualitative, not quantitative, in nature. The EPA has proposed that laboratories use its standard analysis protocols in the event of a national emergency (EPA 2008). These methods are currently in use to monitor human exposure to environmental contaminants and were developed and validated to measure a multitude of pre-selected environmental contaminants. EPA methods were not developed to determine compounds such as CWAs. However, because standardized methods for determining trace concentrations of CWAs are lacking, the protocols have been suggested for use in CWA determination based on the known properties of those agents only and have not been verified by experiments, such as Method Detection Limit (MDL) and stability studies, with selected agents. Thus, laboratories that might be called on to measure the concentrations of agents in air, solid samples, and water will have to invest time researching the chemical literature and developing analytical and quality assurance measures before analyzing real samples.

The EPA is funding a study to experimentally determine the feasibility of using their environmental methods to analyze chemicals of concern to homeland security. The results of the study, as well as those of experimental work that is currently being conducted by the national laboratories, will provide the information (e.g., method detection limits, sampling and extraction efficiencies) necessary to promulgate standard extraction and analysis methods of samples containing trace concentrations of CWAs. In addition to having appropriate analytical protocols, laboratories also need access to actual chemicals of concern to demonstrate that their analyses are accurate and to demonstrate the validity of the data they produce. Such standards are not routinely available to commercial laboratories. Producing “ultra-dilute” analytical standards of CWAs that would be shipped in small quantities to analytical laboratories might allow more laboratories access to authentic standards and the ability to analyze samples in a national emergency as part of an Emergency Response Laboratory Network (ERLN).

Tables D-6, D-7, and D-8 list methods that could be used to determine analytes of interest in air (Table D-6), many types of solid samples, including wipes (Table D-7), and water (Table D-8). The methods represent techniques that have been proposed for use by the EPA in a national emergency as well as methods that have been published in the chemical literature. Several are listed as “standard methods” because they are routinely used by government agencies to measure analytes of environmental significance. These methods, in most cases, have not been validated for use with CWAs, such as sarin, soman, sulfur mustard, tabun, and VX (i.e., method performance with respect to sample storage, analyte extraction, and analyte detection has not been tested). Although the EPA endorses sample storage by refrigeration, it might be more appropriate to store solid samples, including air samples collected on a solid sorbent, at a freezing temperature of -20°C (-4°F). Tables D-6, D-7, and D-8 also include methods published in the scientific literature. Although such methods were found to perform well for the authors’ studies, they have not necessarily been successfully implemented by other laboratories.

Several existing health guideline levels are included in Tables D-6, D-7, and D-8. The values represent examples of available health-based risk levels developed for a variety of uses (see table footnotes) and with which analytical detection limits may be compared. When evaluating an

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analytical method for use in an actual incident, the guidelines ultimately selected or developed for the incident represent the upper limits on concentrations that remediation efforts strive to achieve, and that analytical methods must therefore be capable of accurately measuring.

Several qualifications apply to the three tables that follow. In Tables D-6, D-7, and D-8, various health-based risk levels are given with the intent of allowing the reader to compare them to observed analytical detection limits. Citing such values does not suggest that they must or should be used as clearance goals. In Table D-7, solid samples and wipe samples are considered together because the techniques used for their extraction and analysis are similar. Surface Removal Contaminant Levels (SRCLs) are given for analytes expected to persist on surfaces; these values are expressed in units of mass of analyte per surface area sampled and would be obtained by wipe sampling. Preliminary Remediation Goals (PRGs) for residential soils are given because they represent some of the only health-based risk levels available for CWAs in a solid matrix. PRG values are expressed in units of mass of analyte per mass of sample and would be obtained by extracting a bulk sample. Some, but not all, EPA regions have begun using Regional Screening Levels (RSLs) instead of PRGs (see Annex G for a discussion).

In selecting an appropriate analytical method, the most crucial factors are to choose a method that provides sufficient detection limits to address questions of human safety and that uses technologies that provide accurate, reproducible, and scientifically defensible data. In other words it is essential to use methods that satisfy the DQOs of the project, as specified by the sampling and analysis plan or the QAPP. As can be seen from Tables D-6, D-7, and D-8, many options are available to the analyst. In general, analysis strategies coupling a chromatographic separation prior to analyte detection (for example, GC coupled with FPD, atomic emission detection, or MS; and liquid chromatography coupled with MS) will provide the most reliable data and are recommended. The equipment to perform such analyses is readily accessible in most good commercial laboratories.

When selecting a laboratory to perform the required analyses, the best option is to choose one that is certified or accredited by a known association. For example, the American Association for Laboratory Accreditation (A2LA), which audits laboratories according to ISO/IEC 17025:2005 professional standards, provides some degree of confidence that the analytical laboratory conducts its operation to a specified level of quality. Therefore, if an accredited laboratory performs an analysis, it will incorporate the QA/QC procedures as specified in that method, including instrument performance checks, continuing calibration checks, method detection limit studies, precision studies, method blanks, matrix spikes, replicate analyses, and so forth.

Tables D-6, D-7, and D-8 identify methods to determine selected chemicals of concern in various matrices. The methods listed in Table D-6 are not real-time methods. In addition to monitoring the chemicals of concern themselves, certain degradation products could be monitored as part of the decontamination and clearance process. Many of the methods previously cited can be used to detect degradation products. For example, liquid chromatography/MS can be used to determine VX degradation products (Love 2004) and sulfur mustard degradation products (Creasy 1999). Various chemical reactions to form volatile derivatives of degradation products followed by

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analysis using GC/MS or GC/FPD is another strategy that can be used to detect degradation products (Creasy 1999; Purdon 1989; Naomi 2002; Black 2003).

Table D-6. Air analysis methods for characterization and clearance sampling. Unless stated otherwise, methods have not been validated for use with CWAs.^a

Analyte (exposure limits)	Standard Method	Sampling Method	Sample Storage	Determination	Reference
Cyanogen chloride (G = 0.08 mg/m ³ ; STEL = 0.6 mg/m ³)	EPA Method TO-15 for preparation	Air collected in Summa canister	Ambient temperature for up to 14 days	GC/MS; d.l. for VOCs = 0.001 to 0.1 mg/m ³	EPA (2011)
		May be possible to draw air through basic solution and measure CK as cyanide per NIOSH Method 6010			
Cyclosarin (G = 2×10^{-4} mg/m ³ ; STEL = 5×10^{-5} mg/m ³ ; WPL = 3×10^{-5} mg/m ³)	EPA Method TO-10A	Air sampled on PUF (or combination of PUF and other sorbent)	Stored at ≤4°C and extracted within 1 week	Sorbent Soxhlet extracted; extract analyzed by GC-elements specific detectors or GC/MS; d.l. depends on sample size and ranges from 0.001 to 50 µg/m ³	EPA (2011)
Hydrogen cyanide (G = 0.37 mg/m ³ ; STEL = 5 mg/m ³)	NIOSH Method 6010 Validated method	2 to 90 L air, at 0.05 to 0.2 L/min, drawn through a solid sorbent tube containing lime soda	Ambient temperature for up to 14 days	Sorbent tube extracted with water; sample extract derivatized and analyzed by spectrophotometry; d.l. = 3 mg/m ³	EPA (2011)

See footnotes at the end of this multi-page table.

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Table D-6. Continued.

Analyte (exposure limits)	Standard Method	Standard Method	Sample Storage	Determination	Reference
Phosgene ($G = 0.03 \text{ mg/m}^3$; STEL = 0.82 mg/m^3)	OSHA Method 61 Validated method	~240 L air sampled, at 1 L/min, through XAD-2 coated with 2-(hydroxymethyl)- piperidine	Sample tubes stored at ambient temperature for 14 days	Samples desorbed with toluene and analyzed by GC-nitrogen-specific detection; method d.l. = 0.01 mg/m^3	EPA (2011)
		Air (1 L/min) drawn through an impinger containing a solution of tryptamine		Tryptamine derivative detected by LC/fluorescence; d.l. = 0.04 mg/m^3	Black (2003)
Sarin ($G = 3 \times 10^{-4} \text{ mg/m}^3$; STEL = $1 \times 10^{-4} \text{ mg/m}^3$; WPL = $3 \times 10^{-5} \text{ mg/m}^3$)	EPA Method TO-10A	Air sampled on PUF (or combination of PUF and other sorbent)	Stored at $\leq 4^\circ\text{C}$ and extracted within 1 week	Sorbent Soxhlet extracted and extract analyzed by GC- element-specific detectors or GC/MS; d.l. depends on sample size and ranges from 0.001 to $50 \text{ } \mu\text{g/m}^3$	EPA (2011)
		4800 L air sampled at 20 L/min for 4 hr with charcoal canister to provide a diesel exhaust matrix into which sarin was spiked to simulate collection of this CWA		Charcoal extracted with dichloromethane and concentrated; extract analyzed by GC/MS/MS; <i>estimated</i> d.l. = 70 pg sarin in an extract that represented $5 \times 10^{-4} \text{ m}^3$ of diesel exhaust air; assuming 100% recovery of analyte from a charcoal canister, this would correspond to an <i>estimated</i> d.l. = $1.4 \times 10^{-4} \text{ mg/m}^3$	D'Agostino (1990)
		Air sampled for 5 min with SPME fiber		Detection of 0.1 mg/m^3 could be obtained with GC/MS	Schneider (2001)

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Table D-6. Continued.

Analyte (exposure limits)	Standard Method	Standard Method	Sample Storage	Determination	Reference
Soman ($G = 2 \times 10^{-4}$ mg/m ³ ; STEL = 5×10^{-5} mg/m ³ ; WPL = 3×10^{-5} mg/m ³)	EPA Method TO-10A	Air sampled on PUF (or combination of PUF and other sorbent)	Stored at $\leq 4^{\circ}\text{C}$ and extracted within 1 week	Sorbent Soxhlet extracted and extract analyzed by GC-elements specific detectors or GC/MS; d.l. depends on sample size and ranges from 0.001 to 50 $\mu\text{g}/\text{m}^3$	EPA (2011)
		4800 L air sampled at 20 L/min for 4 hr with charcoal canister to provide a diesel exhaust matrix into which soman was spiked to simulate collection of this CWA		Charcoal extracted with dichloromethane and concentrated; extract analyzed by GC/MS/MS; <i>estimated</i> d.l. = 60 pg soman in an extract that represented 5×10^{-4} m ³ of diesel exhaust air; assuming 100% recovery of analyte from a charcoal canister, this would correspond to an <i>estimated</i> d.l. = 1.2×10^{-4} mg/m ³	D'Agostino (1990)
Sulfur Mustard ($G = 3 \times 10^{-3}$ mg/m ³ and STEL = 3×10^{-3} mg/m ³ and WPL = 4×10^{-4} mg/m ³)	EPA Method TO-10A	Air sampled on PUF (or combination of PUF and other sorbent)	Stored at $\leq 4^{\circ}\text{C}$ and extracted within 1 week	Sorbent Soxhlet extracted and extract analyzed by GC-elements specific detectors or GC/MS; typical d.l. depends on sample size and ranges from 0.001 to 50 $\mu\text{g}/\text{m}^3$	EPA (2011)
		4800 L air sampled at 20 L/min for 4 hr with charcoal canister to provide a diesel exhaust matrix into which sulfur mustard was spiked to simulate collection of this CWA		Charcoal extracted with dichloromethane and concentrated; extract analyzed by GC/MS/MS; <i>estimated</i> d.l. = 30 pg sulfur mustard in an extract that represented 5×10^{-4} m ³ of diesel exhaust air; assuming 100% recovery of analyte from a charcoal canister, corresponds to an <i>estimated</i> d.l. = 6.0×10^{-5} mg/m ³	D'Agostino (1990)

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Table D-6. Continued.

Analyte (exposure limits)	Standard Method	Standard Method	Sample Storage	Determination	Reference
Tabun ($G = 3 \times 10^{-4}$ mg/m ³ ; STEL = 1×10^{-4} mg/m ³ ; WPL = 3×10^{-5} mg/m ³)	EPA Method TO-10A	Air sampled on PUF (or combination of PUF and other sorbent)	Stored at $\leq 4^{\circ}\text{C}$ and extracted within 1 week	Sorbent Soxhlet extracted and extract analyzed by GC-elements specific detectors or GC/MS; typical d.l. depends on sample size and ranges from 0.001 to 50 $\mu\text{g}/\text{m}^3$	EPA (2011)
VX ($G = 2.4 \times 10^{-5}$ mg/m ³ ; STEL = 1×10^{-5} mg/m ³ ; WPL = 1×10^{-6} mg/m ³)	EPA Method TO-10A	Air sampled on PUF (or combination of PUF and other sorbent)	Stored at $\leq 4^{\circ}\text{C}$ and extracted within 1 week	Sorbent Soxhlet extracted and extract analyzed by GC-elements specific detectors or GC/MS; typical d.l. depends on sample size and ranges from 0.001 to 50 $\mu\text{g}/\text{m}^3$	EPA (2011)
		Air sampled at either 4 or 1.5 L/min (depending on tube i.d.) through a felt pad impregnated with silver fluoride; typical sampling conditions were 1 L/min for 2 hr, affording a 120 L air sample; resulting derivative collected on Chromosorb 106		Contents of sorbent tube thermally desorbed into GC/FPD; VX at 2×10^{-6} mg/m ³ could be detected if no interferences present	Fowler (1989)

^a Notes: d.l. = detection limit; EPA = United States Environmental Protection Agency; G = alternative reentry screening guideline from Annex G; GC/FPD = gas chromatography coupled with flame photometric detection; GC/MS = gas chromatography coupled with mass spectrometry; GC/MS/MS = gas chromatography coupled with tandem mass spectrometry; LC/fluorescence = liquid chromatography coupled with fluorescence detection; LC/UV = liquid chromatography coupled with ultraviolet detection; NIOSH = National Institute for Occupational Safety and Health (United States); ppbv = part-per-billion volume; ppmv = part-per-million volume; PUF = polyurethane foam; SPME = solid phase microextraction; STEL = Short Term Exposure Limit values, summarized in Annex G; VOC = volatile organic compound; WPL = Worker Population Limit.

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Table D-7. Characterization and clearance analysis methods for use with solid samples, including wipes. Unless stated otherwise, the methods have not been validated for use with chemical agents.^a

Analyte (exposure limits)	Standard Method	Sample Preparation Method	Sample Storage	Analysis	Reference
Cyanogen chloride CK is a gas at T ≥ 56.8°F (13.8°C), so surface/solid contamination might not be of concern. PRG = 3900 mg/kg.	EPA Method 5035A for sample preparation; EPA Method 8260C for determination; note data suggest CK is not of concern on wipe samples	5 g sample placed in vial and subjected to closed- system purge and trap process in which analytes are collected on a sorbent	Several storage options listed; the simplest is storage at < -7°C for up to two weeks	Analytes collected on solid sorbent, removed by thermal desorption, and transferred to GC/MS; 0.5 µg/kg amounts of VOC typically detected	EPA (2011)
Cyclosarin HBESL _{ind} = 8.2 mg/kg	EPA Method 3541 for sample preparation; EPA Method 8270D for determination	10-g sample processed by automated Soxhlet extraction	Store at 4°C for up to two weeks (EPA 1996)	GC/MS; d.l. ~ 0.7 to 3 mg/kg	EPA (2011)
	EPA Method 3545A for sample preparation; EPA Method 8270D for determination	10- to 30-g sample processed by pressurized fluid extraction	Store at 4°C for up to two weeks (EPA 1996)	GC/MS; d.l. ~ 0.7 to 3 mg/kg	EPA (2011)
	EPA Method 3570 for sample preparation of wipes; EPA Method 8270D for determination	2- to 3-g sample extracted with 12 mL dichloromethane (EPA Method 8290A describes procedures for collecting wipes)	Store at 4 °C for up to two weeks (EPA 1996)	GC/MS	EPA (2011)
Hydrogen cyanide AC is a gas at T ≥ 78°F (26°C), so surface/solid contamination might not be a concern. PRG = 1600 mg/kg.	—	—	—	—	EPA (2011)

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Table D-7. Continued.

Analyte (exposure limits)	Standard Method	Sample Preparation Method	Sample Storage	Analysis	Reference
Phosgene CG is a gas at $T \geq 47^{\circ}\text{F}$ (8.2°C), so surface/solid contamination might not be of concern	—	—	—	—	EPA (2011)
Sarin PRG = 1.3 mg/kg. HBESL _{ind} = 41 mg/kg	EPA Method 3570 for sample preparation; EPA Method 8270D for determination (wipes)	2- to 3-g sample extracted with 12 mL dichloromethane	Store at 4 °C for up to 2 weeks (EPA 1996)	GC/MS	EPA (2011)
	EPA Method 3571 for sample preparation; EPA Method 8270D for determination	5-g sample extracted with 10% isopropanol in dichloromethane	Add 1 mL glacial acetic acid to 1g sample; extract within 3 days; analyze within 14 days	GC/MS	EPA (2011)
		20-mL liquid, 10-g metal, or 10-g soil collected		Extraction with chloroform; 40-150 μL extract into GC/FPD by thermal desorption; d. l. = 0.002 to 0.008 mg/kg	O'Neil (2002)
		1-g soil extracted with 1 mL water (dichloromethane extraction also effective)		5- μL sample injected into LC/ESI/TOF/MS system; 10-mg/kg soil spikes could be detected; method also allowed detection of hydrolysis products	D'Agostino (2001)

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Table D-7. Continued.

Analyte (exposure limits)	Standard Method	Sample Preparation Method	Sample Storage	Analysis	Reference
Soman PRG = 0.22 mg/kg HBESL _{ind} = 8.2 mg/kg.	EPA Method 3545A for sample preparation; EPA Method 8270D for determination	10- to 30-g sample processed by pressurized fluid extraction	Store at 4°C for up to 2 weeks (EPA 1996)	GC/MS; d.l. ~ 0.7 to 3 mg/kg	EPA (2011)
	EPA Method 3570/8290A for sample prep (wipes); EPA Method 8270D for determination	2-3 g sample extracted with 12 mL dichloromethane	Store at 4 °C for up to 2 weeks (EPA 1996)	GC/MS	EPA (2011)
		20-mL liquid, 10-g metal, or 10-g soil collected		Extract with chloroform; 40-150 µL extract into GC/FPD by thermal desorption; d.l. = 0.0004 to 0.001 mg/kg	O'Neil (2002)
		1-g soil extracted with 1-mL water (dichloromethane extraction also effective)		5-µL sample injected into LC/ESI/TOF/MS system; 10-mg/kg soil spikes could be detected; method also allowed detection of hydrolysis products	D'Agostino (2001)

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Table D-7. Continued.

Analyte (exposure limits)	Standard Method	Sample Preparation Method	Sample Storage	Analysis	Reference
Sulfur Mustard PRG = 0.01 mg/kg $SRCL_{24,hr} =$ 3×10^{-4} mg/cm ² $HBESL_{ind} =$ 14 mg/kg	EPA Method 3571 for sample preparation; EPA Method 8270D for determination	5-g sample extracted with 10% isopropanol in dichloromethane	Add 1 mL glacial acetic acid/NaCl per 1-g sample; extract in 3 days; analyze within 14 days	GC/MS	EPA (2011)
	EPA Method 3570/8290 for sample prep (wipes); EPA Method 8270D for determination	2- to 3-g sample extracted with 12-mL dichloromethane	Store at 4°C for up to two weeks (EPA 1996)	GC/MS	EPA (2011)
		Unspecified amount of solid concrete collected		Extract with acetonitrile at elevated temperature (100°C) and pressure (1500 psig) and detection of sulfur mustard degradation products at 2 to 13 mg/kg by GC/FPD	Tompkins (1997)
		1-g soil placed in vial		Water added and soil- water system sampled with polyacrylate or carbowax-divinyl- benzene SPME fiber; d.l. ~0.24 mg/kg by GC/MS	Kimm (2002)
				Direct interrogation of sample by static secondary ion MS/MS; d.l. ~ 100 mg/kg	Gresham (2001)

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Table D-7. Continued.

Analyte (exposure limits)	Standard Method	Sample Preparation Method	Sample Storage	Analysis	Reference
Tabun PRG = 2.8 mg/kg HBESL _{ind} = 82 mg/kg	EPA Method 3545A for sample preparation; EPA Method 8270D for determination	10- to 30-g sample processed by pressurized fluid extraction	Store at 4°C for up to two weeks (EPA 1996)	GC/MS; d.l. ~ 0.7–3 mg/kg	EPA (2011)
	EPA Method 3570/8290A for sample preparation (wipes); Method 8270D for determination	2- to 3-g sample extracted with 12-mL dichloromethane	Store at 4 °C for up to two weeks (EPA 1996)	GC/MS	EPA (2011)
VX PRG = 0.042 mg/kg SRCL _{24 hr} = 3×10^{-4} mg/cm ² HBESL _{ind} = 1.2 mg/k	EPA Method 3571 for sample preparation; EPA Method 8270D for determination	5-g sample extracted with 10% isopropanol in dichloromethane	Extract within 3 days; analyze within 14 days	GC/MS	EPA (2011)
	EPA Method 3570/8290A for sample preparation (wipes); Method 8270D for determination	2- to 3-g sample extracted with 12-mL dichloromethane	Store at 4 °C for up to two weeks (EPA 1996)	GC/MS	EPA (2011)
				Direct interrogation of sample by static secondary ion MS/MS; d.l. ~ 1 mg/kg	Groenewold (2000)
		5 g soil ultrasonically mixed with buffer solution and extracted with hexane/ dichloromethane		GC/FPD; d.l. = 10 mg/kg soil	Montauban (2004)

^a Notes: d.l. = detection limit; EPA = United States Environmental Protection Agency; GC/FPD = gas chromatography coupled with flame photometric detection; GC/MS = gas chromatography coupled with mass spectrometry; HBESL_{ind} = health-based environmental screening levels for industrial soil developed by the U.S. military and summarized in Raber et al. 2004; LC/ESI/TOF/MS = liquid chromatography coupled with electrospray ionization, time-of-flight mass spectrometry; MS/MS = tandem mass spectrometry; PRG = Preliminary Remediation Goal for residential soil, as described in Annex G; SRCL_{24 hr} = Surface Removal Contaminant Level, as described in Annex G; SPME = solid phase microextraction; VOC = volatile organic compound.

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Table D-8. Characterization and clearance analysis methods for use with water samples. Unless stated otherwise, these methods have not been validated for use with CWAs.^a

Analyte (exposure limits)	Standard Method	Sample Preparation	Sample Storage	Analysis	Reference
Cyanogen chloride	EPA Method 5030C for sample preparation; EPA Method 8260C for determination	Collection of sample in vial	4°C for up to 14 days	Purge and trap coupled with GC/MS; d.l. = 1×10^{-4} mg/L	EPA (2011)
Cyclosarin G = <4 µg/L	EPA Method 3520C for sample preparation; EPA Method 8270D for determination	1-L sample extracted, by continuous liquid-liquid extraction, with dichloromethane	4°C for up to 14 days	GC/MS; d.l. for method 8270 can be as low as 10 µg/L for clean samples	EPA (2011)
	EPA Method 3535A for sample preparation; EPA Method 8270D for determination	1-L sample prepared by solid-phase extraction	4°C for up to 14 days	GC/MS; d.l. for method 8270 can be as low as 10 µg/L for clean samples	EPA (2011)
	Method developed to measure concentrations in blood	Liquid extraction with hexane	-80°C	GC/MS; selected ion monitoring provides detection of 1 pg	Reiter (2007)
Hydrogen cyanide (EPA MCL for CN ⁻ = 0.2 mg/L) G = <2 µg/L	EPA Method 335.4 Method has been validated	Reflux-distillation of sample releases HCN into scrubber solution; CN ⁻ reacted with chloramine-T, then pyridine and barbituric acid to yield colored complex	Adjust water to pH ≥ 12 with NaOH; store at 4°C for up to 14 days; samples containing oxidizing agents, e.g., chlorine, must be treated with ascorbic acid	Colored complex is measured by spectrophotometry; d.l. = 0.005 mg/L	EPA 1993
EPA suggests HCN will not be of concern in water	—	—	—	—	EPA (2011)

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Table D-8. Characterization and clearance analysis methods for use with water samples. Unless stated otherwise, these methods have not been validated for use with CWAs.^a

Analyte (exposure limits)	Standard Method	Sample Preparation	Sample Storage	Analysis	Reference
Phosgene EPA suggests that CG will not be of concern in water	—	—	—	—	EPA (2011)
Sarin G = <9.3 µg/L	EPA Method 3571 for sample preparation; EPA Method 8270D for determination	Extract with 10% isopropanol in dichloromethane in ratio of 2-mL solvent to 1-g sample	1-mL glacial acetic acid used to preserve 1-mL sample; extract sample within 3 days; analyze within 14 days	GC/MS	EPA (2011)
	EPA Method 3535A for sample preparation; EPA Method 8270D for determination	Analytes isolated by solid phase extraction from a typical sample size of 1 L	Cool to 4°C; extract within 7 days; if sample contains residual chlorine, add sodium thiosulfate as preservative (EPA 1996)	GC/MS; d.l. for Method 8270 can be as low as 10 µg/L for clean samples	EPA (2011)
		Direct collection of liquid	—	Decontamination solutions extracted with dichloromethane and analyzed by selected ion monitoring GC/MS; d.l. = 0.02 mg/L	Creasy (1999)
		SDME	—	SDME coupled with GC/MS; d.l. = 0.075 mg/L	Palit (2005)
				Direct injection of aqueous sample provides d.l. ~ 10 mg/L by LC/ESI/MS	D'Agostino (1999)
		Solid-phase extraction of ~ 1-mL sample	—	GC/MS; d.l. ~ 50 µg/L	Kanaujia (2007)

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Table D-8. Continued.

Analyte (exposure limits)	Standard Method	Sample Preparation	Sample Storage	Analysis	Reference
Soman G = <4 µg/L	EPA Method 3535A for sample preparation; EPA Method 8270D for determination	Analytes isolated by solid-phase extraction; typical sample size is 1 L	Cool to 4°C; extract within 7 days; if sample contains residual chlorine, add sodium thiosulfate as preservative (EPA 1996)	GC/MS; d.l. ~ 10–1000 µg/L	EPA (2011)
				Direct injection of aqueous sample provides d.l. ~ 10 mg/L by LC/ESI/MS	D'Agostino 1999
Sulfur Mustard G = <47 µg/L	EPA Method 3571 for sample preparation; EPA Method 8270D for determination	Extract with 10% isopropanol in dichloromethane in ratio of 2-mL solvent to 1-g sample	1-mL glacial acetic acid with NaCl used to preserve 1-mL sample; extract within 3 days; analyze within 14 days	GC/MS	EPA (2011)
	EPA Method 3535A for sample preparation; EPA Method 8270D for determination	Analytes isolated by solid-phase extraction; typical sample size is 1 L	Cool to 4°C; extract within 7 days; if sample contains residual chlorine, add sodium thiosulfate as preservative (EPA 1996)	GC/MS; d.l. = 0.01–1 mg/L	EPA (2005)
		Direct collection of liquid		Decontamination solutions extracted with dichloromethane and analyzed by selected ion monitoring GC/MS; d.l. = 0.02 mg/L	Creasy (1999)
		Solid-phase extraction of ~ 1 mL sample		GC/MS; d.l. ~ 50 µg/L	Kanaujia (2007)

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Table D-8. Continued.

Tabun G = <46 µg/L	EPA Method 3535A for sample preparation; EPA Method 8270D for determination	Analytes isolated by solid-phase extraction from a 1-L sample	Cool to 4°C; extract within 7 days; if sample contains residual chlorine, add sodium thiosulfate as preservative (EPA 1996)	GC/MS; d.l. = 0.01 to 1 mg/L	EPA (2011)
				Direct injection of aqueous sample should provide d.l. ~10 mg/L by LC/ESI/MS	D'Agostino (1999)
VX G = <5 µg/L	EPA Method 3535A for sample preparation; EPA Method 8270D for determination	Analytes isolated by solid-phase extraction from 1-L sample	Cool to 4°C; extract within 7 days; if sample contains residual chlorine, add sodium thiosulfate as preservative (EPA 1996)	GC/MS; d.l. = 0.01–1 mg/L	EPA (2005)
	EPA Method 3571 for sample preparation; EPA Method 8270D for determination	Extract with 10% isopropanol in dichloromethane in ratio of 2-mL solvent to 1-g sample	Adjust sample pH to 7-8 with glacial acetic acid or NaOH; extract within 3 days; analyze within 14 days	GC/MS	EPA (2011)
		Direct collection of liquid		Decontamination solutions extracted with dichloromethane and analyzed by selected ion monitoring GC/MS; d.l. = 0.02 mg/L; when interferences present, reaction with silver fluoride or MS/MS needed to obtain d.l. = 0.02 mg/L	Creasy (1999)
				Direct injection (10 µL) of 0.005 mg/L solution of VX (corresponding to 50 pg on-column) could be detected by LC/negative ESI/MS	Love (2004)

^a Notes: d.l. = detection limit; EPA = United States Environmental Protection Agency; ESI/MS = electrospray ionization coupled with mass spectrometry; G = example guideline from Annex G; GC/FPD = gas chromatography coupled with flame photometric detection; GC/MS = gas chromatography coupled with mass spectrometry; LC = liquid chromatography; MCL = maximum contaminant level; SDME = single-drop microextraction; SPME = solid phase microextraction; VOC = volatile organic compound

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Remediation Guidance for Major Airports After a Chemical Agent Attack

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May be exempt from public release under the Freedom of Information Act (5 U.S.C. 552). Exemption and category:

Exemption 2, Circumvention of Statute

Department of Energy review required before public release

Date: October 14 2009

Name/org: Ellen Raber/R Division, Nonproliferation, Homeland and International Security

Guidance (if applicable): CG-CB-2 (July 2004)

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Annex Da. Review of Available Instruments

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Da.1. Available Instruments

This annex summarizes various instruments that are available for the analysis of chemical warfare agents (CWAs) and toxic industrial compounds (TICs). Analytical technology can provide both qualitative (i.e., what compound is present) and quantitative (i.e., how much of a specific compound is present) information about a sample. The most common considerations when selecting an analysis technology include the type and amount of sample available, required limit of detection (LOD), accuracy, precision, cost, speed of analysis, portability, and analyte to be detected. In general, there is a trade-off between detection confidence (accuracy and precision) on the one hand, and cost, instrument portability, and analysis time on the other.

Many different technologies are available for chemical detection. The technologies can be differentiated in terms of their principles of operation, as summarized below.

Colorimetric detection. Chemical reagents on a substrate react with a specific class of chemical agents to yield a characteristic color change.

Surface acoustic wave (SAW) detection. A chemically selective, thin film is deposited on a piezoelectric substrate. When a compound of interest interacts with the film, the mass of the piezoelectric sensor (thus, its frequency of oscillation) changes, and the compound is detected. To enhance response specificity, arrays of polymer-coated SAW (PSAW) devices can be used to detect different gases, and pattern-recognition techniques can be used to interpret data and identify unknowns.

Electrochemical cell. The detector uses an electro-reductive or electro-oxidative process at a microelectrode in a low-volume flow cell.

Photo-ionization detector (PID). An ultraviolet lamp is used to ionize an agent in a gas sample. Current from ionized molecules is measured to quantify the amount of agent in a sample.

Flame ionization detector (FID). A hydrogen/air flame is used to ionize organic molecules, which are detected on an electrode to produce a measurable electrical signal.

Flame photometric detector (FPD). A hydrogen/air flame is used to detect and quantify phosphorus- and sulfur-containing compounds based on chemi-luminescent reactions of the atoms.

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Infrared/Fourier transform infrared spectroscopy (IR/FTIR). Scanned frequencies of infrared light are passed through a sample, and the characteristic absorptions and transmittances of the light for an individual compound are recorded as a function of frequency, producing the compound's spectrum. The unknown compound's spectrum can be matched to a spectrum in a library database for compound identification.

Ultraviolet Raman spectroscopy. An ultraviolet laser illuminates a solid or liquid chemical compound deposited on a surface. The light is Raman scattered by the chemical, which results in an unique wavelength shift in the collected spectrum that provides a "fingerprint" for the chemical and allows its identification.

Ion mobility spectrometry (IMS). An ionizing source, such as ^{63}Ni , is used to ionize analytes of interest, which then flow through a bath gas to a detector. The ions are temporally resolved according to their apparent masses in an electrical field. Specific agents are identified from their drift (transit) times through the IMS system.

Gas chromatography (GC). A chemical separation technique uses a carrier gas to pass analytes through a polymer-coated, fused-silica, capillary column. Mixtures of compounds are resolved into their individual components on the basis of their boiling points and interactions with the column's polymer coating. Data are displayed as a chromatogram, which is a plot of the detector's response to analytes versus elution time from the column (retention time). To determine chemical agents, a variety of detectors, such as flame photometric detectors, photoionization detectors, and mass spectrometers, are coupled with GC separations.

Mass spectrometer (MS). An ionizing source, such as an electron beam from a filament, is used to fragment compounds of interest. Fragments of sample molecules are resolved in time or in space according to their masses and detected with a signal amplifier, such as an electron multiplier. Patterns of mass fragments produced for a compound (i.e., a mass spectrum) are unique for an individual compound. Thus, compound identification can be made by comparing an unknown's mass spectrum with those in a library database.

Gas chromatography-ion mobility spectrometry (GC/IMS). A combination of two previously mentioned technologies.

Gas chromatography-mass spectrometry (GC/MS). A combination of two previously mentioned technologies.

As can be seen from the list, analytical instrumentation and detection techniques for chemical compounds range from simple colorimetric methods to fairly complex GC/MS systems. Specific advantages and limitations of the technologies described above and the matrices that they can sample are summarized in Table Da-1. In general, instruments that are field-portable and available to first responders do not provide absolute identification of a chemical agent and suffer from high (that is, poor) limits of detection (LODs). Examples of such instruments are those using colorimetric detection, an electrochemical cell, SAW, PID, and FPD. Whereas IR/FTIR

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provides more analyte-specific information than SAW, PID, and FPD for pure compounds, it generally fails to provide analyte identification in the presence of mixtures of chemical compounds. IMS instruments are available to first responders and offer a high degree of selectivity for specific chemical agents (i.e., IMS generally has fewer false positive detections, insofar as it has been tested). However, because IMS relies on the mass of analyzed compounds for identification, and because it can be susceptible to cluster ions, there is some potential for false positive identifications when IMS is used in civilian or commercial settings. Coupling IMS with GC can minimize false positive detections.

GC, MS, and GC/MS are typically laboratory-based techniques. Although the techniques can be performed in the field (most often in mobile laboratories), they are usually not available to first responders. Use of these more reliable technologies requires a greater logistics burden because samples must be transported to the site of an instrument. GC, when coupled with specific detectors, such as FPD and MS, is considered to provide definitive identification and quantification of chemical agents.

Tables Da-2, Da-3, and Da-4 list instruments that are commercially available and that can be used to detect the presence of analytes in samples. The instruments are grouped according to their anticipated use. Table Da-2 describes instruments that would be used by first responders. Several of these technologies have been evaluated by the EPA for use in their All Hazards Receipt Facilities (AHRF; see Kelly et al. 2008). Table Da-3 lists more sophisticated instruments that would be used to help characterize the presence of a chemical agent, and Table Da-4 describes instruments that would be used to unambiguously identify the presence of a chemical agent. Included in each of the tables are data regarding each instrument's size, weight, power requirements, LODs, and other pertinent facts.

Da.2 Instrument Selection Based on Required Detection Limits

The LOD is one criterion that determines instrument selection. Tables Da-2, Da-3, and Da-4 show detection limits for selected agents in air that can be obtained with various commercial instruments. In general, SAW-based detectors and IMS can detect low mg/m³ concentrations of agents by directly sampling air. Improved detection limits can be obtained by instruments that concentrate analytes on a sorbent trap prior to detection. Such systems can detect target concentrations on the order of 1×10^{-6} to 1×10^{-4} mg/m³ in air (but exact detection limits are compound-specific).

To understand how required detection limits influence instrument selection, consider the scenario of distilled sulfur mustard (HD) contamination in an unspecified area. For an HD airborne concentration of 0.27 mg/m³ or greater, it is predicted that the general population could experience life-threatening health effects or death (acute exposure guideline level three, or AEGL-3, 8 hr). Referring to Tables Da-2, Da-3, and Da-4, this concentration of HD cannot be directly detected by colorimetric methods, IR/FTIR, FID (MicroFID), FPD, or reliably with a PID (ppbRAE Plus). Thus, those detectors could not be used to determine whether life-threatening HD concentrations existed in an area. However, 0.27 mg/m³ of HD could be directly

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detected by many of the SAW and IMS detectors. Thus, use of such detectors is suitable to detect the presence of HD at life-threatening concentrations.

The airborne concentration of HD above which it is predicted that the general population would experience notable discomfort (AEGL-1, 8 hr) is 0.008 mg/m³. For longer exposures (e.g. > 8 hours, which is possible in an airport setting) concentrations of interest would likely be lower. However, concentrations of HD in the low 10⁻³ mg/m³ range cannot be directly detected by any of the instruments listed. Thus, sample concentration prior to analyte detection is needed to afford HD detection. The commercial systems that can detect such low levels of HD use preconcentration of analytes on a solid sorbent and gas chromatographic separation prior to detection (e.g., the MINICAMS and Agilent's mobile-laboratory-based instruments).

As the examples illustrate, detection of HD in air at concentrations that would be immediately dangerous to the health of remediation workers or transit passengers can easily be accomplished with existing technologies. However, it might be necessary to detect lower concentrations of HD to support long-term air monitoring. To meet the objectives of long-term air monitoring, it might be necessary to detect HD at a concentration of 2×10^{-5} mg/m³ (the concentration of contaminant to which the general population could be exposed, long-term, without suffering ill effects, or the GPL). We know of no currently available methods that claim to measure this concentration of HD in air. However, because methods exist for monitoring other environmental pollutants at trace concentrations in air, it should be feasible to develop a method to sample a sufficiently large volume of air, collect agents on a solid sorbent or in a liquid, and measure HD in the resulting sample extracts by appropriate analytical techniques, such as GC or GC/MS.

Da.3 Knowledge Gaps

This annex summarizes currently available technologies to detect chemical agents. Although the technologies claim to detect chemical agents at low concentrations, many have not been tested for their ability to detect analytes of interest in the presence of potential interferences from common commercial or industrial products, which are used frequently in public settings. The presence of interferences might prevent the detection of chemical agents at optimal detection limits. Almost all of the testing for interferences that has been done to date has involved chemicals encountered by the military in battlefield situations. If the technologies are to be used to detect and quantify chemical agents in civilian settings, this concern must be addressed. False positive and false negative detections of chemical agents in a public setting have much greater ramifications than in a military or battlefield environment.

No single recommendation for sampling and analysis methodology is made in the *Remediation Guidance* because every scenario will be unique. In general, because a goal of characterization is to determine as quickly as possible the locations and levels of contamination, it is desirable to use field instrumentation (e.g., ion-mobility spectrometry with wipe sampling) that can yield real-time analytical data quickly. Use of field instrumentation is only feasible, however, given minimal interference from other compounds in the environment and adequate detection limits. If the use of field instruments is not possible, then laboratory-based analytical methods should be

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used. Because of their ability to unambiguously identify and quantify chemicals of interest, laboratory-based, mass-spectrometric analytical techniques are preferred. In fact, mass spectrometric analyses performed in accredited laboratories, with documented quality assurance procedures, are necessary to provide the defensible data required for clearance.

Table Da-1. Advantages, limitations, and sample matrices that can be analyzed by various detection technologies.
Abbreviations for technologies are defined in Section Da.1.

Detection Technology	Advantages	Limitations	Sample Matrices
Colorimetric	Rapid analysis, inexpensive	Lack of specificity, high LODs	Liquid, aerosol
SAW	Portable, rapid analysis	Problems with interferents and false positives	Gas
EC	Portable, rapid analysis, can be specific to a particular gas	Can have a short shelf life and can be subject to several interfering gases	Gas
PID	Portable, rapid analysis	Lack of specificity, instrument drift	Gas
FID	Portable, rapid analysis	Responds to many compounds, including hydrocarbons	Gas
FPD	Portable, low LODs	Problems with interferents and false positives	Liquid, ^a gas
IR/FTIR	Some instrumentation is portable, rapid analysis, large compound database	Inadequate for mixtures, some instrumentation available for stand-off detection of vapor clouds, high LODs	Solid, liquid
Ultraviolet Raman	Portable, rapid analysis, stand-off detection at up to 3 m	Laser-based system requires protective eyewear, analytes cannot be detected through glass or plastic	Solid surfaces
IMS	Portable, low LODs, rapid analysis	Possible false positives	Solid, ^b gas
GC	Portable, low LODs	Generally in fixed-base or mobile labs	Liquid, ^a gas ^c
MS	Specific identification, low LODs, rapid analysis, large compound database	Generally in fixed-base or mobile labs	Solid, liquid, ^a gas ^c
GC/IMS	Portable, low LODs, rapid analysis, addition of GC affords additional specificity to IMS	Possible false positives	Liquid, ^a gas
GC/MS	Specific identification, low LODs, addition of GC affords additional specificity to MS, analysis times of 0.5 to 1 hr	Generally in fixed-base or mobile labs	Liquid, ^a gas ^c

^a Liquid samples may include solvent extracts of surface wipes or of solid samples.

^b Solid samples in IMS are surface wipes (can include liquids from surfaces) from which compound vapors are extracted by thermal desorption and analyzed.

^c Gas samples may include preconcentration on sorbent materials and subsequent desorption.

Table Da-2. Detection systems available to first responders. Abbreviations for technologies are defined in Section Da.1. N/A means not applicable.

Instrument (manufacturer)	Technology	Detection Capabilities	Analysis Time (min)	Size (in.)	Weight (lb)	Power	Comments and Testing Validation	Cost (\$)
M256A1 system (U.S. military)	Colorimetric	G vapor ^a : 0.005 mg/m ³ VX vapor ^a : 0.02 mg/m ³ HD vapor ^a : 2 mg/m ³	15	7 × 5 × 3	1.2	none	Uses eel enzyme as another indicator for the presence of nerve agents	300
CMS Emergency Response kit (Dräger)	Colorimetric, with electronic components	<500 mg/m ³ (100 ppmv) CWAs and TICs in air	2	8 × 3.6 × 1.7	1.6	battery	Different chips must be selected to detect specific analytes at specific concentrations; kit comes with 50 chips	3600
Color indicator tubes Dräger CDS test kit (Dräger)	Colorimetric	1 to 500 mg/m ³ (0.2 to 100 ppmv) CWAs and TICs in air can be determined	5	8 × 16 × 20	15–20	none	ECBC reports that tubes indicate JSOR levels for GA, GB, and HD; phosphoric acid ester-type tubes provide necessary detection limits to indicate when it is safe to remove mask for GA and GB protection; thioether tubes do not provide sufficient sensitivity to determine when it is safe to unmask for HD ^b	3700/kit (with pump and tubes)

Table Da-2. (Continued)

Instrument (manufacturer)	Technology	Detection Capabilities	Analysis Time (min)	Size (in.)	Weight (lb)	Power	Comments and Testing Validation	Cost (\$)
HazCat Chemical Identification System, Weapons of Mass Destruction Test Kit (Haztech Systems, Inc.)	Colorimetric	Detects nerve agents, HD, HN, L, and selected TICs in solids and liquids	min	20 × 9 × 18	easily carried	none	Test kit filled with different reagents	3700
HazMat Smart-Strips™ (Safety Solutions, Inc.)	Colorimetric	Requires 100 µL for CWAs	<1	N/A	N/A	none	Also detects cyanide, hydrogen sulfide, arsenic, acids, caustics, fluoride, oxidizers, and chlorine in liquid or aerosol form	400 for 25 strips
M8 (C8) paper (Tradeways)	Colorimetric	Detects G, H, and V agents; requires ~20 µL of liquid sample	<1	N/A	N/A	none	False positive detections obtained for many common chemicals	1–30 per card
M9 paper (Tradeways)	Colorimetric	Detects G, H, V and L agents; requires 100 µL liquid sample	<1	N/A	N/A	none	Color change does not distinguish between chemical agents	2–20 per sheet; 50 per 10-m roll
M272 water test kit (Tradeways)	Colorimetric	Detects agents in water. ^c G: 0.02 mg/L V: 0.02 mg/L H: 2 mg/L AC: 20 mg/L L: 2 mg/L	min	10 × 6 × 3	easily carried	none	Developed for military use	300

Table Da-2. (Continued)

Instrument (manufacturer)	Technology	Detection Capabilities	Analysis Time (min)	Size (in.)	Weight (lb)	Power	Comments and Testing Validation	Cost (\$)
HazMatID™ (SensIR/Smith's Detection)	IR	Detects various CWAs and TICS; compounds must be present in liquid or solid at >10% in sample	<1	18 × 11 × 7	23	dc	—	50,000
ppbRAE Plus (RAE Systems)	PID	Detects ≥ 0.03 mg/m ³ of TICs and CWAs in air	<1	8 × 3 × 2	1.2	dc	ECBC concluded this detector requires frequent calibration (calling into question the reliability of the device). GA, GB, and sometimes HD, were not detected at IDLH levels. ^{d, e}	7,000
Dräger Multi-PID 2 (Dräger Safety, Inc.)	PID	—	<1	9 x 4 x 3	2	ac/dc	Integrated gas library holds 70 substances.	—
HAZMATCAD/ HAZMATCAD PLUS (Microsensor Systems)	SAW/EC	0.06–0.2 mg/m ³ various CWAs, including G agents, VX, HD, HN, AC, CG, and hydride and halogen gases	<1–3	2 × 3 × 8	1.4	dc	Tested under EPA ETV program. ^f An array of three coated SAW sensors provide selectivity for CWAs. Detector responded well at IDLH levels. Some interferences noted for GB detection. ECBC testing showed that detectors were unable to consistently detect and identify CWAs in the presence of interferences. ^g	5,000

Table Da-2. (Continued)

Instrument (manufacturer)	Technology	Detection Capabilities	Analysis Time (min)	Size (in.)	Weight (lb)	Power	Comments and Testing Validation	Cost (\$)
SAW MiniCAD MkII (Microsensor Systems)	SAW	Nerve and blister agents detected in air	1	1 × 4 × 5	1.1	dc	ECBC report states that GA, GB, and HD are not successfully detected at JSOR level. Detectors responded sluggishly to the simulant checks and had limited usefulness as viable CWA warning device. ^h	5,500
CW Sentry 3G (Microsensor Systems)	SAW/EC with thermal modulation sample collection	CWAs (vapor): 0.3–1.0 mg/m ³ (meets EC _{t50} mild exposure dose level)	0.5	25 × 20 × 10	40	ac	Can provide continuous operation (24 hours a day/7 days per week) at a fixed site	8,000
MicroFID (Photovac, Inc.)	FID	methane (vapor): 0.3 mg/m ³	<1	17 × 4 × 7	8	battery	Study by ECBC noted that JSOR levels for GA, GB, and H were not met and that this detector is insufficient for CWA detection ⁱ	9,000
Smiths Detection HGVI	IMS PID TGS	CWA, TIC, Rad	<1	17 x 14 x 13	7.5	18V dc, 110/240 ac	—	—

Table Da-2 abbreviations and footnotes.

ECBC = Edgewood Chemical Biological Center; EPA ETV = U.S. Environmental Protection Agency's Environmental Technology Verification Program; IDLH = concentration of an airborne analyte that is Immediately Dangerous to Life and Health; JSOR = Joint Service Operational Requirement (concentration of airborne analyte that the U.S. Military deems relevant to detect for troop protection); ppbv = part per billion by volume; ppmv = part per million by volume.

^a See <http://www.gulflink.osd.mil/library/randrep/mr1018.5.ch5.pdf>

^b Longworth, T. L., J. C. Cajigas, J. L. Barnhouse, K. Y. Ong, and S. A. Procell (1999), *Testing of Commercially Available Detectors Against Chemical Warfare Agents: Summary Report*, Soldier and Biological Chemical Command, AMSSB-REN, Aberdeen Proving Ground, MD.

- ^c Committee for an Assessment of Naval Forces' Defense Capabilities Against Chemical and Biological Warfare Threats, Naval Studies Board, Division on Engineering and Physical Sciences (2004), *Naval Forces' Defense Capabilities Against Chemical and Biological Warfare Threats*, National Research Council of the National Academies, The National Academies Press, Washington, DC; available, in part, at <http://www.nap.edu/openbook/0309088720/html/166.html>.
- ^d http://www.raesystems.com/Products/ppbRAE_Plus; Longworth, T. L. and K. Y. Ong (2001), *Domestic Preparedness Program: Testing of RAE Systems ppbRAE Volatile Organic Compound (VOC) Monitor Photo-Ionization Detector (PID) Against Chemical Warfare Agents Summary Report*, Soldier and Biological Chemical Command, AMSSB-RRT, Aberdeen Proving Ground, MD.
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- ⁱ Longworth, T. L., J. L. Barnhouse, K. Y. Ong, and M. A. Johnson (1999), *Domestic Preparedness Program: Testing of Photovac MicroFID Handheld Flame Ionization Detectors Against Chemical Warfare Agents—Summary Report*, Soldier and Biological Chemical Command, AMSSB-REN, Aberdeen Proving Ground, MD.

Table Da-3. Detection instruments affording some selectivity and moderate detection limits. Instruments assumed to be portable unless designated as fixed base or laboratory based. N/A means not available.

Instrument (manufacturer)	Technology	Detection Capabilities (mg/m ³ unless noted)	Analysis Time (min)	Size (in.)	Weight (lb)	Power	Comments and Testing Validation	Cost (\$K)
AP2C (ProEngin)	FPD	G (vapor): 0.01 HD (vapor): 0.4 VX (surface): 3 µg/cm ² GB (H ₂ O): 0.03 mg/L VX (H ₂ O): 0.03 mg/L HD (H ₂ O): 1.5 mg/L VX (skin): 0.04 µg/cm ² HD (skin): 0.4 µg/cm ²	<1	16 × 4 × 5	4.4	12–24 Vdc	Used by French in 1990-91 Gulf War. Provided better sensitivity than IMS detectors. ^m False positives from compounds containing same elements as CWAs. Use with S4PE-scraper allows the detection of liquid samples. ECBC detected GA, GB, and HD at IDLH/JSOR levels in air and used S4PE unit to analyze wipe samples. False positives were given by >1% gasoline vapor and smoke. ^a	25–50
ADLIF (ProEngin) Fixed base	FPD	CWA (vapor): 0.003 blister (vapor): 0.4	<1	16 × 19 × 34	99	12–32 Vdc/ 120Vac	ADLIF is AP2C detector configured for continuous operation at a fixed site	125– 135
AP4C (ProEngin)	FPD	G, V (vapor): 0.03 H, HD, HL (vapor): 1 L, SA (vapor): 1.5 HN, HCN (vapor): 5 VX (surface): 0.02 mg/cm ² GB (H ₂ O): 0.1 mg/L VX (H ₂ O): 0.08 mg/L HD (H ₂ O): 5 mg/L VX (skin): 0.1 µg/cm ² HD (skin): 1 µg/cm ²	<1	15 x 4 x 5	4.5	Battery or 12–28 Vdc	Expanded analyte list compared to AP2C. Can be transformed into alarm system.	50

Instrument (manufacturer)	Technology	Detection Capabilities (mg/m ³ unless noted)	Analysis Time (min)	Size (in.)	Weight (lb)	Power	Comments and Testing Validation	Cost (\$K)
XM-21	IR	Detects agent clouds up to 5 km distant	N/A	20 × 20 × 12	63 (unit) 45 (case)	21–30 Vdc	Used by U.S. military	N/A
ppbRAE Plus (RAE Systems)	PID	Detects ~0.03 mg/m ³ (ppbv) of TICs and CWAs in air	<1	8 × 3 × 2	1.2	dc	ECBC concluded detector required frequent calibration (questioned reliability of the device) and could not detect GA or GB at IDLH levels. HD could sometimes be detected at IDLH levels. ^g	7
PSAW (Sensor Research and Development Corp./SRDC)	PSAW	Various TICs: 0.1– 0.4	min	N/A	N/A	N/A	Not yet commercially available	N/A
JCAD ChemSentry™ (BAE Systems)	SAW array	Detects agents in air: VX: 0.04 G: 0.1 H: 2 L: 2 AC: 20 CK: 20	min	5 × 8 × 2	2	ac/dc	Tendency for false positives. Selected by JPO. Emerging technology (1–1.5 yr)	15
HAZMATCAD/ HAZMATCAD PLUS (Microsensor Systems)	SAW/EC	G-agents, VX, HD, HN, AC, CG, and hydride and halogen gases at 0.06–0.18	1–3	2 × 3 × 8	1.4	dc	Tested by EPA ETV program. ^h Array of 3 coated SAW sensors provides selectivity for CWAs. Detector responded well at IDLH levels. Some interferences noted for GB detection. ECBC testing showed detectors unable to consistently detect and identify CWAs in presence of interferences. ⁱ	5

Instrument (manufacturer)	Technology	Detection Capabilities (mg/m ³ unless noted)	Analysis Time (min)	Size (in.)	Weight (lb)	Power	Comments and Testing Validation	Cost (\$K)
SAW MiniCAD MkII (Microsensor Systems)	SAW	Nerve and blister agents detected	1	1 × 4 × 5	1.1	dc	ECBC reports that GA, GB, and HD not successfully detected at JSOR level, that the detectors responded sluggishly to the simulant checks, and that the detectors had limited usefulness as a viable CWA warning device. ^h	5.5
CW Sentry 3G (Microsensor Systems) Fixed base	SAW/EC	CWAs: 0.3–1.0	<1	25 × 20 × 10	40	ac	Designed to be wall-mounted in office building, HVAC system, airport, or subway. Pricing depends on configuration of sensors needed for detection of predetermined set of analytes	18–27
SafeSite® (MSA)	SAW, PID, EC	Detects and communicates the presence of ≤6 CWAs in air: G: 0.3 H: 1	<1	25 × 20 × 10	40	ac/dc	Combines detection technology with advanced wireless communications capabilities.	35
LSCAD (Block Engineering)	FTIR	Detects agents in air within 5 km line-of-sight; detection limits similar to M21. M21 detection limits: G-agents: 90 H: 2300 L: 500	<1	10 × 7 × 6	13	28 Vdc, 24 W	Tendency for false positives. Some known military interferences were not problematic.	350–400

Instrument (manufacturer)	Technology	Detection Capabilities (mg/m ³ unless noted)	Analysis Time (min)	Size (in.)	Weight (lb)	Power	Comments and Testing Validation	Cost (\$K)
RAPID (Bruker) Fixed base	IR	Detects agents in air. GA: 200–400 GB: 140–230 GD: 190–300 GF: 220–440 HD: 5200–10000 (722 cm ⁻¹) and 2300–4600 (1212 cm ⁻¹) HN-2: 640–1300 L-1: 1700–4200 AC: 1000–2100 CG: 240–650	<1	20 × 13 × 15	63	24 Vdc	Tendency for false positives. Spectra for CWAs and TICs available in electronic, searchable database.	240
JSLSCAD (General Dynamics) Fixed base	IR	Detects agents in air. Nerve: 135 mg/m ² Blister: 3300 mg/m ² AC: 6600 mg/m ² CK: 6000 mg/m ²	<1	8 × 8 × 33	43	28 Vdc/ 115 Vac	Tendency for false positives. Designed for military use.	N/A
HazMatID™ (SensIR/Smith's Detection)	IR	Detects various CWAs and TICS. Compounds must be present at >10% in liquid or solid sample.	<1	18 × 11 × 7	23	dc	Identifies solid and liquid samples by matching spectra with those in a database.	50
LISA® Manportable (ITT Corporation)	Ultraviolet Raman	Detects low microgram per cm ² amounts of analytes on surfaces	<1	14 × 15 × 6.5	50	120 Vac/ battery	Identifies chemicals on surfaces at ≤3 m	—
MINICAMS- 3001 (OI Analytical)	GC	Detects agents in air. CK: 0.12 PS: 0.14 CG: 0.08 GA: 2 × 10 ⁻⁵ GB: 1 × 10 ⁻⁶ GD: 6 × 10 ⁻⁶ VX: 2 × 10 ⁻⁶	3	12 × 12 × 10	18	ac	Provides near-real-time, continuous air monitoring. Direct-loop sampling or preconcentration on a solid sorbent possible. Flame photometric, pulsed flame photometric, and halogen-	28–42

Instrument (manufacturer)	Technology	Detection Capabilities (mg/m ³ unless noted)	Analysis Time (min)	Size (in.)	Weight (lb)	Power	Comments and Testing Validation	Cost (\$K)
		HD: 6×10^{-4} HN1: 6×10^{-4} HN2: 6×10^{-4} L: 6×10^{-4}					specific detectors available.	
RAID (Bruker)	IMS	Detects agents in air. AC: 0.07 CG: 0.3–1.3 Cl ₂ : 0.7–1.4 GB: 0.02–0.04 HD: 0.07–0.13	1–2	16 × 5 × 6	7.6	12/24 Vdc	Company makes IMS units in several different formats ranging from rugged, hand-held units to stationary systems for area monitoring. RAID M tested by EPA ETV program. ¹ Response threshold for GB was 0.02–0.04 mg/m ³ and for HD was 0.07–0.13 mg/m ³	20
Multi-IMS (Dräger)	IMS	Nerve agents: 0.01–0.1 Blister agents: 0.5–2.0 Blood/choking agents: 20–50	1–2	10 × 4 × 2	1.4	dc	—	11
Chempro 100 (EnviroNics)	IMS	Detects agents in air. VX: 0.04 G: 0.01 HD: 2.0 L: 0.1 HN ₃ : 2.0	0.07–2	10 × 4 × 2	1.8	dc	Tested by U.S. Environmental Protection Agency. ChemPro 100 responded correctly to AC, GB, and HD in most challenges, but responses observed with CK, SA, and Cl ₂ were less reliable. Both false positive and false negative responses in the presence of common indoor interferents. ^{b, k}	9.5

Instrument (manufacturer)	Technology	Detection Capabilities (mg/m ³ unless noted)	Analysis Time (min)	Size (in.)	Weight (lb)	Power	Comments and Testing Validation	Cost (\$K)
Chempro 100i (EnviroNics)	IMS with metal oxide semi- conductor sensors	Improved agent sensitivity and expanded analyte list compared to Chempro 100	—	—	—	—	Figures of merit comparable to Chempro 100	—
M90-D1-C (EnviroNics)	IMS	Detects agents in air. Nerve: 0.01 Blister: 2 Blood: 30	0.5–2	11 × 4.2 × 11	10.8	dc	ECBC tested. GA, GB, and HD detected at IDLH, but not AEL levels. Detector adversely affected by several interferences, such as diesel vapors and exhausts. ^c	17.5
Dynasensor (General Dynamics)	IMS	GA, GB, GD, VX, HD, HN ₃ , L, AC, AK detected in air at 0.01	<1	7 × 11 × 6	6	ac/dc	Developed for military. Also available for homeland security applications.	N/A
M43A1 (General Dynamics)	IMS	Various CWAs in air: 0.01	<1	7 × 11 × 6	6	6–40 Vdc/115/ 240 Vac	Developed for military use in full NBC protective posture.	N/A
Juno™ (General Dynamics)	IMS (differential)	VX, GA, GB, GD, GF, HD, L, HN ₃ , AC, CK	<1	8 x 4 x 2	2	6 Vac/ 6 Vdc	Vendor states detects CWAs below JSOR level. With preconcentrator, can detect at miosis levels. Developed as a personal monitoring device.	N/A
APD 2000 (Smith's Detection)	IMS	Detects agents in air. V: 0.04 G: 0.1 H: 2 L: 2	<1	4 × 3.5 × 11	6	dc	ECBC tests; IDLH/JSOR levels for GA, GD, and HD successfully detected, but AEL levels not detected. ^d Unit also detects pepper spray, mace, and gamma radiation (1-999 mRem/hr)	9.6
CAM (Smith's)	IMS	Detects agents in air. V: 0.04	<1	4 × 3.5 × 11	4.2	6 Vdc	ECBC concluded CAM met JSOR levels for GA, GB, and	9.4

Instrument (manufacturer)	Technology	Detection Capabilities (mg/m ³ unless noted)	Analysis Time (min)	Size (in.)	Weight (lb)	Power	Comments and Testing Validation	Cost (\$K)
Detection)		G: 0.1 H: 2 L: 2					HD, but not AEL levels. Some false positives noted for engine exhausts, smoke, and other vapors. ^e	
GID-3 (Smith's Detection)	IMS	Detects agents in air. V: 0.04 G: 0.1 H: 2 L: 2	<1	11 × 7 × 6.5	14.1	dc	Hardened for military use. Model is available for 24/7 unattended operation.	15–20
GID-M (Smith's Detection)	IMS	Various TICs and CWAs	<1	18 × 8 × 8	16	ac/dc	—	N/A
LCD 3.2E (Smith's Detection)	IMS	VX, VXR: 0.04 GA, GB, GD, GF: 0.1 HD: 2 L: 2 HN3: 2 AC: 22 CK: 20	<2	30 in. ³	1.5	dc	Developed for use by individuals and small groups of soldiers.	8.3
SABRE 4000 (Smith's Detection)	IMS	Responds to 40 TICs, CWAs, & explosives in air samples or collected by wipes. Earlier model (Sabre 2000) tested by ECBC could detect GA, GB, and HD at IDHL levels (0.2 mg/m ³ for GA/GB and 2 mg/m ³ for HD)	<1	14.5 × 4 × 4.5	7	dc	Earlier model (SABRE 2000) tested: fuel and bleach vapors caused interferences and false positive detections. High humidity prevented detection of analytes near detection limit. ^f	26

Instrument (manufacturer)	Technology	Detection Capabilities (mg/m ³ unless noted)	Analysis Time (min)	Size (in.)	Weight (lb)	Power	Comments and Testing Validation	Cost (\$K)
		but not AEL levels (0.0001 mg/m ³ for GA/GB and 0.003 mg/m ³ for HD) ^f						
QS-H100 (handheld)	IMS	Picogram to nanogram detection of explosives such as Semtex, C4, RDX, NC, PETN, EGDN, TNT dynamite, ANFO, TATP, smokeless powder, and black powder	<1	23 × 5 × 6 (handheld)	12 (hand- held)	Battery or 110 Vac (hand- held)	Has not been tested for CWA detection. Uses a proprietary opto-electrical ionization technique rather than a radioactive source for ionization.	30 (hand- held)
QS-BT100 (bench) (Implant Sciences, Corp.)				18 × 19 × 9 base with 11 × 5 × 5 analyzer unit (bench)	45 (bench)	110 Vac (bench)		45 (bench)
Centurion (Smiths Detection) Fixed base	IMS	CWAs and TICS	<1	18 × 16 × 11	31	110/120 Vac	Designed for 24/7 operation. Can be used in HVAC system. Can transmit data to central location by Ethernet connection.	35
EVM II (FemtoScan Corporation)	GC/IMS	0.1 mg/m ³ detection of many compounds in air; not specifically tested for CWAs	<1	Handheld	N/A	24 Vdc	Uses Automated Vapor Sampling (AVS)–Transfer Line Gas Chromatography (TLGC)	N/A
GC/IonScan® (Smith's Detection) Fixed base	GC/IMS	Picogram to nanogram detection limits for organic compounds; not specifically tested for CWAs	<5	16 × 21 × 18	71	110 Vac/ 60Hz	Operation with or without GC separation. Solid-phase desorption unit available for analysis of solid samples. GC temperature maximum is 300°C.	N/A

Instrument (manufacturer)	Technology	Detection Capabilities (mg/m ³ unless noted)	Analysis Time (min)	Size (in.)	Weight (lb)	Power	Comments and Testing Validation	Cost (\$K)
IMS 5000 series (Dräger) Fixed base	GC-IMS	Various TIC HCN: 0.005 Phosgene: 0.002	0.5	5 × 19 × 14	22	24–28 Vdc	Detects toxic gases and airborne molecular contaminants.	N/A
E5000 (Scintrex Trace Corp.) Fixed base	GC-IMS	pg–ng analyte detected	0.1–0.3		55	90–265 Vac	Developed for narcotics and explosive detection. Unknown response to CWAs and TICs	N/A
HGVI Hand-held, Multi-Sensor Gas and Vapor Identifier (Smiths Detection)	IMS, PID, TGS	TICs and CWAs at 0.1 x IDLH	<1	17 × 5.5 × 5	7.5	18 Vdc; 110/240Vac; or battery pack	Multiple sensors used to minimize false-positive alarms	25-45
MM2 (Bruker)	MS (quadrupole)	—	15	17 × 12 × 17	77	24 Vdc	Contains air/surface probe	N/A
Eco-Sys P (ESS)	MS	TICS of <300 amu: 0.05	<1	32 × 22 × 9	—	110 Vac or 12 Vdc battery pack	Has not been tested for response to CWAs.	N/A
FieldMate/ Radiance Pro® CW (Syagen)	MS	DMMP (CWA surrogate): 0.1	<1	N/A	60	24 Vdc	Emerging technology with photoionization/quadrupole ion trap time-of-flight MS. Direct air and liquid sampling possible. 1–1000 amu mass range.	130
Scentinel® (Mass Spec Analytical Ltd.)	MS/MS	Untested for CWAs. Similar technology can determine low-mg/m ³ concentration of volatile organic compounds	<1	49 × 57 × 28	N/A	110/220V 50/60 Hz	Trace detection system using a Sciex API 2000 MS. Tandem MS reduces potential interferences.	N/A

Table Da-3 abbreviations and footnotes.

AEL = adverse effect level, airborne concentration of analyte that yields adverse health effects; ECBC = Edgewood Chemical Biological Center; EPA ETV = U.S. Environmental Protection Agency's Environmental Technology Verification Program; IDLH = concentration of an airborne analyte that is Immediately Dangerous to Life and Health; JSOR = Joint Service Operational Requirement (concentration of an airborne analyte that U.S. Military deems relevant to detect for troop protection); ppbv = part-per-billion by volume ; ppmv = part-per-million by volume.

- ^a Longworth, T. L. and K. Y. Ong (2001), *Domestic Preparedness Program: Testing of Detectors Against Chemical Warfare Agents—Summary Report, UC AP2C Portable Chemical Contamination Control Monitor Collective Unit*, Soldier and Biological Chemical Command, AMSSB-RRT, Aberdeen Proving Ground, MD.
- ^b “Testing and Evaluation of Portable Detector Begins,” news from 7/1/05; available at www.epa.gov/nhsrc/news/news070105.htm.
- ^c Longworth, T. L., K. Y. Ong, and J. L. Barnhouse (2000), *Domestic Preparedness Program: Testing of M90-D1-C Chemical Warfare Agent Detector Against Chemical Warfare Agents Summary Report*, SBCC, AMSSB-RRT, Aberdeen Proving Ground, MD.
- ^d Ong, K. Y., T. L. Longworth, and J. L. Barnhouse (2000), *Domestic Preparedness Program: Testing of APD2000 Chemical Warfare Agent Detector Against Chemical Warfare Agents Summary Report*, Soldier and Biological Chemical Command, AMSSB-RRT, Aberdeen Proving Ground, MD.
- ^e Longworth, T. L. and K. Y. Ong (2001), *Domestic Preparedness Program: Testing of CAM-Chemical Agent Monitor (TypeL) Against Chemical Warfare Agents Summary Report*, Soldier and Biological Chemical Command, AMSSB-RRT, Aberdeen Proving Ground, MD.
- ^f Longworth, T. L. and K. Y. Ong (2001), *Domestic Preparedness Program: Testing of Sabre 2000 Handheld Trace and Vapor Detector Against Chemical Warfare Agents Summary Report*, Soldier and Biological Chemical Command, AMSSB-RRT, Aberdeen Proving Ground, MD.
- ^g http://www.raesystems.com/Products/ppbRAE_Plus; and Longworth, T. L. and K. Y. Ong (2001), *Domestic Preparedness Program: Testing of RAE Systems ppbRAE Volatile Organic Sompound (VOC) Monitor Photo-Ionization Detector (PID) Against Chemical Warfare Agents Summary Report*, Soldier and Biological Chemical Command, AMSSB-RRT, Aberdeen Proving Ground, MD.
- ^h Battelle, Columbus, OH (under contract to U.S. Environmental Protection Agency) (2004), *Environmental Technology Verification Report: Microsensor Systems Inc. HazMatCAD™ Plus Surface Acoustic Wave/Electrochemical Detector*.
- ⁱ Longworth, T. L., K. Y. Ong, and J. M. Baranoski (2002), *Domestic Preparedness Program: Testing of HAZMATCAD Detectors Against Chemical Warfare Agents Summary Report*, Soldier and Biological Chemical Command, AMSSB-RRT, Aberdeen Proving Ground, MD.
- ^j Longworth, T. L., K. Y. Ong, and M. A. Johnson (2001), *Domestic Preparedness Program: Testing of SAW MiniCAD MKII Detector Against Chemical Warfare Agents Summary Report*, Soldier and Biological Chemical Command, AMSSB-RRT, Aberdeen Proving Ground, MD.
- ^k Derringer, T., Kelly, T., Folsom, D., Krile, R., and Z. Willenberg (2006), *Technology Evaluation Report Environics USA Inc. ChemPro 100 Hand-Held Chemical Detector*, EPA 600/R-06/141, National Homeland Security Research Center, Office of Research and Development, U.S. Environmental Protection Agency, 944 East Harmon Ave., Las Vegas, NV 89119.
- ^l Hofacre, K., Derringer, T., Folsom, D., Larkowski, P., Kelly, T., Sinnott, L., Hamilton, C. and Z. Willenberg (2004), *Environmental Technology Verification Report: ETV Safe Buildings Monitoring and Detection, Technologies Verification Program, Bruker Daltonics Inc. RAID-M, Ion Mobility Spectrometer*, Battelle Columbus, Ohio 43201.
- ^m GAO (April 2001), United States General Accounting Office, *Coalition Warfare: Gulf War Allies Differed in Chemical and Biological Threats Identified and in Use of Defensive Measures*, Report to the Chairman, Subcommittee on National Security, Veterans' Affairs, and International Relations, House Committee on Governmental Reform, GAO-01-13.

Table Da-4. Detection technologies with high selectivity and low detection limits. Only the Hapsite and Guardion-7 are portable. Most other systems can be mounted in a mobile laboratory platform. Systems can analyze air samples either directly or collected on solid sorbents, and liquid samples and extracts. N/A means not applicable.

Instrument (manufacturer)	Technology	Detection Capabilities (mg/m ³)	Analysis Time (min)	Size (in.)	Weight (lb)	Power	Comments and Testing Validation	Cost (\$K)
6850N (Agilent)	GC/FPD	GA: 1×10^{-6} GB: 2.5×10^{-7} GD: 1×10^{-6} GF: 1×10^{-6} VX: 2.5×10^{-7} H: 5×10^{-5} HT: 5×10^{-5} HD: 5×10^{-5}	15–45	23 × 12 × 22	65	AC	Standard laboratory equipment	15
6890N (Agilent)	GC/FPD	same as above	15–45	20 × 23 × 22	108	AC	Standard laboratory equipment	20
7890A (Agilent)	GC/FPD	same as above	15–45	19 x 23 x 20	108	AC	Standard laboratory equipment	20
MM-2 (Bruker)	MS (quadrupole)	CWA (air): 1 Blister (air): 0.3 CWA (surface): 100 mg/m ² Blister (surface): 50 mg/m ²	15	15 × 11 × 15	66	24 VDC- 240 W	Equipped with membrane probe, GC, and thermal desorption inlets. Mass range 0–520 amu.	250

Table Da-4. (Continued)								
Instrument (manufacturer)	Technology	Detection Capabilities (mg/m ³)	Analysis Time (min)	Size (in.)	Weight (lb)	Power	Comments and Testing Validation	Cost (\$K)
CDS A/DAM-SVS 6890N-5973N-IACEM (CDS and Agilent)	GC/MS	CWAs: 1×10^{-6} TICs: 1×10^{-7} GB: 2.5×10^{-4} VX as G-Analog: 2.5×10^{-5} HD: 7.5×10^{-4}	10–45	20 × 39 × 22	200	AC	Thermal desorption used for sample introduction	80–120
CT-1128 (Constellation Technologies)	GC/MS	Various TICs and CWAs	15–45	15 × 23 × 15	80	AC	Based on Agilent 5973 quadrupole with mass range 1.6–800 amu. Liquid or SPME sample introduction available. Tested under EPAs ETV program. ^a	140
E ² M (Bruker)	GC/MS	Detects various TICs Direct: 10 Preconcentration: 0.01	20	18 × 12 × 17	75	24 VDC	Gas chromatograph with thermodesorber/injector programmable up to 240°C. Mass range 0–520 amu.	Not available
Griffin 400 (Griffin Analytical Technologies, a subsidiary of ICx Technologies, Inc.)	MS (cylindrical ion trap)	toluene: 0.06 methyl salicylate: 0.002	min	19 × 19 × 18	82	115/120 VAC	Emerging technology. MS ³ demonstrated. Mass range 40–420 amu.	90
Griffin 450 (Griffin Analytical Technologies, a subsidiary of ICx Technologies, Inc.)	MS (cylindrical ion trap)		min	19 × 19 × 21	96	130/250 VAC	Performs air sampling with integrated sample loop (ppb-ppm concentrations detected). Pre-concentrator tube for low concentration samples (pptr-ppb).	

Table Da-4. (Continued)								
Instrument (manufacturer)	Technology	Detection Capabilities (mg/m ³)	Analysis Time (min)	Size (in.)	Weight (lb)	Power	Comments and Testing Validation	Cost (\$K)
CBMS-II (Hamilton Sunstrand Sensor Systems)	MS (simultaneous CWA and BWA detection; ion trap)	CWAs: 0.01 (low ppbv)	<2	53 × 30 × 18	192	220 VAC	Tested against standard military interferents at Dugway Proving Ground; no problems noted. U.S. Army will complete testing prototypes for abilities to detect biological warfare agents (bacteria, toxins, and viruses) and liquid toxic industrial chemicals. Mass range 10–500 amu.	Not available
Hapsite (Inficon)	GC/MS	TICS/CWAs: 0.01 (<1 ppbv)	15	18 × 17 × 7	35	AC/DC	Direct sample introduction. Accessories include head-space sampling system, situ probe for water analysis, and thermal desorption accessory to collect and analyze air samples. GC is temperature programmable from 45° to 200°C. Mass range 1–300 amu.	80–120
Guardion-7 (Torion Technologies)	GC/MS	Not available	5	Fits in briefcase	25	battery	Based on toroidal ion trap technology with mass range 50–500 amu. Samples collected and injected through solid-phase microextraction syringe.	100

Table Da-4. (Continued)								
Instrument (manufacturer)	Technology	Detection Capabilities (mg/m³)	Analysis Time (min)	Size (in.)	Weight (lb)	Power	Comments and Testing Validation	Cost (\$K)
Mobile Laboratory (New Age/Landmark)	Various	Only EPA SW-846 and 600 Series waste-water methods	Analysis-specific	N/A	N/A	Generator and shore power	Fleet of 8 configured mobile labs and personnel. Supports GC/MS, ICP/MS, XRF, and wet chemistry analyses in the field.	Not available
PHILIS Mobile Laboratory [EPA, Office of Solid Waste and Emergency Response's (OSWER) Office of Emergency Management (OEM)]	Mobile labs have 6 GC units equipped with MS and FPD detectors, LC/MS/MS, automated SPE and PSE for sample preparation, and wireless LIMS.	CWA and TICS	Analysis-specific	N/A	N/A	Generator and shore power	Portable High-Throughput Integrated Laboratory Instrument System (PHILIS) given by DHS to EPA. Provides 100–200 analyses per 24-hr day. Units designed for on-site assistance during terrorist events, natural disasters, or accidental releases. Mobile labs produce reliable, validated analytical results.	Not available
Mobile Laboratory (Farber Specialty Vehicles)	Various	Application specific	Analysis-specific	N/A	N/A	Generator and shore power	Company produces mobile laboratories based on customer needs. Does not provide laboratory services.	Not available
Edgewood Chemical and Biological Center, Mobile Laboratories and Kits Team	Various	Application specific	Analysis-specific	N/A	N/A	Generator and shore power	Partners with Federal agencies and customers to design, fabricate, integrate, and validate modular and mobile analytical capabilities	Not available
Automated NBC system Used by U.S. military	Computer system	N/A	Not available	Not available	Not available	Not available	Used with detection systems. Links computer support in U.S. to field forces. Provides greater identification of hazard areas by drawing maps.	Not available

Table Da-4 abbreviations and footnotes.

LIMS = laboratory information management system; ppbv = parts per billion by volume; pptv = parts per trillion by volume; PSE = pressurized solvent extraction; SPE = solid phase extraction.

- ^a Mangaraj, R., A. Dindal, Z. Willenberg, and K. Riggs (2006). *Environmental Technology Verification Report, Constellation Technology Corporation* N CT-1128 *PORTABLE Gas Chromatograph-Mass Spectrometer*, prepared by Battelle, Columbus, OH, under a cooperative agreement with U.S. Environmental Protection Agency.

Da.4. Reference

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Annex E

Annex E. Statistical Approaches for Characterization and Clearance Sampling of a Chemical of Concern

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E.1 Sampling Strategies

This Annex is an overview of statistical sampling strategies that might be used during the remediation of a large airport or other indoor facility following a terrorist attack involving the release of a CWA or TIC. The phases of response to such an event (see Figure 1-1 in the *Remediation Guidance*) are:

- Notification.
- First Response.
- Characterization.
- Remediation.
- Clearance.
- Restoration/Reoccupancy.

This Annex focuses on the design of statistical sampling programs for characterization and clearance. Other designs are identified in Table E-1. Except for a brief discussion of limit of detection (LOD), this Annex does not address issues surrounding the collection, transportation, extraction, and analysis of samples. See Annex C for more information on those topics. Annex E concludes with an extended bibliography in Section E.5.

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Table E-1. Summary of sampling designs and sources of further information.

Stage of Process	Sampling Goals	Applicable Sampling Designs	References
Notification	No sampling.	None	None
First response	Screening sampling. Determine type of CWA or TIC, concentration, and grade. Begin to assess the nature and location of the source.	Judgmental	EPA 1999 and 2002a, Gilbert 1987
Characterization	Obtain data to support design of decontamination process(es), including extent and magnitude of contamination. Discovery sampling. Mapping. Further development of a conceptual model.	Judgmental, random, combined judgmental and random, stratified, systematic (gridded), adaptive, ranked set, and sequential	EPA 2002a, McKenna 1998, Barnes 1989, Gilbert 1987, Thompson and Seber 1996
Decontamination	Monitor and assess decontamination process(es).	Judgmental, random, stratified, and systematic (gridded)	EPA 2002a, McKenna 1998, Barnes 1989, Gilbert 1987, Thompson and Seber 1996
Clearance	Provide defensible basis for confirming that residual levels of contamination meet clearance goals. Confirmation sampling.	Judgmental (including targeted and biased), random, combined judgmental and random, stratified, systematic (gridded), ranked set, and sequential	EPA 1999 and 2002a, Wright 1992, Grieve 1994
Restoration	Confirm that levels of contamination, if any, continue to meet clearance goals; detect it if they do not.	Air monitoring sample designs	Carlsen et al. 2001

The sampling strategies identified in Table E-1 are briefly described below. They are explained in more detail, with examples, in the companion report (McKenna et al. 2007), which includes an extensive literature review of sampling designs used for characterization and clearance in various fields, and in guidance documents created by the EPA and other agencies for statistical sampling. Gilbert and Pulsipher (2005) is an in-depth report on the capabilities and limitations of different sampling designs for environmental applications.

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E.1.1 Judgmental Sampling

Judgmental sampling is the selection of sampling locations using expert opinion, professional judgment, or a conceptual site model (CSM). Judgmental sampling is used when an investigator believes that sampling results from a particular location will be useful and informative. A special case of judgmental sampling during clearance is targeted sampling, that is, sampling the exact location(s) where a chemical of concern was detected during characterization. Another special case of judgmental sampling during clearance is biased sampling, that is, sampling location(s) close to those where a chemical of concern was found during characterization or locations expected to have considerable contact by people. The problem with judgmental sampling is that one must rely on the validity of the judgment, which can often be disputed. The degree of confidence in decisions that are based on judgmental samples alone is often difficult to quantify and defend. See Section C.3.1 as well as 2.4.1.2 and 2.4.3 (in the main text) for additional discussion of judgmental sampling.

E.1.2 Random Sampling

Sample locations are selected at random. Simple random sampling occurs when all possible sample locations have an equal likelihood of being selected. Random sampling is sometimes less appealing than other approaches because uniform spatial coverage is not guaranteed.

E.1.3 Combined Judgmental and Random Sampling

This approach combines confidence based on random sampling results together with confidence based on other (non-sampling) information to achieve greater confidence with fewer samples than with random sampling by itself. To use this approach while planning a sampling strategy it is necessary to either (1) specify that judgmental sampling locations are more likely to find the agent than random sample locations; or (2) specify, based on prior information, a likelihood that the agent is not present at detectable levels. See Sego, et. al., 2010.

E.1.4 Stratified Sampling

An area to be sampled is subdivided into separate areas, and a sampling strategy is implemented separately within each stratum. Example bases for stratification include the design of air-handling systems, the function of different areas of a facility, and the results of predictive transport modeling. If the strategy to locate samples within each stratum is random, then the term stratified random sampling is used. If separate decisions are to be made for each stratum, a separate sampling design is developed for each. If a single decision is to be made for all strata combined, a stratified sampling approach is developed.

E.1.5 Systematic (Gridded) Sampling

Samples are located in a systematic manner, for example, evenly spaced along the length and width of an area. Square, rectangular, and triangular grids are often suggested. The origin of the grid may be placed in a random location (a random-start grid). Rather than placing samples at each node of the grid, samples can be placed at random locations with each grid cell (a special case of stratified random sampling). Systematic grid sampling is appropriate when the entire area

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within a grid is to be sampled (wipe sample) or when only the node of the grid will be sampled (point sample).

E.1.6 Adaptive Sampling

Adaptive sampling consists of two or more rounds, or phases, of sampling in which the sample locations in each round are determined by the results of the previous round(s). For example, in each round, samples could be placed near those locations having the greatest concentrations in the previous round. Methods used to choose new locations in each round range from simple “nearest-neighbor” approaches to sophisticated mathematical methods, such as simulated annealing. The choice depends on the sampling goal.

E.1.7 Sequential Sampling

Rather than collecting at one time all of the randomly located samples anticipated to be necessary to carry out a statistical test, sequential sampling collects only a subset. If the subset turns out to be sufficient to reach a conclusion using the statistical test, sampling stops. If not, more samples are collected, and sampling is repeated until the test is conclusive. The number of samples collected each time could be as few as one. Sequential sampling can, on average, require fewer samples than if all samples were collected at once, but such sampling may take longer. Sequential sampling differs from adaptive sampling in that sequential sampling does not consider the spatial context of the samples.

E.1.8 Ranked Set Sampling

This approach combines professional judgment or information from an auxiliary attribute with a simple random sampling approach. An auxiliary attribute is used to rank individual samples within small groups of samples. Only one of the individual samples within each group is analyzed.

E.1.9 Collaborative Sampling

This approach is appropriate when a relatively inexpensive, quick, but less-precise analytical method is available that produces results that are correlated with a more expensive but precise method (i.e., field-based versus laboratory-based methods). If samples cannot be measured with both methods, co-located samples would be appropriate. The correlation between the main analysis method and the quicker or cheaper method is used to estimate desired attributes of the area being sampled. Collaborative sampling designs are especially useful as input to multivariate spatial estimation techniques, such as co-kriging, and have the potential for major cost savings.

E.1.10 Important Aspects of Sampling and Analysis

Several aspects of sampling and analysis methods affect the statistical sampling design. They are:

- **Sample area for surface samples.** If the sampled area is large enough, compared to the total area, the area sampled can be viewed as a finite population. For example, collecting

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a single wipe from a 100-ft² surface area in a 50,000-ft² room means that the room can be viewed as consisting of 500 potential distinct samples. From the point of view of statistical methods, this is a finite population, and the mathematical models must take that fact into account. If wipe samples represent a smaller area, for example, 100-cm², there would be about 460,000 distinct samples, far more than could be collected and analyzed in a reasonable time and sufficiently large that the population of possible sample locations could be treated as infinite. Thus, statistical models based on infinite populations would be used.

- **Sample volume for air samples.** Air sampling methods range from small (a small volume of air sampled over a short time) to large (a large volume of air sampled for a relatively long time). The choice depends on the sampling goal and, in particular, on the type of exposure being assessed. See Annex C.
- **Sample volume for bulk samples.** The analytical laboratory should provide guidance on the volume of material to collect. The volume affects the extraction procedure and analytical detection limit.
- **Quantitative verses qualitative results.** Some analytical methods can detect the presence of a chemical of concern but do not produce good concentration estimates. Such methods are called qualitative. Such a limitation is less of a problem for chemicals of concern than for biological agents, but a sampling designer should be aware of the potential limitations of qualitative samples.
- **Nondetections.** When true sample concentrations are nearly zero, the detected signal may not be distinguishable from instrument noise, resulting in nondetections. When results are mixed, i.e., some samples have estimated concentrations but others yield nondetections, the calculation of summary statistics and statistical tests is complicated. Data-quality objectives delineated in the SAP determine what is done with nondetections. See Section E.3 for additional discussion.
- **Composite samples.** Composite sampling physically combines several different samples into a single sample.
- **Analysis time.** Certain analysis techniques for some chemical compounds are rapid enough that results can be used in a near-real-time scenario to guide the collection of additional samples. Other techniques are slower. Analysis time should be considered when identifying the sampling design, especially when adaptive sampling is proposed.
- **Persistence.** If the chemical of concern being sampled changes chemical form spontaneously and rapidly relative to the time it takes to return an analytical result from the laboratory, then the analytical results may not be relevant when they are received. Such a consideration is important for chemicals of concern that volatilize rapidly. Knowledge of a chemical's degradation byproducts is highly relevant to this topic as well as the selection of appropriate analytical techniques.

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E.2 Goals of Sampling Design

Sampling programs are designed with specific goals in mind. In many traditional environmental applications (see for example EPA 2002a), the goal has been to estimate the mean concentration within an area and to compare that value to a threshold value, or to ensure that some extreme value in the population is sampled. Sampling for characterization and clearance in an indoor setting may focus on other attributes of the areas sampled, such as sizes of contaminated areas, estimating the maximum concentration in an area, finding hotspots, or simply deciding whether contamination is or is not present in a particular room or set of rooms. Another purpose is creating maps of contamination. Various purposes and goals, decision rules, and confidence statements are summarized in Tables E-2 through E-5. These tables are intended to contain as complete a list of options as possible. The only criterion for inclusion is that the option be potentially useful.

Numeric (continuous) parameters are relevant when decisions are being made relative to a specified nonzero concentration of CWA or TIC, as is the case when risk-based clearance goals have been established for a chemical of concern. Presence/absence parameters are relevant when decisions are a function of whether or not any measurable level of CWA or TIC is present.

Evaluations based on numeric (continuous) population parameters include:

- Deciding whether a mean or one or more upper percentiles of the underlying distribution is above or below a specified concentration threshold.
- Finding the proportion of area exceeding a concentration threshold.
- Finding hotspots, defined by some concentration threshold.
- Contour mapping of concentrations.
- Estimating contamination load for use in designing the decontamination process.

Evaluations based on presence or absence parameters include:

- Maximizing the probability of discovering contamination that may be present.
- Finding hotspots, defined by detectability.
- Finding the proportion of an area with detectable levels.
- Contour mapping of the likelihood of a chemical of concern being detectable.
- Placing confidence in demonstrating the absence of a chemical of concern.

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Table E-2. Possible decision rules and resulting confidence statements for the mean.^a

Decision Criteria	Design Criteria	Resulting Decision Rule and Confidence Statement
Mean vs. threshold	Determine n such that there is no more than a 100P% chance of deciding the true mean is $<$ limit if the true mean is $>$ limit; and only a 100Q% chance of deciding the true mean is $>$ limit if it is significantly $<$ limit	If we are 100(1 – P)% confident that the mean is $<$ limit, then the decision unit is deemed to be uncontaminated; otherwise it is deemed to be contaminated
Mean vs. background mean	Determine n so there is no more than a 100P% chance of deciding the true mean = the background mean when the true mean is significantly greater than background; and only a 100Q% chance of deciding the mean is $>$ background when there is no significant difference.	If we are 100(1 – P)% confident that the mean is $>$ the background mean, then the decision unit is contaminated; otherwise it is deemed to be uncontaminated.
Mean: confidence interval or limit	Determine n such that the half-width of a 100(1 – P)% confidence interval is no greater than X , e.g., estimate the mean to within $\pm X$ with 100(1 – P)% confidence.	We are 100(1 – P)% confident that the true mean is within the upper and lower limit of the confidence interval.

^a N is the number of all possible units that could be sampled; n is the number of units in a subset of N ; P is a probability level, as a fraction; Q is a probability level, as a fraction; UTL is the upper tolerance limit; X is a user-specified concentration threshold; R is a specified percentage of measurements; c is a specified number of units or samples.

Table E-3. Decision rules and resulting confidence statements for individual samples.

Decision Criteria	Design Criteria	Resulting Decision Rule and Confidence Statement
Individual sample results: hotspot decision criteria	Develop a sampling grid and n to ensure 100(1 – P)% confidence in obtaining at least one sample from a hotspot of a specified size and shape, if one exists.	If all measured values $<$ limit, we are 100(1 – P)% confident that a hotspot of specified size and shape does not exist. If any measurement $>$ limit, the decision unit is deemed to be contaminated; therefore hotspots exist.
Percentile (UTL) or maximum: less than some proportion of area contaminated	Determine n such that if all of the n measurements are $<$ limit, then there is $<$ 100P% chance that $>$ R% of the possible measurements are $>$ limit. May use nonparametric UTL or parametric UTL for finite or infinite populations; also compliance sampling approach.	If the maximum measured value (for nonparametric UTL) or the computed UTL is $<$ limit, then we are 100(1 – P)% confident that no more than R% of all possible measurements is $>$ limit. Otherwise, the decision unit is deemed to be contaminated.
Individual sample results: no exceedances allowed	Determine n such that if all of the n measurements are $<$ limit, there is $<$ 100 P% chance of any of the remaining $N-n$ possible measurements to be $>$ limit.	If all n results are $<$ limit, then we are 100(1 – P)% confident that all remaining unsampled areas are $<$ limit. Otherwise the decision unit is deemed to be contaminated.
Individual sample results: some sample exceedances allowed	Determine n and c such that if the true number of exceedances in the population are $<$ X , then there is $<$ 100P% chance of getting more than c exceedances; and only a 100Q% chance of getting $\leq c$ sample exceedances if the number of exceedances in the population is $>$ Y .	If there are c or fewer sample results that are $>$ limit, then there is $<$ 100P% chance that there are more than X exceedances in the population, so the contamination is deemed to be acceptable. Otherwise the decision unit is deemed to be contaminated.

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Table E-4. Sampling goals having to do with spatial extent.

Sampling Goal	Design Inputs	Method description and Notes
Estimate spatial extent of contamination at levels above a defined threshold	Desired spatial resolution (e.g., within 10 ft, or within 50 ft, or per room). The threshold (e.g., detectable or a clearance target level). Whether or not there is a need to interpolate concentrations between sampled locations. Assume or not assume spatial correlation. Specify an upper bound on the uncertainty (σ^2) at unsampled locations.	Design criteria will determine the sampling density.
Find hotspots	Threshold concentration that defines hotspots. Detection probability for a specified size (area) hotspot. Assumes smaller sizes are not of concern.	Grid-based sampling strategy with a single round of sampling.
Find and delineate hotspots	See above, plus: Specify a maximum uncertainty (σ^2) of estimated concentrations within hotspots. Specify spatial precision of boundary.	Sequential sampling strategy minimizing the uncertainty in estimates of hotspot size and concentration.
Create a map of contamination on a large surface (a contour plot)	Whether or not to incorporate spatial correlation. How precisely should the contour lines be located?	Can be simple interpolation from grid-based sampling, or a geostatistical method. Can use sequential sampling as an optimization method to improve the estimation of contour line locations.
Identify a single decontamination approach and the necessary amount of decontamination reagent	Minimize the global (all locations) estimation variance (σ^2).	Estimate the local distribution of the concentration of a chemical of concern at all locations. Simulated annealing or genetic algorithms with multiple sampling rounds can be used to minimize σ^2 .
Classify areas (strata) where the CWA or TIC concentration is relatively uniform so that different decontamination approaches, or different applications of the same approach, can be applied to each area	Minimize the local (all locations within a predefined area or volume) estimation variance (σ^2).	For each area (stratum) within the building (e.g., air handling unit, room, or floor), sample locations are determined such that the average estimation variance across all locations in that area is less than σ^2 . Can start with strata based on conceptual site model, and improve them, or base strata entirely on sampling results.
Collaborative sampling for any of the above goals	Minimize the estimation covariance over either global or local areas of the building	Any of the above three decision rules are the same, but the measure is not variance, but covariance.

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Table E-5. Sampling goals using presence or absence of contamination.

Sampling Goal	Design Inputs	Method description and notes
Confirmation sampling: desire confidence that CWA or TIC is not present	Desired confidence level. Discrete vs. continuous model. Willing or not willing to assume a Bayesian prior.	Incorporates the hypergeometric or binomial statistical distribution.
Discovery sampling: desire to find it if CWA or TIC is there	Discovery probability for a specified degree of presence. Discrete vs. continuous model.	Incorporates the hypergeometric or binomial statistical distribution.
No exceedance allowed; use prior information	Prior (judgmental) probability that decontamination succeeded. Desired confidence level.	If all are nondetections, decontamination is confirmed. Axelrod (1995) Bayesian method.
No exceedance allowed; combine judgmental with statistical	Estimated (prior) probability that CWA or TIC is present in samples selected for judgmental sampling.	Sieber (2006) Bayesian method.

E.3 Limits of Detection

Statistical interpretation of chemical analyses requires understanding the limits of detection (LODs). LODs in chemical analyses of environmental samples include three considerations. The first is the nature of the analytical method, that is, exactly how the method works in terms of identifying and quantifying the chemical of concern. Issues include the correct identification of peaks in a spectrogram (signal to noise ratio), calibration curves, interpretation of signals outside the calibration range, and others. The issues are highly technical, hence the need to have a qualified analytical chemist available for consultation. The second consideration is how the results of an analysis are reported by the laboratory. The third is how sets of reported results are interpreted and used to make inferences and decisions about the environment that was sampled.

E.3.1 Types of Methods

Analytical methods for environmental samples can be categorized as qualitative, semi-quantitative, or quantitative.

- Qualitative results report the presence or absence of a chemical of concern. Either it was detected in the sample or it was not detected.
- Semi-quantitative results identify the type of CWA or TIC with high confidence, but its concentration in a sample is highly uncertain. The uncertainty is intrinsically large because of the nature of the analytical method. Results might be categorized, for example, as “high,” “medium,” “low,” or “not detected.”
- Quantitative results consist of a numerical estimate of the concentration of a CWA or TIC. Uncertainty is relatively less at greater concentrations.

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E.3.2 Types of Limits of Detection

All analytical methods have LODs. This section summarizes LODs and how they affect statistical analyses of environmental samples. More detailed discussions can be found in EPA (2004), Helsel (2005), and Gibbons and Coleman (2001).

There are several types of LODs. The names used here are found in the literature, but there are no universally accepted names for the limits. The following concepts apply to quantitative methods. Starting with the lowest level or limit, the detection limits are:

- **Critical level.** A level above which an instrument signal cannot credibly have come from a sample in which the chemical of concern is not present. Such a signal is therefore considered to represent a detection. The signal is statistically greater than zero based on the noise in the system when analyzing samples without the chemical of concern. The critical level sets the false positive (false detection) rate of the method.
- **Detectable level.** The detectable level satisfies this criterion: when analyzing samples that are truly at or above the detectable level, the instrument signal is unlikely to be below the critical level. The detectable level sets the false negative (fail to detect) rate of the method.
- **Quantification limit.** A level at which the estimated concentration in the sample has a relatively low uncertainty (e.g., 10 to 20 percent).
- **Reporting limit.** An arbitrary level. A laboratory and its client agree that if the estimated concentration is greater than the reporting limit, the laboratory will report the estimated concentration, otherwise it will report that the chemical of concern was less than the reporting limit. The reporting limit is not actually a detection limit, but results less than the reporting limit are sometimes mislabeled as nondetections.

The critical level and detectable level are statistically defined concepts, and their definition is such that the critical level must be less than the detectable level. The critical level is used after a sample has been analyzed to decide whether or not the chemical of concern is present in the sample. The detectable level, in contrast, represents a level at which successful detection is likely. That is, when a chemical of concern is actually present in a sample at (or above) the detectable level, it is likely that presence will, in fact, be detected (where “detected” is defined as exceeding the critical level). The detectable level is a statement about the capability of the system to detect the chemical of concern, not a statement about any particular sample.

A quantification limit might be about 5 to 10 times greater than the critical level because the relative uncertainty tends to be high at levels close to the critical level. The reporting limit is usually above the detectable level because the client normally expects the laboratory to be able to detect the presence of the chemical of concern in samples when the actual concentration is above the reporting limit.

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The reporting limit should be well below any value of concern, such as a clearance goal. Otherwise unacceptably high concentrations might not be reported. Nondetections are normally reported as “less than L ” where L is the numerical value of one of the limits. It is important to know which limit is being provided in the report. For example, if L is the reporting limit, it is possible that a chemical of concern was detected in the laboratory, but that fact was not reported as such.

E.4 Software

Software is available to implement most of the methods described this Annex. The Visual Sample Plan software (VSP; Hassig et al. 2004) has a comprehensive set of options for creating statistically designed sampling plans for both indoor and outdoor settings. VSP and Hassig et al. (2004) can be downloaded free from <http://dgo.pnl.gov/vsp>. The Field Environmental Decision Support (FIELDS) software was developed by the EPA, Region 5. This software can be downloaded free from <http://www.tiem.utk.edu/~fields>. It offers a variety of design options. BROOM software, developed by researchers at Sandia National Laboratories, includes modules for optimizing some spatial designs. The Spatial Analysis and Decision Analysis (SADA) software is available at <http://www.tiem.utk.edu/~sada/>. SADA was funded by the EPA, Region 5, FIELDS Group and the U.S. Nuclear Regulatory Commission and was developed for outdoor applications; however, it may be useable for some indoor designs.

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Annex F

Annex F. Decontamination Technologies

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F.1. Introduction

Annex F focuses on decontamination technologies most appropriate for use in a large airport that has been intentionally contaminated with one or more CWAs or TICs. The content of this Annex does not cover all possible methods of decontamination; some methods that have been superseded by newer technologies are not included. The content draws heavily from existing information and data, in particular, from the U.S. Army (DOD 1990, Yurow 1981, Yurow and Davis 1982, Zamejc et al. 1985, and Grotta et al. 1983) and the U.S. Environmental Protection Agency (EPA 2005). Other government and private-sector organizations have studied decontamination technology for use against CWAs for decades.

A large airport contains many different types of areas that may need to be decontaminated, ranging from large, open atria to relatively narrow boarding areas and retail concessions. Airports have specialized equipment, such as baggage handlers and industrial air handlers, which can facilitate the spread of a CWA or TIC. Computers, security screening machines, and other complex equipment may need decontamination as well.

Because the term “CWA” encompasses several classes of chemicals, remediation will require the use of decontamination technologies appropriate to the specific chemical(s) and materials involved. Some criteria that drive the selection of a decontamination technology for civilian application are efficacy, toxicity, and environmental impact of the technology used. Such considerations are critical in the enclosed or semi-enclosed spaces of an airport that may require large quantities of decontamination reagent to be dispensed in restricted spaces. Whereas many decontamination technologies are in development at various stages, the decontamination recommendations in this Annex (Section F.4) focus on those that are commercially available. Recommendations herein are thus likely to require updating as new technologies become available and are proven for large-scale use.

F.2. Preparation for Decontamination

Remediation after a CWA or TIC attack will have much in common with a large hazardous material incident involving a highly toxic compound. Decontamination for reuse, as opposed to expedient decontamination to limit the spread and penetration into materials of chemicals of concern, should be conducted only after characterization has delineated the areal extent of contamination along with the types of materials and equipment that have been contaminated at one or more specific locations within an airport. See Section 1.1, the introduction to Section 2, Section 2.2.9, and Section 2.4.1 for discussions that pertain to the coordination of

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characterization with decontamination. The range of activities associated with remediation and leading to the actual implementation of decontamination is discussed in Section 3 of the main text. Other steps, such as providing indemnification for decontamination contractors, are addressed near the end of this Annex.

F.2.1. Isolation Barrier Technologies

Isolation of a contaminated area is typically required to prevent the spread of contamination by air movement or the movement of workers and equipment. Isolation of various parts of a building will also be required for several of the decontamination technologies.

The extent of isolation and type of isolation technologies used will depend on factors such as the type of CWA or TIC involved, size of the affected area(s), types of surfaces involved, and extent of contamination. Before constructing isolation barriers, it is helpful to have formulated a general idea of the decontamination approach so the planning team can accommodate egress corridors for removing carpet, ceiling tiles, and fixtures and plan for how decontamination work will proceed in a way that does not recontaminate completed work areas. If the CWA or TIC is relatively nonvolatile (has relatively low vapor pressure as does the nerve agent VX) and the area of contamination is small, discrete, and confined to limited surfaces, then it may be sufficient to simply cordon off the area. If the chemical of concern is highly volatile (has a relatively high vapor pressure, as does the nerve agent sarin), it will easily spread through the air. In such cases, sections of a building may need to be closed off using plastic sheeting, tape, and other products. Air movement from a contaminated area may also need to be controlled and either directed through appropriate filters (such as activated carbon) or diluted with clean air to a safe level.

A survey of air purification technologies (Peiterson 2001) provides a guide to the type of carbon impregnate to use for many different TICs, notably phosgene and hydrogen cyanide. Besides vendors of air purification technologies, information on the design and operation of carbon beds for capturing organophosphate compounds such as the nerve agents can be found in a report by Hughes Associates (Jonas 1988). This report compares absorption capacities and bed breakthrough times for different carbon sorbents for an organophosphate compound, dimethyl methylphosphonate, which is similar in structure to the G-series nerve agents, especially sarin. Graphitized carbon black and other commercial sorbents used for sampling gases all collect each of five organophosphate compounds commonly used as nerve agent simulants more efficiently than isopropyl alcohol and pinacolyl alcohol (Ellzy 1993).

Some plastics are known to be permeable to some CWAs. For example, polyethylene (polythene) and polyvinyl chloride (PVC) films have been reported to be fairly permeable to sulfur mustard, but much less permeable to VX (DOD 1990; Daugherty, Watson, and Vo-Dinh 1992). Chlorinated polyethylene films and duct tape show good resistance to CWAs. Although Tyvek provides good protection against particle contamination (bioagents), it is not recommended for chemical protection (Daugherty, Watson, and Vo-Dinh 1992; Pal et al. 1993). The resistance of a given polymer film to chemicals can vary by thickness and manufacturer. Special fabrics designed by the DOD for CWA personnel protection could also be considered for

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use in isolation barrier construction, although such fabrics (i.e. Hammer® Chemical Protective Overgarment, Saratoga® Chemical Protective Undergarment, Giat® SWAT One-piece Chemical Protective Overgarment, TOMPS® Two-Piece Chemical Protective Overgarment, LANX® Chemical Protective Undergarment) are not commercially available for this specific application. Such fabrics were designed to be impermeable to CWA vapors; are strong, durable, and lightweight; can be welded or sealed; and are resistant to decontamination reagents. However, they can be costly and could have a long acquisition lead-time. Thus, if they are used, consideration should be given to advance purchase and stockpiling.

Although the following examples demonstrate isolation barrier techniques used after a biological warfare agent (BWA) attack (i.e., use of *Bacillus anthracis*), many of the same techniques can apply for CWAs, such as sarin. During decontamination of the Hart Senate Office Building, construction and removal of isolation barriers was conducted by HMHTTC Response Team, Inc. At the Sterling Facility, the entire building underwent extensive sealing to prevent escape of particulates and gas from the facility into the atmosphere. The Sterling Facility was sealed from both the interior and exterior. On the inside, visible cracks in floors, walls, and ceilings were sealed with expanding foam sealant or silicone caulking; all floor drains were sealed; and windows on outside walls were covered. Seals were checked weekly during decontamination activities. On the outside, all visible cracks in walls were sealed with foam sealant or caulking; all skylights and any other openings in the roof were covered, sealed, and insulated with poly-sheeting and foil tape; truck dock areas were framed and covered with poly-sheeting; and all roof leaks were sealed.

A greater level of isolation can be achieved by creating negative air pressure to prevent the outward flow of air. Negative air pressure can be attained using portable, HEPA-filtered, negative air units. If gas- or vapor-phase decontamination is to be conducted, such units can also be used to prevent escape of the decontaminant, and can be fitted with carbon canisters or other filtration devices that can break down the decontaminant. Containment tents over contaminated areas can reduce the size of the equipment required for gas- or vapor-phase decontamination. Such tents can also be used to protect uncontaminated equipment, such as luggage scanners, from secondary contamination during characterization and other site activities.

F.2.2. Process for Selecting Decontamination Technologies

Figure F-1 summarizes a process for screening and selecting decontamination technologies. No perfect decontamination technology exists. Selection of decontamination technologies must be a site- and scenario-specific decision that takes into account tradeoffs among availability, effectiveness, reuse requirements, material compatibility, and waste-disposal implications. The magnitude of contamination and surface properties of materials also have major impacts on the efficacy of decontamination technologies. The screening process in Figure F-1 was used to develop the list of recommended decontamination technologies identified in Section F.4.

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Screening and Selecting Decontamination Technologies	
Establish reuse requirements for the contaminated items:	
<ul style="list-style-type: none"> • Reused item cannot be damaged/destroyed; hazard must be reduced below clearance guideline. • For disposal, damage is okay; intent is to protect workers doing demolition and disposal. 	
Identify decontamination requirements for:	
<ul style="list-style-type: none"> • Hot spots (see Section F.2.3) • Volumetric spaces (see Section F.2.4) • Sensitive equipment (see Section F.2.5) 	
List chemicals of concern	
List potential decontamination technologies (see Tables F-2, F-3, and F-4)	
Screen potential decontamination technologies considering:	
<ul style="list-style-type: none"> • Reactivities and hazards from Material Safety Data Sheets (MSDSs) • Reliability, availability, and maintenance • Time, efficacy, corrosiveness, toxicity, cost, and residue • Disposal volumes 	
Select decontamination technology or technology suite:	
Characteristics of contamination (from characterization sampling)	Decontamination method
	Surface reagents
Liquid contamination on nonporous and nonpermeable accessible surfaces (especially transferable contamination) ?	If yes, use liquids, foams, or gels
Liquid contamination on porous or permeable surfaces?	If yes, use liquids, foams, or gels
	Removal
Persistent and resistant to oxidizing vapors?	If yes, remove item or material
	Volumetric space
Volatile or natural decay?	If yes, use natural attenuation
Semi-volatile or temperature-sensitive decay?	If yes, use ventilation (ambient or hot air) (see Section F.3.3.1) If not, consider pilot-scale test of oxidizing vapor technology (See Section F.3.3.2)
Note that decontamination methods can be deployed in different orders, depending on conditions specific to a particular incident. For example, natural attenuation might be used first while contamination is being characterized, then if semi-volatiles were present, ventilation could be applied with the HVAC system while oxidizing vapor equipment is being set up to treat more persistent contamination. Alternatively, certain items might be treated first with surface reagents (liquids, foams, or gels) if a contamination were known to be located on accessible surfaces.	

Figure F-1. Process of screening and selecting decontamination technologies.

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The first step in screening is to identify the decontamination requirements for surfaces and hot spots, volumetric spaces, and sensitive equipment. Decontamination requirements will be driven, in part, by the maximum level of CWA or TIC that can remain following decontamination in a material, on a material's surface, and emitted as vapors from the material. Other considerations include minimizing the decontamination time, extent of destruction of equipment and materials, and amount of damage to structural materials within a facility. The second step is to list other chemicals, in addition to the CWAs or TICs, that may be of interest. Such chemicals could include cleaning and cooking materials in the area, petroleum fuels and lubricants, herbicides, and pesticides. The purpose of this step is to plan for, or to avoid, reactions that may occur between decontaminant technologies and other chemicals that are located at a facility. The remaining steps—listing, screening, and selecting potential decontamination technologies—are the subjects of the remainder of this Annex. For many chemical incidents, more than one decontamination technology can be selected, but Figure F-1 illustrates the key role that characterization sampling plays during the final selection of those technologies.

Decontamination technologies discussed in this Annex are applicable to a broad range of chemicals. Chemical properties, including reactivities, are important considerations in selecting decontamination technologies. Many such properties are shown in Table F-1. The nine chemicals in the table include the six CWAs and three TICs that are considered in this *Remediation Guidance* to represent significant threats to airports. The properties most relevant to selecting decontamination technologies are described in Section F.3.

The scope of this *Remediation Guidance* document is airport remediation after a CWA or TIC attack that occurs inside an airport terminal building. The discussion therefore focuses on treatments appropriate for interior equipment and materials. Remediation of outdoor airport equipment or building surfaces is not discussed. Different incident scenarios will result in different distributions of the types of decontamination needed. In some incidents, there may only be surface contamination in a small area, others will result in a more extensive and complex distribution of contamination. The most appropriate decontamination strategy will also depend on the exact CWA or TIC used. An attack involving a persistent CWA, such as VX, would require a different response from one involving a less-persistent CWA, such as cyanide or sarin.

Interior equipment and materials are subdivided into items for reuse and those for disposal. Examples of items in the disposal group include carpets, furniture, ceiling tiles, food, and general supplies. Such items would be either decontaminated in place before demolition or immediately removed to a holding area. If contaminated above acceptable levels for disposal, they would be decontaminated in the holding area, then disposed; therefore, the possibility of damage by the decontamination method is not an issue. Examples of items likely to be reused are structural elements, such as walls, beams, or floors, and sensitive or mechanical equipment that cannot easily be replaced, such as elevators, HVAC ducting, or baggage scanners. Materials and equipment in this group are further divided into three treatment categories: (1) liquid treatment of liquid-contaminated hot spots, (2) gas or vapor treatment of vapor-contaminated surfaces, and (3) sensitive equipment. The three categories are addressed in more detail below.

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Table F-1. Chemical and physical properties of airport scenario CWAs and TICs.

Properties of CWAs and CAS number	Tabun ^a (GA) 77-81-6	Sarin ^b (GB) 107-44-8	Soman ^c (GD) 96-64-0	Cyclosarin ^d (GF) 329-99-7	VX ^e 50782-69-9	Sulfur Mustard ^f (HD) 505-60-2
Corrosivity • pH • Steel corrosion (inches per year) ^g	Nonaqueous 4.08 × E ⁻⁴ @ 65°C	Nonaqueous ^h Stabilized GB can be stored in steel for ≤10 y @ 20–5°C	Nonaqueous 1.2 × E ⁻⁴ @ 65°C	Nonaqueous 6.36 × E ⁻⁴ @ 65°C	Nonaqueous High-purity VX stable in steel	Nonaqueous 1.2 × E ⁻³ @ 65°C
Ignitability • Flash point °C (F) • Oxidizer	78 (172.4) ⁱ No	>138 (280.4) ^j No	121 (249.8) ^j No	94 (201.2) ^j No	159 (318.2) ^j No	105 (221) ^{g,i} No
Reactivity Violent reaction with H ₂ O? Hazardous quantities of toxic gases, fumes, or vapors generated when mixed with H ₂ O? Reactive –S ₂ or –CN bearing waste? NFPA rating (0 to 4)	No ⁱ No ^k Potential ^{k,m} 1 ⁱ	No ⁱ No ^k No ^{k,n} 1 ⁱ	No ⁱ No ^l No ⁿ 1 ⁱ	No ⁱ No ^g No ⁿ 1 ⁱ	No ⁱ No ^l No ^g 1 ⁱ	No ⁱ No ⁱ No ⁱ 1 ⁱ
Boiling Point °C (F)	245 (473) ^j	158 (316.4) ^j	198 (388.4) ^j	239 (462.2) ^j	298 (568.4) ^j	218 (424.4) ^{o,j}
Melting Point °C (F)	-50 (-58) ^j	-56 (-68.8) ^j	-42 (-43.6) ^j	-12 (10) freezes at –30 (–22) ^{g,j}	-39 (–38.2) calculated ^j	14.45 (58.01) ^g
Molecular Weight	162.13 ^j	140.10 ^j	182.178 ^j	180.2 ^j	267.37 ^j	159.08 ^{j,p}
Physical State	Liquid (colorless to brown) ^j	Liquid (colorless) ^j	Liquid (colorless) ^j	Liquid ^j	Liquid (oily, amber-colored) ^j	Liquid or crystal (colorless, oily liquid or yellow prisms) ^{p,j}
Specific Gravity (g/mL)	1.07 @ 25°C ^j	1.10 @ 20°C ^j	1.02 @ 25°C ^j	1.13 @ 20°C ^j	1.01 @ 20°C ^j	1.27 @ 25°C ^g
Vapor Density (air = 1) ^j	5.63	4.86	6.33	6.2	9.2	5.4
Vapor Pressure (mm Hg) ^j	0.037 @ 20°C	2.10 @ 20°C	0.40 @ 25°C	0.044 @ 25°C	0.0007 @ 20°C	0.072 @ 20°C
Water Solubility (g agent/g H ₂ O)	7.2g/100g@20°C ^g	Miscible ^g	2.1g/100g@20°C ^g	3.7g/100g@20°C ^g	3.0g/100g@25°C ^o	0.92g/100g @ 22°C ^g practically insoluble

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Table F-1. Chemical and physical properties of airport scenario CWAs and TICs—continued.

Properties of TICs	Hydrogen Cyanide (AC)	Cyanogen Chloride (CK)	Phosgene (CG)
CAS number	74-90-8	506-77-4	75-44-5
Corrosivity • pH • Steel corrosion (inches per year) ^q	N/A < 0.002 @ 25, 50 75, and 100°C	N/A < 0.02 @ 25°C	N/A <0.002 @ 25°C (when dry) >0.05 @ 25°C (when containing 10% H ₂ O)
Ignitability • Flash Point °C (F) ^g • Oxidizer	-18 (-0.4) No	Nonflammable No	Nonflammable No
Reactivity Violent reaction with H ₂ O? Hazardous quantities of toxic gases, fumes, or vapors generated when mixed with H ₂ O? Reactive -S ₂ or -CN bearing waste? NFPA rating (0 to 4)	No ^{g,r} Potential ^{g, t} Potential ^x 2 ^y	No ^s Potential ^{u,v} Potential ^{u,yy} 2 ^s	No ^s Potential ^{g,w} No ^s 1 ^y
Boiling Point °C (F)	25.6 (78.08) ^z	12.8 (55) ^{g,z}	8.2 (46.76) ^z
Melting Point °C (F)	-13.4 (7.88) ^z	-6.9 (19.58) ^{g,z}	-128 (198.4) ^z
Molecular Weight	27.03 ^z	61.48 ^g	98.92 ^z
Physical State	Liquid or gas (bluish liquid or colorless gas) ^z	Liquid or gas (colorless) ^{g,k}	Gas ^z
Specific Gravity (g/mL)	0.68 @ 25°C ^g	1.19 @ 20°C ^p	1.38 @ 20°C ^l
Vapor Density (air = 1)	0.941 ^z	2 ^p	3.4 ^z
Vapor Pressure (mm Hg)	746 @ 25°C ^g	1010 @ 20°C ^u	1215 @ 20°C ^z
Water Solubility (g agent/g H₂O)	Miscible ^g	71.4g/1200g @ 20°C ^g	Limited solubility in water ^g

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Table F-1 footnotes:

- a Ethyl N, N-dimethylphosphoramidocyanidate.
- b Isopropyl methylphosphonofluoridate.
- c Pinacolyl methylphosphonofluoridate.
- d O-cyclohexyl methylphosphonofluoridate.
- e O-ethyl-S-(di-isopropylaminoethyl) methyl phosphonothiolate.
- f Bis-(2-chloroethyl) sulfide.
- g Potential Military Chemical/Biological Agents and Compounds FM 3-11.9, MCRP 3-37.1B, NTRP 3-11.32, and AFTTP(I) 3-2.55 (January 2005); available at Army Knowledge Online, www.us.army.mil.
- h Sarin hydrolyzes to yield decomposition products that include hydrogen fluoride and methylphosphonic acid. See *The Chemistry of GB (Sarin)*, Mitretek Systems at: <http://www.mitretek.org/ChemistryOfGBSarin.htm>
- i U.S. Army Soldier and Biological Chemical Command MSDS, Edgewood Chemical Biological Center, Aberdeen Proving Ground, MD 21010, 410-436-4411.
- j National Research Council, Committee on Toxicology (2003), *Acute Exposure Guideline Levels for Selected Airborne Chemicals*, Vol. 3, National Research Council, National Academies Press, Washington, DC (Nerve agents, pp. 39-43; Agent HD, p. 307); available at www.nap.edu.
- k Merck Index (2001), 13th Ed., Merck Research Laboratories Merck and Co., Inc., Whitehouse Station, NJ.
- l Clark, D. N. (January 1989), Review of Reactions of Chemical Agents in Water, Final Report to U.S. Army Biomedical Research and Development Laboratory, Battelle, Columbus, OH, Report ADA213287.
- m Waste will require monitoring to determine potential reactivity. When neat GA liquid is treated with high-pH chlorine decontaminant solutions, cyanogen chloride may be generated as an intermediate. Any resulting CK concentrations depend on reaction temperature, reaction yield, and other variables. See "Tabun," in *The Columbia Encyclopedia*, 6th Ed., Columbia University Press, New York, NY (2001-2004); available at www.bartleby.com/65/ (last accessed December 14, 2005).
- n Does not contain -CN anion, or nitrogen or sulfur (needed to form cyanide and sulfide-bearing compounds, respectively).
- o Nat. Library of Medicine, Specialized Info. Services, <http://www.sis.nlm.nih.gov/enviro/chemicalwarfare.html>.
- p National Library of Medicine, Toxicology Data Network, Toxnet, <http://toxnet.nlm.nih.gov/>.
- q Hamner, N. E. (1974), *Corrosion Data Survey (Metals section)*, 5th Ed., National Assoc. of Corrosion Engineers.
- r Unstabilized or impure hydrogen cyanide can polymerize violently, especially at elevated temperatures ($\geq 50^{\circ}\text{C}$) in a closed vessel with generation of gaseous products that can result in pressure rupture to a storage vessel. The conditions are unlikely under the current release scenario. Long storage can degrade stabilizers and lead to container rupture. See Aaron, H.S. (1996), "Potential Hazards in the Handling of Aged AC and CK Munitions; A Literature Review," in *Bretherick's Handbook of Reactive Chemical Hazards*, 6th Ed., Butterworth-Heinemann Ltd., ERDEC-SP-039.
- s NIOSH Emergency Response Safety and Health Database, Emergency Response Card; available at <http://ershdb.consolidatedsafety.com/AgentListAlpha.asp>.
- t Depends on concentration and solution pH. As HCN vapor reacts with plain water, it disproportionates into ions (H_3O^+ and CN^-) that form an acidic solution. HCN is not very water-soluble and cannot disproportionate in acidic waters. Thus, cyanide-bearing fumes would not be evolved. In high concentrations, HCN can begin to cyclize and form dark-colored and (violently) unstable compounds. This is a problem in closed vessels (see footnote r).
- u Lewis, R. J., Sr. (2000), *Sax's Dangerous Properties of Industrial Materials*, 10th Ed., Wiley and Sons, Inc.
- v Depends on concentration and solution pH. If water were introduced as mixed with a decontamination reagent, which is normally caustic and contains some oxidant, gases, fumes, or vapors may not be an issue. Water of a basic pH will capture cyanide and not release cyanide. The basic solution containing cyanide is acidified, and depending on the solution pH, HCN or HCl could evolve.
- w Depends on concentration and reaction chemistry of solution. Decomposition of phosgene in water yields HCl and CO_2 . Although HCl is soluble in water up to 30% (after which HCl in water is saturated and could evolve), presence of the CO_2 reaction product will tend to reduce HCl solubility in water.
- x Waste will require monitoring to determine potential reactivity. Although hydrogen cyanide (HCN) does not react when exposed to pH conditions between 2 and 12.5 to liberate dangerous quantities of toxic gas, neat HCN is, in and of itself, an extremely lethal cyanide-bearing gas.
- y NFPA 49 Hazardous Chemicals Data, 1994 edition.
- yy Waste from a CK release incident would require monitoring to determine potential reactivity.
- z NRC, Committee on Toxicology (2002), *Acute Exposure Guideline Levels for Selected Airborne Chemicals*, Vol. 2, NRC, National Academies Press, Washington, DC (HCN, p. 217; phosgene, p. 19); available at www.nap.edu.

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F.2.3. Decontamination of Surfaces with Liquids and Foams

Many of the materials and equipment in need of decontamination will fall into the “hot spots” category because the items will be heavily contaminated with a chemical of concern. Examples include walls, floors, and ceilings near the point of release where there may be droplets or puddles of a chemical of concern. Decontamination of hot spots most likely will involve liquid sprays, foams, or gels, which are most appropriate for nonporous and nonpermeable surfaces with good accessibility. Porous or permeable surfaces with liquid contamination will likely require removal, but surface decontamination may still be done to reduce the hazard associated with disposal. Several technologies are widely available and are discussed in Section F.3.

Variations within this category are important. Surfaces are likely to differ in the degree to which they are contaminated. Heavily contaminated areas, or hot spots, will require more extensive treatment than lightly contaminated areas. Some surfaces are easily accessible, whereas others (such as the interior of a HVAC duct) are not. Some materials are easily moved or replaced, whereas some are permanent parts of a structure. Different kinds of materials (wood, metal, tile, cloth, and plastic) will also differ in the degree to which they physically absorb or chemically react with a CWA or TIC and decontamination reagents. If decontamination for reuse is even possible, porous materials (wood, tile, wall board, and concrete) are likely to require a heavier application of decontamination reagent and a longer exposure time. After surface decontamination, permeable materials (paints, vinyl tile, elastomers), especially those exposed to liquid CWA or TIC for more than a few minutes, will likely require an evaluation to determine if agent that penetrated below the surface of the material still represents a hazard. Volatile agents will eventually offgas from or react with the surface and require no further surface treatment, but extremely low-volatility CWAs such as VX that have penetrated permeable materials may require multiple surface treatments or disposal. Different exposure situations will have different optimal treatments, but recommendations in this annex emphasize the smallest number of technologies needed to do the job.

Understanding how a chemical of concern chemically and physically interacts with the substrate material, plus interactions between the decontamination reagent and absorbed chemical of concern, are active areas of research. A limited number of answers to questions involving CWA fate are available at this time. The Department of Defense (DOD) is studying CWA fate for materials relevant to their mission, including some materials used in transportation facilities (Munro *et al.* 1999, Manthei *et al.* 1986, and Brevett *et al.* 2005). New experimental evaluations were performed for informing this *Remediation Guidance* about the extent to which CWAs are likely to sorb into, react with, or re-emit from a surface. The EPA’s National Homeland Security Research Center (NHSRC) is also also researching CWA fate and decontamination technology efficacy.

Hot spots may include materials destined for disposal rather than decontamination. Decontamination of such materials will not be highly time-critical and thus could be done in parallel with (or after) remediation of a facility because treating them would not be on the critical

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path for reopening a facility. In such cases, the goal is to decontaminate materials well enough that they meet applicable disposal requirements. Waste treatment and disposal (see Annex L) could represent a large part of the cost of building remediation. Emphasis should be on an inexpensive but thorough treatment that does not produce hazardous byproducts. Concerns about corrosivity or potential damage to a substrate do not apply in the context of disposal.

F.2.4. Decontamination of Surfaces with Gases or Vapors in Volumetric Spaces

In some cases, it may be appropriate to flood a volume of space with gases or vapors, rather than individually treating all the surrounding surfaces. The purpose of such an approach is to treat all surfaces at once, including hard-to-reach surfaces, rather than individual surfaces or merely the air volume itself. An example is a large room that is lightly contaminated, such as a passenger concourse that is only contaminated by air circulating from a different part of the airport where the actual release occurred. Another example is a region that is not easily accessible, such as HVAC ducts. Depending on the CWA or TIC involved, decontamination of volumetric spaces would be done by ventilation and weathering or by gas, vapor, or aerosol decontamination technology. Several such technologies that are available are discussed in Section F.3.

F.2.5. Decontamination of Sensitive Equipment and Items

This category of materials includes items that are critical for normal operations; would be difficult, expensive, or time-consuming to replace; but are likely to be damaged by standard decontamination treatments. A prime example is the Transportation Security Administration (TSA) luggage scanners, each of which costs more than a million dollars, has substantial lead times for replacement, and is heavy enough to make quick relocation difficult.

Other electronic equipment, such as standard computers, terminals, and fax machines, are not in this category. If decontamination of a persistent chemical of concern is required, then it may be faster and cheaper to replace such equipment rather than to decontaminate the items in a way that avoids damage. Such a recommendation does, however, assume that data stored on the equipment are adequately backed up elsewhere. Given the lack of reliable and quick options for decontaminating sensitive equipment, This *Remediation Guidance* recommends early isolation of any sensitive equipment that is at risk for further contamination by remediation activities. Such equipment can be isolated using tents or other materials described in Section F.2.1.

Decontaminating sensitive items will require item-specific decisions that should include the equipment manufacturer to ensure the equipment is able to be restored to its original function. Depending on the CWA or TIC involved, larger pieces of equipment could be treated with ventilation or fumigated using a gas, vapor, or aerosol technology; smaller items might be treated with solvent baths.

Artwork, which is often displayed in airports, is another example of sensitive items that require decontamination. Although artwork is not on the critical path for reopening a facility, some art is likely to be among the items requiring decontamination rather than being slated for disposal.

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Specific materials comprising a particular piece of art would determine the appropriate offsite decontamination strategy.

F.3. Survey of Decontamination Technologies

Decontamination methods are often categorized as physical and mechanical methods, chemical methods, or biological methods. Examples of physical and mechanical methods include wiping, adsorption, sandblasting, evaporation, or weathering. Such methods generally transfer the chemical of concern from the material of interest to a different material that may become part of a waste stream, but often do not actually neutralize the chemical of concern. In such cases, the waste stream may need to be treated using some other decontamination technology. Examples of chemical methods include reaction by application of a liquid or solid reagent, or gas- or vapor-phase decontamination. Such methods neutralize a chemical of concern by altering its chemical structure to make it less hazardous. Examples of biological methods include degradation via microbial or plant enzymatic pathways.

For CWA or TIC contamination of an indoor environment where time is an issue, chemical decontamination methods have generally been used and are probably the best developed. Accordingly, most of the discussion in this section concerns such methods. Other technologies under development that might be applicable in the future are briefly mentioned as emerging technologies. At present, such methods have insufficient test data using real CWAs or TICs to develop realistic decontamination protocols, or they may not be commercially available.

Chemical destruction of a CWA or TIC is generally accomplished through three types of reactions: hydrolysis, substitution, and oxidation. For discussions of the chemistry involved, see for example, Yang, Baker, and Ward (1992) or Wagner and Yang (2002). Proven decontamination compounds that can be used in different situations are available in gas, liquid, and solid forms. Hydrolysis can be done using water, hydroxyl ions, or other nucleophiles. The rate of hydrolysis and nature of products formed can depend on the solubility of the chemical of concern in water and on the pH of the solution. For example, HD is best hydrolyzed using neutral to acidic solutions – although its aqueous solubility is limited – whereas VX has a high aqueous solubility, and is most efficiently hydrolyzed in strong alkaline solutions (NRC 1996). Strong oxidizing chemicals, such as bleach, ozone, hydrogen peroxide, chlorine dioxide, and iodine, can destroy many chemical and biological agents, but they can also destroy or damage equipment. Effectiveness of the decontamination reaction depends on the specific chemical of concern, chemical conditions (e.g., solubility and penetration, of a CWA or TIC into the material, surface hydrations, pH, temperature, presence of reactive surface sites, and surface roughness, among others), and the specific decontamination reagent used.

The properties of CWAs and TICs that are most relevant when selecting decontamination technologies are (1) physical state, (2) vapor pressures and densities, and (3) reactivities. These properties are discussed in Section F.3.1. Sections F.3.2, F.3.3, and F.3.4 discuss the specifics of decontamination technologies for surfaces and hot spots using liquids or foams, or by flooding

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volumetric spaces with gases or vapors, and for sensitive equipment, respectively. In each case, a group of technologies is discussed because any given decontamination technology is unlikely to be satisfactory for all chemicals of concern and all contaminated objects.

F.3.1. Properties of Chemical Warfare Agents and Toxic Industrial Chemicals

The six CWAs considered in evaluating decontamination technologies include five nerve agents [tabun (GA), sarin (GB), soman (GD), cyclosarin (GF), and VX] and the blister agent sulfur mustard (HD). The three widely used TICs considered are hydrogen cyanide (AC or HCN), cyanogen chloride (CK), and phosgene (CG). Hydrogen cyanide is a precursor of many industrial chemicals and a common byproduct of chemical processes. Cyanogen chloride is used to fumigate ships and warehouses, in ore-extraction, for cleaning metals, and for synthetic rubber. Phosgene is used in large quantities for the synthesis of dyes, pesticides, bulk polymers, and other organic chemicals.

The six CWAs and hydrogen cyanide are less volatile than water at room temperature; whereas the remaining two industrial chemicals are virtually always gases. Raising the temperature of the liquid chemicals above the standard office temperature range of 68° to 78°F (20° to 25°C) can increase their vapor pressure; but raising the temperature has little effect on vapor pressure of industrial gases. At cooler temperatures, mustard can be present as a solid, and in very cold climates, cyanogen chloride can also be present as a solid in unheated buildings. Cyanogen chloride exists as a liquid only over a narrow temperature range, 20° to 55°F (−7° to 13°C).

The vapor pressure and volatility of both solid and liquid CWAs and TICs increase with temperature. In reference to decontamination, the terms persistent and nonpersistent do not equate only to volatile and nonvolatile. A volatile chemical of concern may persist for weeks in oils, grease, soils, and permeable materials such as rubber, carpet, and concrete. The vapor densities of CWAs are all much greater than that of air. Hence, vapors and gases from these chemicals can collect in low spaces, such as the bottom of stairwells and elevator shafts if there is no air current in the space. The TICs hydrogen cyanide, cyanogen chloride, and even the heavier phosgene have densities sufficiently close to air that they are less likely to accumulate in low spaces unless the air is very still. Even then, hydrogen cyanide would not accumulate in low spaces.

Many common materials can be used in an improvised manner to interact with or prevent the spread of CWAs and TICs. Many common reactive materials are recommended by the military as field expedients (methods that may not be optimized, but are quick and easy to apply) for decontaminating trace concentrations or disposing of small quantities of CWAs (DOD 1990, p. 783). Judicious and prompt use of improvised methods to remove liquid contamination on surfaces may significantly reduce decontamination times and the volume of wastes. Appropriate application of firefighting foam to prevent volatilization or absorbent fabric to soak up liquids can potentially result in important improvements in the surface contamination and facilitate an easier remediation of released CWA. For materials that are permeable to chemicals of concern, actual decontamination times may be on the order of days, weeks, or months rather than the

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minutes often cited in the descriptions, below, of several of the decontamination methods. Decontamination time for permeable surfaces may depend on factors such as the reactivity with the surface, the contact time for the agent on the material, diffusion time for the agent within the material, or diffusion time for the decontamination technology to permeate into the material to reach the agent.

Improvised approaches could be used during the emergency-response phase or early in the decontamination phase to clean up pools of liquid CWA or TIC; however, they may leave residuals that must be considered during selection of the final decontamination technology. For instance, emergency spraying of cold water from fire sprinklers could both condense and destroy phosgene or cyanogen chloride, leaving salts of hydrochloric acid as residuals. The CWAs are soluble in readily available hydrocarbon solvents, such as gasoline and diesel fuel. The nerve agents tabun, sarin, soman, cyclosarin, and VX are also soluble in water. Mustard is soluble in a mixture of water and either acetone or ethanol.

Material Safety Data Sheets (MSDSs) provide useful information for assessing hazards posed by combinations of decontamination materials and chemicals. For instance, the reaction of common cleaners with phosgene can proceed energetically, producing hot liquids and corrosive gases. Reactions of common cleaners that contain large amounts of water with hydrogen cyanide and cyanogen chloride, although less energetic, can produce steam and hot, corrosive gases. Such hazards are only a concern when substantial amounts of a chemical of concern are present, such as a pool of liquid, rather than in situations involving small droplets of the chemical or residual vapors. Ammonia, although itself corrosive, neutralizes the acidic gases released when industrial chemicals hydrolyze.

F.3.2. Decontamination of Hot Spots with Liquids or Foams

Contaminated surfaces can be decontaminated by either removing the entire surface and exposing a clean underlying layer, or by surface treatments that remove only the chemical of concern from the surface layer. Examples of surface-removal techniques include stripping paints, sandblasting concrete, and sanding wood. If effective, surface treatment is generally preferable to surface removal for both porous and nonporous surfaces. Several techniques for removing chemicals of concern from nonporous surfaces have been demonstrated to leave the surface intact. If a chemical of concern dissolves into paint or other surface coatings, stripping the coating may speed decontamination. For porous and permeable surfaces, the toxic chemical may penetrate into the material too deeply for surface removal alone to be an attractive option. For example, iodine imaging techniques recently developed at the Edgewood Chemical Biological Center (ECBC) have shown that surrogates or chemicals of concern can penetrate a centimeter or more into concrete, and presumably other porous surfaces as well. Removal or treatment of liquid contamination on the surfaces of porous and permeable materials soon after an incident (within minutes or hours) will reduce the severity of the surface contamination, which then leads to easier decontamination and reduced waste volumes. Surface treatment of liquid contamination days to weeks after an incident will make porous and permeable materials safer to handle for

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disposal (even if contamination on a given item cannot be reduced sufficiently for its reuse) and may permit the reuse of some nonporous and nonpermeable materials.

Several formulations are available for treating surfaces, including liquid sprays, gels, and foams. Tables F-2a and F-2b summarize data available on the performance of those technologies with HD, VX, and the G agents. Table F-2a summarizes data for the decontamination technologies where peer-reviewed publications are available to support performance. Table F-2b summarizes data for “emerging technologies,” defined herein as those technologies—regardless of the status or length of availability—when peer-reviewed data are unavailable, with limitations noted on the applicability of the reported data. Such sources include vendor and DOD reports posted on the Internet.

The term “gross removal” in Tables F-2a and F-2b (as well as in Tables F-3 and F-4) describes the performance of decontaminants with respect to the amount of CWA or TIC removed from a contaminated material, whether the contaminant is present in a bulk phase above the surface, adsorbed to the surface, or in the subsurface. References for gross removal data are provided when possible. A high gross-removal efficiency indicates that the mass of chemical of concern has been greatly reduced without regard to where contamination was originally present. A high gross-removal efficiency does not necessarily indicate that the decontaminated material is safe to handle or reuse. Conclusions about the safety of decontaminated materials would require data on residual CWA or TIC concentrations on or within the material. Most testing and evaluation reports on decontamination technologies either do not provide residual CWA or TIC levels or used methods with detection limits typically greater than levels of concern for civilians. Therefore, little to no data exist to conclusively state whether or not a given decontamination technology will adequately decontaminate a surface to any specified level of concern. Gross removals presented in the tables were determined using several different testing and evaluation methodologies, sometimes unspecified, and under a range of conditions. Hence, gross removals reported in the tables for different materials are not directly comparable with one another and should be viewed as only semi-quantitative.

In cases where numerical values for gross removal of CWA or TIC are not available, ratings such as “good” or “fair” are generally derived from reports that give results in such terms or, in a few cases, on expectations according to what is known about the chemistry of the decontamination method. Many of the test methods used by vendors and the DOD are not available for review. Consult the references and, for more recent references, the authors of identified reports, for additional information on test methods.

The ratings (L = low, M = medium, H = high) for corrosiveness, cost, and deployment are meant as general guides to the extent that a specific issue is important for a given technology. A rating of “L” favors selection of the technology while a rating of “H” suggests a significant hurdle or concern.

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Table F-2a. Decontamination technologies, with supporting peer-reviewed data, for treating hot spots.

Decon ¹ Technology	HD		VX		G Agents		Corrosive -ness	Deployment	Cost	Residue	Supplier
	Contact Time	Gross Removal	Contact Time	Gross Removal	Contact Time	Gross Removal					
L-Gel ²	24 hr	>99%	24 hr	69% on asphalt 99% on concrete	24 hr	98% on asphalt 99% on concrete	M	M	M	Yes	Proprietary; by special arrangement with LLNL
HTH ³	5 min	✓	5 min	✓	5 min	✓	H	H	L	Yes	Nonproprietary; easily formulated
STB ³	30 min	✓	30 min	✓	30 min	✓	H	M	L	No	Nonproprietary; easily formulated
Bleach ^{3,4}	5 min ⁵	✓	5 min ⁵	✓	5 min ⁵	✓	H	M	L	No	Nonproprietary; widely available
Decon Green ⁶	20 min 15 min	99.9% 99%	20 min 15 min	>99.9% 96%	20 min 15 min	>99.9% 90%	H	M	M	Yes	Proprietary; Strategic Technologies Enterprises

1. See the remainder of section F.3.2 for discussions on the reliability and completeness of data on gross removal.

2. Surface testing on concrete and asphalt surfaces, respectively (Raber et al. 2002), alkyd paint, polyurethane paint, indoor–outdoor carpet.

3. DOD 1990; for HD, see Yang et al. 1992; for VX see Durst et al. 1988; for GB see Rosenblatt et al. 1995; and for GD see Ekanow 1978.

4. Household bleach (5% sodium hypochlorite in water) diluted by adding 1 part bleach to 9 parts water (McGuire et al. 2001).

5. Slower decontamination for hydrophobic materials (see section F.3.2.1.4).

6. Wagner et al. 2010; CWA removal on CARC coupons (Wagner 2004c).

✓ Technology significantly reduced the mass of mobile CWA or TIC; numerical value not given. Gross removal varies with application method, especially for foams and liquids in which the chemical of concern is sparingly soluble. For the high initial CWA or TIC concentrations used for most of the measurements, gross removal is expected to be largely independent of the composition of the material contaminated.

For corrosiveness and cost, L = low, M = medium, H = high. For deployment, L = easy, M = moderately difficult, H = highly difficult.

For residue, Yes indicates the presence of visually noticable residue that must be cleaned off before reuse.

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Table F-2b. Emerging decontamination technologies for treating hot spots (little or no peer-reviewed data available).

Decon ¹ Technology	HD		VX		G Agents		Corrosive -ness	Deployment	Cost	Residue	Supplier
	Contact Time	Gross Removal	Contact Time	Gross Removal	Contact Time	Gross Removal					
DF-200 ²	30 min	>99.8%	30 min	>99.8%	30 min	>99.9%	L	M	M	Yes	Proprietary Modect, Inc., EnviroFoam Technologies Inc.
CASCAD ³	5 min	>99% ⁴	5 min	✓	5 min	>99%	L	M	M	Yes	Proprietary Allen-Vanguard
GDS 2000 ⁵	1 min 3 hrs	>99.8% 99.87%	1 min 3 hr	>99.8% 99.97%	1 min 3 hr	>99.8% 99.95%	—	M	—	Yes	Proprietary Kärcher Futuretech
Liquid ClO ₂ ⁶	—	—	Hours	Poor	—	None	M-H	M	L	No	Nonproprietary widely available
BIT ^{TM7}	sec to min	98%	sec to min	99% >99.999%	sec to min	99%	L	M	M	No	Proprietary L3 Titan
FASTACT [®] Powder ⁸	1 hr	60%	2 hr	99% (@50°C)	—	—	L	L	M	Yes	Proprietary Nanoscale Corporation
Alkaline solutions ⁹	Variable	Variable	2 hr pH 13	99%	<1 min pH 13	99%	H	L	L	Yes	Nonproprietary widely available

See footnotes to Table F-2b on the next page.

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Table F-2b footnotes:

1. Refer the remainder of section F.3.2 for discussions on the reliability and completeness of the data on gross removal.
 2. DF-200 efficacy measured in surface testing on chemical-agent-resistant coating (CARC) coupons in DOD testing (Tucker 2008).
 3. According to concentrations in liquids in a laboratory stirred reactor, posted on an Allen-Vanguard website (2005).
 4. Liquid-phase trials with liquid SDF™.
 5. First numbers: liquid concentrations in a laboratory stirred reactor (Franke and Toepfer 2002). Second numbers: field tests on painted metal at 12.5°C, includes cold water wash after treatment (Toepfer 2002).
 6. Review comments on aqueous chlorine dioxide reaction with VX (Rosenblatt 1995) and a 1969 internal Edgewood Arsenal research report cited by Durst et al. 1988. Several reports indicate that liquid ClO₂ does not decontaminate G agents (e.g., Grotta 1983; Rosenblatt 1995).
 7. See Binary Ionization Technology (BIT™) from L-3 Applied Technologies/Titan Corporation (<http://www.l-3com.com/divisions/overview.aspx?id=232>). Numbers are primarily for painted surfaces (CARC); additional number for VX is for bare metal surface.
 8. See Nanoscale Technologies, available at: <http://www.nanoscalecorp.com/content.php/chemdecon/home>; accessed March 3, 2011.
 9. Rosenblatt 1995.
- ✓ Indicates that the technology significantly reduced the mass of mobile CWA or TIC associated with a material, but a numerical value was not given. Gross removal of a CWA or TIC varies with application method, especially for foams and for those liquids in which the chemical of concern is sparingly soluble. For the high initial CWA or TIC concentrations used for most of the measurements, gross removal is expected to be largely independent of the composition of the material contaminated.
- Indicates that data are not available.
- For corrosiveness and cost, L = low, M = medium, H = high.
- For deployment, L = easy, M = moderately difficult, H = highly difficult.
- For residue, Yes indicates the presence of visually noticeable residue that must be cleaned off before reuse.

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Most performance testing of decontaminants has evaluated decontamination from a bulk solution or on nonporous and nonpermeable surfaces, which are the easiest matrices to decontaminate. Because most facilities have numerous porous and permeable surfaces, additional testing was performed specifically for this *Remediation Guidance* to evaluate the efficacy of four selected decontamination technologies [0.5% bleach solution with trisodium phosphate, Allen Vanguard Surface Decontamination Foam (SDF™), U.S. military Decon Green™, and Modec Inc. and EnviroFoam Technologies Sandia Decontamination Foam (DF-200)]. These four reagents were evaluated on typical civilian porous and permeable surfaces after exposure to the liquid CWAs sarin (GB), soman (GD), sulfur mustard (HD), and VX. Residual surface contamination on test coupons was periodically measured for up to 24 hr after applying one of these four reagents. Results from the studies indicate that aqueous-based decontamination liquids and foams have limited efficacy on hot spots associated with porous and permeable surfaces, and significant residual concentrations remained on or in such surfaces. Nonaqueous-based decontamination liquids and foams had improved efficacy over aqueous-based formulations for permeable surface hot spots, but they typically damaged polymeric material. Therefore and in general, liquids and foams do not have demonstrated efficacy in terms of the reuse of porous and permeable items with gross contamination.

Without full documentation, vendor and DOD reports that a decontaminant meets military standards are indicators, but not evidence, that it may also meet civilian standards. Military exposure limits are generally greater (less stringent) than civilian limits, so technical details on the military limits are necessary to assess the relevance of such limits to civilian requirements. On the other-hand, military limits on decontamination time are generally more stringent than civilian requirements. Therefore, some decontamination methods, notably natural attenuation, which are too slow for the DOD, may work in a civilian context. In a civilian context, many days rather than a few hours, may be available for decontamination.

The foregoing discussion illustrates the complex nature of chemical decontamination. This *Remediation Guidance* alone may be adequate to guide the reader in selecting decontamination technologies for easy-to-decontaminate materials and for identifying materials that are unsuitable for decontamination for reuse. Nonporous and impermeable materials such as glass, steel, other metals (e.g., copper in pipes), and graffiti-resistant wall paneling are examples of easy-to-decontaminate materials. All of the decontamination technologies evaluated specifically for this *Remediation Guidance* document (as well as most of those shown in Table F-2a) remove the bulk of surface contamination for such materials. For determining the disposition of other materials, especially ones that are dirty, porous, or permeable, the reader should consult with experts and reliable vendors who can provide recommendations specific to a facility or incident, or information on the latest developments in decontamination technologies.

Excluding furnishings that will be disposed, many types of surfaces can be present in airport buildings, including sealed concrete, painted and unpainted wood or wallboard, tile, metal, various plastic and composite materials, and glass. Although little test data is available for

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specific combinations of chemicals of concern and surface materials, some general guidance follows from considering the physical properties of the CWAs and TICs.

Numerous studies have documented the extended persistence of CWAs in porous and permeable matrices, such as paints, concrete, soil, and clothing (McGrath et al. 1985; Smith and Moyer 1988). If a CWA penetrates into a porous or permeable surface, hot spot decontamination may remove the surface contamination without destroying contamination within the material matrix. Such residual contamination can potentially migrate toward the surface via diffusion or displacement and re-accumulate on the surface of the material. Therefore, understanding the bulk contamination of materials is important when evaluating the significance of hot spot decontamination on the overall reduction of risk, both current and future.

F.3.2.1. Decontamination of Hot Spots by Technologies with Peer-Reviewed Data

The five decontamination technologies with supporting peer-reviewed data are discussed first, with citations provided. Emerging technologies are discussed in Section F.3.2.2, with supporting URLs or other information given when available.

F.3.2.1.1. *L-Gel*

Lawrence Livermore National Laboratory (LLNL) researchers have developed a decontamination technology, L-Gel (Raber and McGuire 2002; McGuire et al. 2001), which consists of a gelled decontamination material that is sprayed onto surfaces to be decontaminated. The gel is designed to adhere to vertical surfaces and the undersides of horizontal surfaces. It dries to a powder, so wiping or vacuuming after treatment may be required. L-Gel is not yet available commercially. It is based on Oxone™ (the active ingredient is potassium peroxydisulfate, a mixture of KHSO_5 , KHSO_4 , and K_2SO_4), a commercial product manufactured by DuPont, in an acidic aqueous solution. Initial laboratory tests showed that L-Gel (Oxone) is more than 99% effective at oxidizing both CWA and BWA surrogates that were placed on common materials, such as carpet, wood, and stainless steel. Previous research at U.S. military laboratories had demonstrated the effectiveness of Oxone in decomposing both VX and mustard-type agents (Yang et al. 1992). The more recently developed L-Gel 200 contains 10% t-butanol cosolvent to promote penetration on surfaces with heavily coated paint or varnish. Rinsing after treatment is optional.

L-Gel was independently tested on real CWAs at four locations from October 1998 to October 2000 (McGuire et al. 2001). The tests were conducted at the Military Institute of Protection, Brno, Czech Republic; Edgewood Chemical Biological Forensic Analytical Center, Maryland; the Defense Evaluation and Research Agency, United Kingdom; and the Soldier Biological and Chemical Command at Dugway. Field tests showed that L-Gel was a more effective decontaminant of agents VX, GD, and sulfur mustard than the military standard (calcium hypochlorite) on such materials as acrylic-painted metal, polyurethane-coated oak flooring, and indoor-outdoor carpet. Two of the field trials also demonstrated that the L-Gel 200 formulation improved penetration and thus promotes solution and oxidation in thickened CWAs. L-Gel 200

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was tested on real CWAs, such as thickened distilled mustard, thickened soman (persistent nerve agent) and VX, as part of the Restoration of Operations series of experiments at Dugway Proving Ground. The CWAs were applied on 16-gauge mild steel test panels painted with chemical agent resistant coating (CARC) (Mil-C-53039), Air Force air-ground equipment paint, (Mil-PRF-85285) and Navy shipboard coating (Mil-E-24635). Panel test results (McGuire and Raber 2001) for L-Gel 200 showed 64 to 82% of thickened distilled mustard destroyed on the test panel materials, 75 to 96% of thickened soman destroyed, and 80 to 91% of VX destroyed on the test panels, with the poorest decontamination performance in these tests consistently arising from Navy shipboard coating.

F.3.2.1.2. High-Test Hypochlorite (HTH)

High-test hypochlorite (HTH) is a powder of calcium hypochlorite. HTH is effective in destroying blister and V-series agents [Rosenblatt et al. 1995]. It is a long-practiced decontamination technology that can be used as a dry powder or slurry. However, HTH is highly corrosive, has a toxic vapor, attacks skin, and requires rinsing after treatment. Fire has been reported when a “significant quantity” of HD comes into contact with HTH powder (Yang et al. 1992).

The decontamination reaction time for mildly basic aqueous solutions of sodium hypochlorite is rapid—within a few minutes for HD (Yang et al. 1992) and VX (Durst et al. 1988; DOD 1990) or a few seconds for GB (Rosenblatt et al. 1995) and sufficiently short for effective decontamination of GD (Eskanow 1978). Actual decontamination times may be much longer for the many hydrophobic materials that are permeable to chemicals of concern and that HTH permeates slowly, if at all. Rapid decontamination of sulfur mustard with any aqueous solution often requires vigorous mixing or scrubbing to promote contact between aqueous decontaminants, including HTH and bleach, and the sulfur mustard, which is sparingly soluble in aqueous solutions. Longstanding practices in CWA laboratories confirm that basic solutions of HTH rapidly hydrolyze or oxidize the G and V nerve agents, HD, and sulfur mustard.

Small quantities of toxic products may result from the reaction of HTH with CWAs. Known toxic products include the sulfoxide formed from HD, and highly toxic products when reacted with VX at a pH less than 11 (Grotta 1983). HTH must be used with care around fuels and flammable materials with which it can react explosively.

F.3.2.1.3. Supertropical Bleach (STB)

Supertropical bleach (STB), which was standardized in the 1950s, is a mixture of 93% calcium hypochlorite and 7% sodium hydroxide. It is more stable than bleach in long-term storage, is easier to apply, and adheres to surfaces better. Supertropical bleach is effective against blister and nerve agents; therefore, it is considered to be an all-purpose decontaminating reagent. STB is a standard military decontaminant recommended for applications on contaminated roads and terrain or metals and fabrics (DOD 1990).

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STB is prepared as a paste by mixing solid STB with water (approximately 70% STB by weight). Slurries of 13 and 40% STB in water (by weight) are recommended for horizontal and vertical surfaces, respectively (DOD 1990). STB is caustic to skin and eyes and presents a vapor hazard to personnel; it is also highly corrosive to many materials. It requires rinsing after treatment. Because STB, like HTH, is a concentrated form of a hypochlorite solution, refer to the discussion of HTH, above, for an overview of reaction times, reaction conditions, and possible toxic byproducts and hazards associated with use.

F.3.2.1.4. Household Bleach

Household bleach usually contains 5% sodium hypochlorite in water. The diluted form for some decontamination purposes is made by adding 1 part bleach to 9 parts water (McGuire et al. 2001); a 2 to 6% solution of NaOCl in water has been used for skin and equipment applications (Yang et al. 1992). As hypochlorite is the active ingredient in aqueous bleach solutions as well as for HTH and STB, the reaction time is rapid with blister and nerve agents, within 5 minutes (DOD 1990; Epstein et al. 1956; Eskinow 1978; Durst 1988; Yang 1992). Actual decontamination times may be much longer than reaction times for the many hydrophobic materials that are permeable to chemicals of concern that household bleach permeates slowly, if at all. There is some concern that the reaction products from VX decontamination with bleach may be toxic (Grotta et al. 1983). Bleach solutions are corrosive and toxic, but they are an inexpensive decontaminant that is easily obtained (DOD 1990). Decontamination with bleach generally requires rinsing two to three times with water after treatment. Refer to the above discussion of HTH for an overview of reaction times, reaction conditions, and possible toxic byproducts associated with decontamination using bleach.

A dilute alkaline solution consisting of 5% sodium hydroxide was used to rapidly restore service after the sarin attack on the Tokyo subway system (Tu 2007). Rapid destruction of mustard would require agitation of the alkaline aqueous solution. Otherwise, sparingly soluble HD may polymerize at the HD–water interface and shield the bulk of contamination from hydrolysis (MacNaughton and Brewer 1994).

F.3.2.1.5. Decon Green™

Decon Green™ (Wagner 2002; Wagner 2004c; Wagner et al. 2010) is based on relatively nontoxic, environmentally acceptable materials, such as baking soda, hydrogen peroxide, a surfactant, and propylene carbonate co-solvents. Although not yet commercially available, production costs are projected to be relatively low for this decontaminant because all materials are commercially available and are associated with a broad industrial base. Decon Green™ is an organic solution, so CWAs and thickeners are highly soluble in this solution, and the claim is made—though with little supporting data—that it can reach chemicals of concern sorbed in other organic materials, such as paints or plastics. The organic nature of Decon Green™ makes concentration (which is beneficial for transportation and storage) difficult. The decontamination mixture will not freeze at subzero temperatures (Reynolds 2006), is effective at low temperatures (–32°C) in studies done with VX and HD simulants (Wagner et al. 2010), and is still effective at

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high temperatures. The oxidant in Decon Green™ is 35% hydrogen peroxide, which is reactive to skin. Rinsing painted, plastic, or rubber surfaces after treatment is recommended.

Decon Green™ has been developed to decontaminate VX, GD, and HD. It has been tested against these CWAs (including thickened HD and GC) at ECBC. Data from both laboratory stirred reactors and on CARC panels were reported (Wagner 2004c). At room temperature Decon Green™ removed about 90% of HD from a CARC panel. Treatment for 40 minutes at sub-freezing temperatures with a cold-weather formulation CA2WT (Cold and Arctic Weather Type) and subsequent rinsing with an aqueous polyethylene glycol solution removed on average 90% of VX and HD simulants from CARC aluminum disks (Reynolds 2006 and 2008).

Testing of Decon Green™ on polymeric surfaces and concrete specifically for informing this *Remediation Guidance* document generally showed limited efficacy of the liquid for CWAs on a surface where CWA had penetrated into the material. Bleach and foams out-performed Decon Green™ for penetrating highly polar concrete surfaces. However, Decon Green™ typically matched or outperformed the aqueous-based foams for most other surfaces tested. Decon Green™ was the only decontamination technology of the four evaluated (5% bleach solution, SDF™, DF-200, and Decon Green™) that was able to reduce residual HD contamination on latex-painted wallboard to below detection limits (<1 µg) within 24 hr. Decon Green™ also was the best decontamination technology of those studied for reducing residual VX contamination on latex-painted wallboard within 24 hr. Nevertheless, its application resulted in measurable VX residual contamination after 24 hr. The results of evaluations indicate that this organic formulation aids decontamination by reaching into organic materials to react with the penetrated CWA better than aqueous formulations.

Materials compatibility tests showed relatively little change to aluminum, steel, and tin, but some discoloration of copper. Some thermoplastic lenses had increased haze, but others were not noticeably affected. However, some paint surfaces (including CARC) were damaged after 24-hour exposure (Wagner et al. 2008). Decon Green™ can be applied by spraying and has been licensed to Strategic Technologies Enterprises, Inc. (STE), a subsidiary of STERIS Corp.

F.3.2.2. Emerging Technologies for Decontamination of Hot Spots

Several decontamination technologies, some of which are under development, may be useful in the future for decontaminating surfaces and hot spots. At present, however, they have not been proven to be effective against CWAs in independent tests reported in peer-reviewed publications. We refer to them as “emerging technologies” regardless of how long they have been available. For example, the results of testing DF-200—and most other results of vendors of decontaminants posted on the Internet or otherwise publicly available without complete descriptions of test methods and materials—must be assessed judiciously to evaluate applicability of the decontaminant. Some technologies, such as liquid chlorine dioxide, are widely available, whereas others are not. Examples of emerging technologies include the use of ultraviolet light or other photochemical methods, extraction techniques, additional enzyme-based technologies, inorganic catalysts, and plasma technologies.

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F.3.2.2.1. Sandia Decontamination Foam Technology (DF-200)

The DF-200 decontamination foam (Tucker 2003; Tadros and Tucker 2003; and Tucker et al. 2003) developed at Sandia National Laboratories (SNL) is based on a cationic surfactant system containing cationic hydrotropes to increase the solubility of CWAs and reactivity with nucleophilic reagents. A mild oxidizing agent, a solid form of hydrogen peroxide, is added at a low concentration. The formulation is a two-solution system that, when mixed, creates the decontamination solution. Hydrogen peroxide in the solution reacts with bicarbonate in the foam to form a highly reactive and oxidizing species, hydroperoxycarbonate. The formulation also contains a water-soluble cationic polymer to increase bulk viscosity of the solution, and fatty alcohols to increase the surface viscosity of the formulation. The formulation can be used in solution or foam form for decontamination. Rinsing after treatment is optional.

The technology reduces the surface concentrations of both CWAs and BWAs, including use in emergency response situations where the actual chemical of concern may not be known. It is also effective for many TIC threats. Tests of DF-200 effectiveness on chemicals of concern, primarily for military applications, have been performed by the ECBC, by the Illinois Institute of Technology Research Institute (IITRI), by the Southwest Research Institute, and for DARPA (Applied Physics Laboratory of The Johns Hopkins University). The most complete test results available conclude that DF-200 foam is suitable for decontaminating free chemicals of concern on the surface of impermeable and nonporous materials to military standards, but not for other materials, notably elastomers. The limited information on test methods, conditions, and the military standards provided indicates that DF-200 is promising for civilian impermeable and nonporous materials. Testing of DF-200 on polymeric surfaces and concrete specifically for informing this Remediation Guidance Document showed limited efficacy of DF-200 foam for CWAs on these surfaces where CWA had penetrated into the material

The tests with DF-200 foam applied to surfaces contaminated with GD, HD, and VX effectively decontaminated those surfaces coated with a chemical agent resistant coating (CARC) of GD, HD, and VX. Results with other surfaces, including a rigid polycarbonate polymer and an elastomeric rubber, were mixed. These results, and results with other decontaminants used in the tests, are consistent with the expectation that once a chemical of concern has penetrated elastomers or other materials, the materials will be difficult for any decontamination method to decontaminate quickly without degrading the material. For reuse of such materials, the only recourse may be to apply a decontaminant such as DF-200, and wait, depending on the degree of exposure and permeability of the materials, days or weeks for the chemical of concern to diffuse back out of the materials to the surface.

Many publicly available DF-200 tests were performed on surfaces with free liquid rather than foam, and the developer claims that the foam performs as well as the free liquid is incompletely substantiated. Other publicly reported tests were performed in solution, especially aqueous solution, and provide an upper limit on the potential of a decontamination fluid to perform on a

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surface, but provide little insight into what residual concentrations are likely to remain on surfaces after decontamination.

Solution test results summarized by Modec Inc., a supplier of DF-200 (Sandia 2008), show that DF-200 has the capacity to neutralize more than 99% of GB, HD, and VX in solution within minutes. Similarly, a small-scale reaction-rate test in solution showed that the liquid used to produce the foam attained complete destruction of GD and VX within 10 minutes, and HD within one hour. The DF-200 decontamination foam is commercially available from Modec Inc. and EnviroFoam Technologies.

F.3.2.2.2. GDS 2000

GDS 2000 (Franke and Toepfer 2002) is a nonaqueous decontamination system based on alkoxides. It consists of several components including an aliphatic alcohol, two amino alkoxides, and an aliphatic triamine or a cyclic amide. It is the latest in a series of decontaminants, such as GD 5/6, developed and sold by Kärcher Futuretech GMBH. Although no data were available to support the claim, it may be that nonaqueous solutions more efficiently detoxify CWAs that have penetrated paint coatings or polymeric materials than aqueous solutions. In contrast to aqueous solutions, which can be stored as concentrates with water added prior to use, nonaqueous decontaminants require more space for transport and storage.

GDS 2000 has been shown to be effective against HD, GD, and VX (as well as some thickened agents). Field tests on painted samples were done by Kärcher and the Military Technical Institute of Protection in Brno, Czechoslovakia. Laboratory stirred-reactor measurements, which determine the maximum capacity of the formulation under ideal conditions, were done at the German Armed Forces Institute for Protection Technologies, in Munster, Germany. A post-treatment wash with water or steam is recommended but not required. Similar to the results of available data for both DF-200 and SDF™, the decontamination efficiency of GDS 2000 is expected to vary with the permeability and porosity of the surface and to be greatest for impermeable and nonporous surfaces.

F.3.2.2.3. Canadian Aqueous System for Chemical–Biological Agent Decontamination (CASCAD™) and Surface Decontamination Foam (SDF™)

Surface Decontamination Foam (SDF™) is a member of the foam family based on the Canadian Aqueous System for Chemical/Biological Agent Decontamination (CASCAD™) that has been designed and tested specifically for building decontamination (Allen-Vanguard 2008). According to the manufacturer, whose claims are supported by the Canadian government laboratory that developed the foam, a part of Defense Research and Development Canada (DRDC) (Defense Canada R&D 2008), the foam decontaminates chemical and biological agents for building cleanup without damaging contaminated surfaces or sensitive equipment. DRDC further modified the SDF™ so that it can be used for an extended time and in colder climates. Additional work on design of the application equipment has resulted in claims that CASCAD™ and SDF™ formulations are suitable for dual use as a blast containment and mitigation foam

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(DSF and DDSF formulations). Although the posted results are consistent with expectations in terms of the chemistry of chemicals of concern and the decontamination process, insufficient information on test methods is available for an independent assessment of the claims.

The CASCAD™ foam family (see Defense Canada R&D website 2008) contains active ingredients derived from readily available industrial chemicals. The foam comes in the form of two concentrates, which, when mixed with water, generate a low-corrosivity foam that decontaminates surfaces or materials contaminated with G- and V-type nerve agents, vesicant agents (such as mustard gas, nitrogen mustards, and lewisite), organophosphorus pesticides, and many recognized BWAs. Rinsing after treatment is optional.

CASCAD™ formulations and associated application equipment have undergone evaluation in a series of live-agent (mustard) field trials (Trial EvDecon), which were integral with training exercises for Canadian Forces (CF) Decontamination Units and the CF Nuclear, Biological, and Chemical Response Team. The results of many of these and later trials are available from Allen-Vanguard (Allen-Vanguard 2008). The trials found CASCAD™, and presumably the milder SDF™ formulation, to be compatible with electronic equipment, coatings, and one polymer, polycarbonate. Other liquid-phase trials found liquid SDF™ to destroy more than 99% of the following CWAs within 40 minutes: tabun (GA), sarin (GB), soman (GD), GF, VX, and mustard (HD). As expected, decontamination efficiencies were less for surfaces, with liquid SDF™ decontamination efficiencies varying between 50 and 100% for pesticides on painted steel, floor and ceiling tiles, carpet, painted steel panels, wallboard, carpet, steel plates, and vinyl floor tile. The pesticides tested included the organophosphates diazinon and malathion and the carbamates methomyl, oxamyl, and carbofuran. Variable decontamination efficiencies were also obtained in testing of SDF™ decontamination efficacy for CWAs on painted steel panels, wallboard, carpet, varnished wood, floor tiles, asphalt, concrete, and rubber tires. As noted for DF-200 in Section F.3.2.2.1, the value of results from liquid-phase trials and liquid solutions of decontaminants such as SDF™ and DF-200 applied to surfaces for estimating the efficacy of foam applications to surfaces is unknown.

Testing of SDF™ foam on polymeric surfaces and concrete specifically for informing this *Remediation Guidance* document showed limited efficacy of the foam for CWAs on these surfaces where CWA had penetrated into the material. For example, on horizontally oriented, latex-painted wallboard, SDF treatment reduced residual GB contamination from ~50% to no difference compared to no-treatment controls after 24 hr. Reduction of HD contamination on horizontally oriented, latex-painted wallboard after SDF treatment was measured to be ~88% after 24 hr. Reduction by SDF of GD on latex-painted wallboard was ~82% after 24 hr. SDF left a residual contamination of ~43% of VX on latex-painted wallboard. On horizontally oriented concrete with initial HD contamination, SDF treatment performed in a manner similar to that for no-treatment controls, suggesting that the concrete tested has a reactivity that affects the observed degradation of HD more than the treatment technology itself. The performance of SDF on VX residual contamination on concrete was better (from 370 µg starting concentration to 6 µg residual contamination after 24 hr).

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SDF™ can be readily applied to vehicle and aircraft surfaces using in-service Kärcher Multi-Purpose Decontamination Systems (MPDS) and a DRDC Suffield-developed inductor system. The foam reduces the amount of CWA vapor emanating from contaminated surfaces, in many cases to below the detection limits of CWA monitoring equipment. In one successful test, after allowing the decontaminant to remain on vehicle surfaces for approximately 20 minutes, with scrubbing for some absorptive surfaces, then rinsing off with water, no residual contamination was detected. SDF™ is commercially available from Allen-Vanguard and Life Safety Systems.

F.3.2.2.4. Liquid Chlorine Dioxide (ClO₂)

Liquid chlorine dioxide (ClO₂) is a strong oxidant, but its effectiveness for decontaminating chemicals on surfaces has not been well documented. Liquid chlorine dioxide is a solution of gaseous chlorine dioxide dissolved in water. Like gaseous chlorine dioxide, liquid chlorine dioxide may perform well against mustard and VX (Popov 1967). The liquid form, like the gaseous form, is not expected to react with G agents (Grotta 1983; Rosenblatt 1995). Solution-based testing has been done by the EPA (EPA/600/R-09/012).

Liquid chlorine dioxide can be applied by wiping, mopping, or spraying. Such formulations were first registered in the 1960s as disinfectants and are used for a variety of applications including on pets and farm animals; in bottling plants; in food processing, handling, and storage plants; and in many others. This commercially available sterilant was used during decontamination following the U.S. anthrax incidents (EPA website 2005).

F.3.2.2.5. Binary Ionization Technology (BIT)

BIT™ is the patented process of spraying an atomized cleaning and disinfecting mist (less than 7.5% hydrogen peroxide) through an atmospheric cold plasma (Titan Group 2008). The plasma creates a high concentration of oxidative reactive oxygen species (ROS), such as hydroxyl ions that concentrate on the atomized droplet surfaces. Because of the unique physico-chemical structure of the charged droplets, the hydroxyls remain uncombined with atmospheric products for as long as ten seconds, allowing time for the spray to reach airborne or surface-attached CWA. About 10 seconds after initial formation, the radical species lose enough energy to allow recombination with the air, and the sterilizing mixture dissociates into environmentally friendly water and gaseous oxygen. Because of the short life of the oxidative mixture, the mixture does not damage a treated area, and no secondary cleanup is required. L3 Titan Corporation has prototype spray and air-purification units.

The BIT system has primarily been tested against biological warfare agents, but it has undergone limited testing against CWAs at the ECBC. On bare metal, BIT showed a high efficacy of >5 log reduction of VX. On painted surfaces (CARC), 1.6 to 2 log reductions were observed for HD, GD, and VX. About 1% of the CWA is reportedly absorbed into CARC and cannot be removed unless strong solvents are used. In laboratory tests against aerosolized HD and VX surrogates, BIT showed >5 log reductions in airborne concentrations with a <0.2 sec interaction time.

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F 3.3.2.2.6. FAST-ACT

One emerging technology that is commercially available is FAST-ACT[®] nanoparticles. FAST-ACT[®] is a fine powder marketed for first response for a broad spectrum of chemicals. The powder includes magnesium oxide (MgO) and titanium dioxide (TiO₂) particles with high surface area, small crystallite sizes, and high porosity. The reactivity of nanoparticles with chemicals of concern is documented in the peer-reviewed literature (Wagner 2000a; Wagner 2001a). The FAST-ACT[®] powder has been demonstrated by Battelle and ECBC to decontaminate HD, VX, and GD (see Nanoscale Technologies website provided in the References). The fine powder is primarily intended for use outdoors. The powder is not recommended for decontamination of large areas in an indoor facility in that it would be difficult to clean up after use.

F.3.3. Decontamination of Surfaces with Gases or Vapors in Volumetric Spaces

Most cases of CWA contamination have generally been treated by surface decontamination, and little test data are available for decontamination technologies using gases and vapors in volumetric spaces against real CWAs. Table F-3 summarizes the data available on performance of technologies for volumetric spaces contaminated with HD, VX, and G agents. The ratings (L = low, M = medium, H = high) for corrosiveness, cost, and deployment are meant as general guides to the extent that a specific issue is important for a given technology. A rating of “L” represents a low barrier to using the technology, whereas a rating of “H” represents a high barrier. The disparate data on gross removal of CWAs were collected using a variety of procedures on various materials, so most quantitative measurements in the table for the various decontamination materials are not directly comparable. See Section F.3.2 for a discussion of the limitations of data on gross removal. All of the materials are assumed to be clean; dirt, especially oils, on materials may protect the chemical of concern indefinitely. Very few of the analytical methods used were sufficiently sensitive to detect contamination at concentrations required to assess the suitability of a material for reuse. Instead, decontamination performance assessments are derived from measurements of the gross removal of contamination. The greater the gross removal, the greater the reduction in CWA remaining as a potential hazard. In cases where numerical values for gross removal are not available, ratings such as “good” or “fair” are derived from reports that give results in such terms, or in a few cases, on expectations according to what is known about the chemistry of the decontamination method.

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Table F-3. Expected effectiveness of decontamination technologies for volumetric spaces (developer and vendor data).^{a,b}

Decon Technology	HD		VX		G Agents		Corrosiveness	Deployment	Cost	Residue	Supplier
	Contact Time	Gross Removal	Contact Time	Gross Removal	Contact Time	Gross Removal					
Natural attenuation	Days to weeks ^c	Decreases with increasing polymerization	Days to months ^d	Unknown	GB: hours Others: days to weeks	Good	L	L	L	No	Nonproprietary widely available
Forced ventilation	Days to weeks ^c	Decreases with increasing polymerization	Days to months ^d	Unknown	Days to weeks	Good	L	L	L	No	Nonproprietary widely available
Hot-air ventilation	Days ^c	Good	Days	Unknown	Hours	Good	L	M	L	No	Nonproprietary A&E Firm ^e
Steam	Hours	Good	Hours	Good	Hours	Good if condensate alkaline @ low temps	H	M	L	No	Nonproprietary A&E Firm ^e
mVHP [®]	Hours	Good	Hours	Good	Hours	Good	L	M	M	No	Proprietary STERIS
Ammonia (gas)	—	Good	—	Poor	—	Poor	M	M	M	Yes	Nonproprietary A&E Firm ^e
Ammonia (gas) and steam	Minutes	Good	Days	Good	Minutes	Good	L	M	M	Yes	Nonproprietary A&E Firm ^e
ClO ₂	—	—	Hours	Fair	Hours	Poor	H	M	H	Yes, must be neutralized to minimize corrosion	Proprietary Sabre

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Table F-3. (Continued.)

Decon Technology	HD		VX		G Agents		Corrosiveness	Deployment	Cost	Residue	Supplier
	Contact Time	Gross Removal	Contact Time	Gross Removal	Contact Time	Gross Removal					
Ozone ^f	—	Good	Hours	Fair – toxic byproducts	—	None	M	M	M	No	Nonproprietary A&E Firm ^e
Perchloryl fluoride	—	Fair (thin films only)	Hours	Poor	—	—	H	H	H	Yes	Nonproprietary limited distribution A&E Firm ^e
Nitrogen tetroxide	Hours	Good	—	—	—	None	H	H	M	No	Nonproprietary A&E Firm ^e

^a General notes: Numerical values for efficacies are not available, thus qualitative indicators are used. Gross removals are an assessment of the fraction of associated contamination removed from a material.

For corrosiveness and cost, L indicates low, M indicates medium, H indicates high.

For deployment, L indicates easy, M indicates moderately difficult, H indicates highly difficult.

For residue, Yes indicates the presence of visually noticable residue that must be cleaned off before reuse.

— Indicates that data were not available.

^b Except for hydrogen peroxide, Grotta et al. (1983) estimates performance of all these vapor-phase decontaminants for at least one CWA. All materials are assumed to be clean. See text for other references supporting table entries, especially decontamination efficacies.

^c 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.

^d For VX, efficiency depends on droplet size. Although nonzero vapor pressure suggests VX will eventually vaporize, no experimental studies were found of the extent of VX vaporization from surfaces.

^e Architectural and Engineering Firm.

^f See Wagner et al. (2000b) for efficacy with VX and GD.

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F.3.3.1. Hot Air, Ventilation, and Monitored Natural Attenuation

Natural attenuation, or weathering, refers to physical and chemical processes that occur in the absence of active and engineered decontamination. Depending on the properties of a CWA or TIC, the chemical of concern may evaporate or react with either chemical species that naturally occur in the air or material on the surface underneath the contamination. If volatility is sufficiently high, ventilation with room temperature or heated air represents an inexpensive method for large-scale decontamination. Ventilation is most useful for decontaminating an indoor volumetric space that is bordered by hard surfaces, lightly contaminated, and contaminated with a nonpersistent—especially gaseous—chemical of concern. Ventilation may also be useful in other cases, such as for sensitive equipment or materials destined for disposal. Ventilation with moist air may be useful for low volatility water-soluble chemicals that react with liquid water, but the potential corrosion that could result may be prohibitive in practice.

Natural attenuation will occur during much of every remediation period, both during characterization and after decontamination with a more aggressive technology. For low-permeability materials into which significant CWA has penetrated, even after active surface decontamination, many days or even weeks may be required for natural attenuation to reduce to safe levels the rate of transport of CWA from the subsurface back to the surface. Primarily for this reason, decontamination for reuse by natural attenuation, or any other method, of most porous or permeable materials that can be removed, such as carpets, is not recommended.

Many polymeric materials used in aircraft absorb more than 3% of their weight of CWAs when exposed to vapors of GD), sulfur mustard (HD) and VX for days or weeks (Pfau et al. 1988). Many of these same materials, including nylons, thermoplastics, elastomers, fluoroelastomers, silicone, grease, acrylics, polyurethane enamel, polyacrylate, and fluorocarbons, may also be used in facilities. Other materials absorbed less than 1% of their weight of CWAs, including a two-part polyurethane coating, a graphite fiber thermal plastic, polyimide thermosets, a Kevlar composite, epoxy composites and adhesives, a polyester and fiberglass composite, and mylar. After decontamination of the surface, return of contamination from the subsurface for many of these materials—some of which continued to take up CWA after 15 weeks—would be expected to continue for months. Such recontamination of the surface would be at lower rates than the original uptake of the CWA by the material. No information on the magnitude of the hazard presented by the movement of subsurface contaminant back to the surface was provided by Pfau et al. (1988).

Structural concrete, which is porous and permeable, is an exception to the recommendation to dispose of contaminated porous or permeable materials rather than decontamination for reuse. The effectiveness of natural attenuation and of active ventilation with air for decontaminating concrete for reuse must be thoroughly evaluated. Unsealed concrete may decontaminate itself. Studies on unsealed concrete (Groenewold et al. 2002; Wagner et al. 2001b) have shown that chemical reactions occur that slowly decompose CWAs. Painting or sealing of concrete adds complications. Military studies (Sidman et al. 1982) and those done to inform this *Remediation*

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Guidance documents have shown that CWAs sorb into paint layer(s) and then can be difficult to remove or neutralize. Once absorbed, vapor off-gassing is greatly suppressed in magnitude but is extended over long times. Extended monitoring or aggressive surface treatment will be required for chemicals that permeate into paint and concrete surfaces.

When ventilation with hot air is appropriate, a building's HVAC system could be used to decontaminate a building, although supplementary fans might be needed to ensure that locations in a facility where the air is stagnant have sufficient air circulation. The exhaust plume leaving a building may also need filtration or treatment. Some airports, such as LAX, have carbon filters in HVAC systems.

The time required for ventilation is likely to range from a few hours for gaseous chemicals, such as phosgene and cyanogen chloride, to many days or weeks for persistent chemicals (mustard and VX) and nonpersistent chemicals (such as sarin), which persist after they permeate into materials. The rate of surface decontamination by evaporation is governed by several factors, including CWA volatility, air speed, temperature, humidity, as well as droplet size (and the use of thickeners) and the rate of permeation out of the underlying material. Characteristics of a surface, such as porosity and the presence of paint, dirt, or grease, are also likely to alter the effectiveness of decontamination by ventilation.

The G agents sarin and soman and small, dispersed droplets of the blister agent HD can be removed by ventilation before they permeate far into moderately permeable materials. Because nerve agents hydrolyze relatively quickly, treatment of low-volatility agents, such as VX, with aqueous solutions may be preferable to ventilation. However, such treatment must be done with care because it may form EA2192 if not done correctly. HD requires surfactants or other solubility enhancers before it will hydrolyze rapidly in aqueous solutions. For outdoor contamination, predicted persistence times of ~30 to 50 hours (at 25°C for a 1500× decrease in the amount of HD on a surface) have been published for large HD droplets, depending on wind speed and rain conditions. Ventilation of large HD drops or deep pools for more than a few days may not be effective. HD at an air interface eventually polymerizes and forms a heel, a nearly impermeable layer that prevents underlying mustard from volatilizing. Such aged HD has persisted for weeks in soils contaminated with bulk HD (and some soil may be present indoors, e.g., in potted plants). For VX persistence, an estimate in the literature is that 90% of initially applied VX in soil would be lost in ≤15 days (Watson and Griffin 1992).

For volatile and semi-volatile CWAs, a variety of equipment could be used to heat a building to accelerate ventilation of chemicals of concern. An unmodified building HVAC system may be able to bring building temperatures to 40°C or higher, and up to 60°C with supplemental heaters installed in the HVAC system. At temperatures greater than 60°C, insulation on wires and some plastics begin to soften and degrade. The maximum hot-air temperature assumed in the tables in this section is 60°C, which would require no extraordinary measures to protect building contents from temperatures higher than those reached in August in Phoenix.

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Porous and permeable materials, such as carpets, elastomers, and many plastics, should usually be removed before or during ventilation. Such materials are likely to absorb chemicals and may slow their natural degradation and then release the chemicals slowly back to the air. Most crosslinked polymers, such as melamine resins used in plastic kitchen utensils and dishes, formica, and wall panels, and phenolic resins used in wall panels, are nearly impermeable to chemicals and can be left in place without undue risk of extending cleanup times. Except for a few chemicals of concern, especially gaseous chemicals that do not permeate, removal of porous and permeable materials will reduce the decontamination time. Porous and permeable materials may be partially decontaminated in place prior to removal to facilitate their handling and disposal.

F.3.3.2. Vapor-Phase Hydrogen Peroxide with Ammonia

The vapor-phase hydrogen peroxide process typically involves flash vaporization of an aqueous peroxide mixture that is delivered to the decontamination area. The mixture is generally close to, or greater than, the saturation level in air and may require humidity control before and during treatment. Hydrogen peroxide decomposes to water and oxygen, and it leaves no residue. Use of the vapor form minimizes corrosion and optimizes distribution of the decontamination chemicals. Vapor-phase hydrogen peroxide generators are available from both Bioquell and STERIS. STERIS also provides a complete system, called the VHP[®] system, for using vaporous hydrogen peroxide to decontaminate rooms.

Vapor-phase hydrogen peroxide is more widely known as a biological agent decontaminant, but it has also been proposed for decontamination of CWAs as well. Recent studies at ECBC have shown that the addition of low levels of ammonia gas renders vapor-phase hydrogen peroxide reactive towards GD, converting it to pinacolyl methylphosphonic acid. This modified vaporous hydrogen peroxide process results in the broad-spectrum decontamination of agents VX, GD, and HD and is available commercially from STERIS as their proprietary mVHP[®] process.

Demonstration tests involving gas- or vapor-phase decontamination of HD, GD, and VX at the room scale were conducted using a building at ECBC and a C-141 aircraft at Davis-Monthan Air Force Base (Wagner et al. 2004a and b, Brickhouse et al. 2007a and b). Large-scale tests in ECBC engineering chambers evaluated the use of mVHP[®] to decontaminate real CWAs on various materials, including stainless steel, glass, CARC-painted steel, aluminum 2024, Air Force topcoat-coated aluminum, butyl rubber-covered cloth, Kapton, nylon webbing, and concrete. At treatment levels of 250-ppm VHP[®] + 20-ppm NH₃ for 24 hours, the residual CWA contact and off-gas hazards were reduced to minimum detection levels on most test materials. For HD vapor hazard, however, detectable amounts remained, especially on porous surfaces, which may require longer mVHP[®] treatment times. For their large-scale tests, ECBC placed hydrogen peroxide generators throughout the building rather than generating hydrogen peroxide at one location outside the building and distributing it through a network of pipes. Like many

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oxidants, hydrogen peroxide is short-lived, and its destruction is catalyzed by many common materials, especially the metals in ductwork (Verce 2008).

Recent EPA (2010) and DoD (2007) studies have examined the potential for modified vaporous hydrogen peroxide to be used for CWA remediation in civilian remediation applications, but this testing has demonstrated limited efficacy of modified vaporous hydrogen peroxide for a number of materials used with indoor facilities.

F.3.3.3. GDS 2000

The nonaqueous decontamination solution from Kärcher, described in Section F.3.2.2.2, could be used for volume decontamination by blowing a spray of the solution into a contaminated region. More information, such as the ability of the spray to remain airborne in HVAC piping, is needed to evaluate the practicality of this method.

F.3.3.4. Chlorine Dioxide (ClO₂)

Gaseous chlorine dioxide (ClO₂), used for biological decontamination of volumetric spaces, is not recommended for gas- or vapor-phase decontamination of chemicals of concern. Although chlorine dioxide is effective against mustard and has some efficacy towards VX (Grotta 1983; Popov 1967), it is not effective against the G agents (Brickhouse 2005). When used, gaseous chlorine dioxide must be kept in the dark because light breaks it down. Consistent with the foregoing reactivities with CWAs, gaseous chlorine dioxide reacts with 100% of the mustard simulant, 2-chloroethyl ethyl sulfide, within 2 minutes and with only 30% of the sarin simulant, ethyl-methylphosphorofluoridate, in 30 minutes (Cowser 1987).

A recent EPA (2009) study examined the potential for chlorine dioxide to be used for CWA remediation in civilian remediation applications. This testing demonstrated limited efficacy (only substantial efficacy for VX) of chlorine dioxide vapor for decontamination of CWA contaminated indoor surfaces.

F.3.3.5. Steam and Ammonia

Like air at temperatures greater than a few hundred degrees Celsius, superheated steam at 1000°F (538°C) (Scott 2004) may be considered for decontaminating structural concrete, utility runs, and other materials. Superheated steam has been included in the design of facilities at the Pueblo Chemical Agent Destruction Plant to treat materials contaminated with both propellant and CWAs (NRC 2005). Treated porous materials include wooden pallets and cloth. Steam is currently used to decontaminate CWAs in the Metal Parts Furnace at Tooele Army Depot. The steam temperature that is required may be lowered by adding surfactants (Cante 1981) or ammonia (Grotta et al. 1983). Because steam can condense on surfaces and block further penetration, superheated steam may perform better for nonporous surfaces. Steam has been used to decontaminate ton containers of undistilled mustard (H) (Mankovich 1970). Saturated steam at 100°C reportedly destroys all but minute residuals of HD in 5 to 10 minutes (Davis 1950). Steam condensate at such lower temperatures must be kept alkaline, or G agents may re-form as

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materials cool and residual steam condenses. Ammonia reacts directly with mustard but must first dissolve in water to form ammonium hydroxide to react with the G and V agents (Grotta et al. 1983; Franke 1968; Corwin 1968). Ammonia and other nucleophilic reagents react rapidly with VX to form nontoxic products (Domjan 1975). The combination of heat and water is expected to facilitate corrosion, so steam should only be applied in applications where corrosion is not a concern.

F.3.3.6. Ozone

As a strong oxidizer, ozone (O_3) has been investigated as a decontaminant by Wagner et al. (2000). They reported that ozone did not degrade GD and that the VX degradation products were also toxic. Given that ozone is not a viable decontaminant for GD or VX, its use is not recommended in this *Remediation Guidance*.

F.3.3.7. Perchloryl Fluoride and Nitrogen Tetroxide

The two gases, perchloryl fluoride ($ClFO_3$) and nitrogen tetroxide (N_2O_4), have been considered for decontamination. Perchloryl fluoride is a strong oxidant and a moderately toxic gas. It reacts with combustible and reducing materials and attacks some forms of plastics, rubber, and coatings. It is expected to be effective against HD vapors and in surface films (Grotta et al. 1983). It forms a film of byproducts when reacting with HD. Perchloryl fluoride also reacts with VX, but reactions to completion with VX have not been reported. Nitrogen tetroxide is a brownish-yellow liquid that is easily vaporized. It is a powerful oxidizer and is highly toxic and corrosive. Like many of the other oxidants, nitrogen tetroxide rapidly and completely decomposes HD (Grotta et al. 1983). Nitrogen tetroxide did not react with GF and is presumed to be ineffective with all nerve agents.

F.3.3.8. Emerging Technologies

Several technologies for decontaminating volumetric spaces contaminated with chemicals of concern have been proposed, including fog, cloud, or aerosol versions of the liquid decontaminants described above, such as DF-200, Oxone (the active ingredient in L-Gel), or CASCAD. Other technologies that may be useful in the future are under development. At this time, however, they have not been proven effective against CWAs and TICs in independent tests or are not commercially available.

F.3.4 Sealants and Coatings for Surfaces

Test results show that technologies do not yet exist to permanently decontaminate the surfaces of a variety of porous or permeable materials. Such materials include those that cannot be easily removed, such as structural concrete, wood, and elastomeric sealants such as silicone (Rivin et al. 2004). Rather than removing contaminated concrete or wood, the residual contamination could be sealed in place. Results of tests of alkyd and polyurethane coatings by the military are inconclusive. In one test series (Marshall 1989) alkyd paints were resistant to thickened GD agent but were penetrated by HD and thickened HD. In the same test series, polyurethane

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displayed the opposite behavior and was resistant to HD and thickened HD but was penetrated by thickened GD.

A better alternative for flooring and rigid surfaces may be chemically resistant epoxy coatings, which are widely used to protect concrete floors in laboratories and chemical plants. Such epoxies are resistant to nearly all chemicals and solvents. Epoxy materials dominated the list of materials that Battelle found absorbed less than 1% of their weight of CWA upon exposure for up to 15 weeks (Pfau et al. 1988). Decades of experience with laboratory benches coated with epoxies in ECBC's chemical agent laboratories has shown that there is no significant desorption from chemical-resistant epoxies after decontamination with bleach. Chemically resistant epoxies are available from industrial flooring suppliers, including Top Coat Systems and Florock.

F.3.5. Decontamination of Sensitive Equipment and Items

Few candidates are available to decontaminate sensitive equipment following CWA or TIC contamination, and the most promising are in somewhat early stages of development and testing. For sensitive equipment, it is more practical to propose decontamination technologies that involve removing the chemical of concern, rather than in situ neutralization. Removal technologies, such as volatilization with hot air or solvent washing, are less corrosive than technologies that destroy the chemical of concern in situ. Solvent washing must be performed with care for sensitive equipment because many rubber and other polymeric parts can be damaged by solvents. Solvent washing should always be done with guidance from the equipment manufacturer to avoid damage from the decontamination process. Such situations should generally be smaller scale, where capturing and treating exhaust or waste streams is more practical. Table F-4 summarizes the data available on decontaminating sensitive equipment contaminated with HD, VX, and the G agents. The ratings (L = low, M = medium, H = high) for corrosiveness, cost, and deployment are meant as general guidelines to the extent that a specific issue is important for a given technology. In cases where numerical values for decontamination efficacy are not available, ratings such as "good" or "fair" are generally derived from reports that provide results in such terms, or in a few cases, on expectations according to what is known about the chemistry of the decontamination method. The study by Wagner et al. (2004a) with mVHP[®] is the best one available for assessing the potential decontamination efficacy of any of the technologies, not just mVHP[®], for reuse of sensitive equipment.

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Table F-4. Decontamination technologies for treating sensitive equipment (developer and vendor data).

Decon Technology	HD		VX		G-Agents		Corrosiveness	Deployment	Cost	Residue	Source
	Contact Time	Gross removal	Contact Time	Gross removal	Contact Time	Gross removal					
Forced ventilation	Days to weeks	Decreases with increasing polymerization	Days to months	Unknown	Days to weeks	Unknown	L	L	L	No	Nonproprietary and widely available
mVHP ^a	24 hr	✓ Variety of material)	24 hr	✓ Variety of materials	24 hr	✓ Variety of materials	L	M	H	No	Proprietary from STERIS
ClO ₂ ^b	30 min	Good (materials unknown)	Hours	Poor (materials unknown)	Hours	None (materials unknown)	M-H	M	L	Yes, must be neutralized to minimize corrosion	Proprietary from Sabre
Solvent ^c bath	15 min	>99.0% (materials unknown)	15 min	>99.99% (materials unknown)	15 min	>99.93% (materials unknown)	L	H	—	No	Proprietary prototypes from Battelle and Guild Assoc.

✓ Indicates that the technology is stated to be effective, but a numerical value was not provided. — Indicates that data are not available.

For corrosiveness and cost, L = low, M = medium, H = high. For deployment, L = easy, M = moderately difficult, H = highly difficult.

For residue, Yes indicates the presence of visually noticable residue that must be cleaned off before reuse.

a Vaporous hydrogen peroxide with ammonia. Large-chamber tests (Wagner et al. 2004a).

b See EPA reports on material compatibility for ClO₂ fumigants focused on sensitive equipment. Efficacy can be inferred from EPA (2009).

c Coupon test data from Joseph Rossin of Guild Associates, Inc. (unpublished).

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F.3.5.1. Hot-Air Ventilation

For the case of an attack using a nonpersistent CWA, hot-air ventilation may be a useful decontamination method for sensitive equipment. The rate of decontamination from evaporation is governed by several factors, specifically:

- Agent volatility.
- Air speed.
- Temperature.
- Humidity.
- Droplet size.

Heating the air increases vapor pressure, which leads to an increase in the evaporation rate. Increasing the humidity of air would also be expected to speed the decontamination process for chemicals of concern susceptible to hydrolysis. Smaller pieces of equipment can be treated in enclosed systems; larger equipment could be wrapped and treated. Exhausted air should be filtered or decontaminated separately. Vacuum drying, where decreased total pressure is used to speed the removal of a chemical of concern, could also be useful for sensitive equipment with small, enclosed spaces, but such drying has not been extensively tested. Whereas hot air ventilation can be used to decontaminate porous and permeable materials, items such as carpet or cushioned furniture are not recommended for reuse.

F.3.5.2. Vaporous Hydrogen Peroxide with Ammonia (mVHP®)

Another candidate technology for sensitive equipment is the mVHP® method described in Section F.3.3.2. Tests at the laboratory scale (Wagner 2003, 2004 a and b) showed removal of VX, HD, and GD within 6 hours. ECBC tests evaluated the use of mVHP® to decontaminate real CWAs on representative aircraft interior materials. Only minor damage was observed (Heater et al. 2004) on representative materials tested rather than actual equipment. The mVHP® had little to no effect on wire insulation and caused slight discoloration of exposed copper contacts on printed circuit boards. The unmodified VHP process was used to decontaminate sensitive intensive-care-unit equipment in a Singapore hospital during the SARS epidemic (Adams 2004).

F.3.5.3. Chlorine Dioxide (ClO₂)

Although readily available, gaseous chlorine dioxide (ClO₂) is not recommended for gas- or vapor-phase decontamination of chemicals of concern on sensitive equipment (EPA 2009). Although chlorine dioxide is effective against mustard and has some efficacy towards VX (Grotta 1983; Popov 1967), it has not been shown, nor is it expected to be, effective against the G agents (Grotta 1983; Brickhouse 2005). Residues from reactions with chlorine dioxide on equipment must be neutralized after application to minimize

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corrosion of materials. The residues include HCl from ClO₂ decomposition with moisture in air and then corrosive salts from HCl neutralization on surfaces, as well as products of reactions with organics, such as mustard.

A recent EPA (2009) and study examined the potential for chlorine dioxide to be used for CWA remediation in civilian remediation applications. This testing demonstrated limited efficacy (only substantial efficacy for VX) of chlorine dioxide vapor for decontamination of CWA contaminated indoor surfaces.

F.3.5.4. Solvent Baths

Sensitive equipment that has been contaminated with a persistent CWA will require an active decontamination method. Prototype versions of a Joint Service Sensitive Equipment Decontamination (JSSED) system have been developed by Battelle Eastern Science and Technology Center and by Guild Associates, Inc. for the U.S. Army Soldier and Biological Chemical Command. The transportable ultrasonic bath system incorporates a recirculating solvent wash combined with drying systems. It uses a fluorocarbon solvent and is designed for decontamination of small and sensitive battlefield equipment that has been exposed to chemical and biological agents.

F.3.5.5. Emerging Technologies

Several technologies under development may be useful in the future for decontaminating sensitive equipment. At present, however, they generally have undergone only limited testing against CWAs or simulants, or they are still in development. Examples include supercritical CO₂ and downstream plasma treatments.

F.4. Recommended Decontamination Technologies for Airports

The scope of this *Remediation Guidance* is an indoor attack involving a CWA or TIC. Accordingly, recommendations are focused on decontamination technologies most suited to such a situation. The basic criteria for making decontamination recommendations are:

- Efficacy proven in independent testing.
- Current commercial availability of the technology.
- Time and cost information required.
- Corrosivity and toxicity as low as possible.
- Low waste production.
- Ease of deployment.

The recommendations are divided into the same three categories at those used above: (1) liquid decontaminants for surfaces and hot spots, (2) gas and vapor decontaminants to flood volumetric spaces, and (3) sensitive equipment. As new decontamination technologies and technical data

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become available, contact the authors or use the process described in Section F.2.2 to update the recommendations.

When several choices have acceptable technical performance, ease of acquisition and use are more important factors. In cases where none of the available technologies meet the desired criteria, the best candidate is recommended with the assumption that further developmental work and testing will soon improve the range of options.

F.4.1. Liquids and Foams for Decontaminating Hot Spots

For surfaces on which corrosion is not a consideration, we recommend using a solution prepared by mixing 1 part household bleach into 9 parts, with the pH amended to avoid the pH range of 7-10. The solution could potentially be used on most of the materials destined for disposal. Residual chlorine may need to be neutralized or rinsed from waste materials before disposal. Large quantities of rinse water, in addition to the original waste, may then need to be disposed.

For nonporous and impermeable surfaces to be decontaminated for reuse, and for which corrosion is an issue, the two decontaminants SDF™ or GDS 2000 may be suitable. Contact the suppliers for information on compatibility with the specific materials of concern. Whereas these technologies may decontaminate for reuse those surfaces that are clean, impermeable, and nonporous, they are either likely to leave greater residual concentrations on dirty, porous, or permeable surfaces (SDF) or damage polymeric material (GDS 2000). Although liquids and foams can be used to decontaminate porous and permeable materials, items such as carpet or cushioned furniture are not recommended for reuse.

Test results indicate that bleach and the other recommended liquid decontaminants will adequately decontaminate for reuse the surfaces of nonporous and impermeable materials, such as glass, metal, and cross-linked polymers such as phenolic wall boards and melamine tiles. Use of the recommended decontaminants on porous and permeable materials, such as carpet and other furnishings, is most appropriate for items to be disposed, and any reuse of those materials would require extensive monitoring and evaluation.

F.4.2. Decontaminating Surfaces with Gases or Vapors in Volumetric Spaces

Technologies for decontaminating surfaces by flooding volumetric spaces with gases or vapors have not been well tested. For light contamination with a nonpersistent CWA or one of the TICs considered here, ventilation should be considered, especially ventilation with heated gases. Engineering requirements have not been established for implementing hot air decontamination, but it is important to ensure the amount of heat provided and the distribution of that heat create uniformly heated areas. Careful planning and evaluation would be required to heat spaces to more than 120° to 140°F (49° to 60°C) and avoid damaging materials, such as insulation, wall coverings, and electronic equipment. Engineering requirements are likely to be both site- and seasonally specific. Understanding the impact of humid air at elevated temperatures also requires consideration in that the combination of hot and humid air can facilitate corrosion. For more heavily contaminated spaces, or for contamination with a persistent agent, gas/vapor

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technologies with ClO₂ or mVHP® may be considered, but given the limited evidence of efficacy for indoor surfaces it is recommended that pilot testing at the facility be conducted in order to demonstrate efficacy before the technology is deployed facility-wide.

For inaccessible locations where chemicals of concern persist, such as in pipe and electrical traces, hot air may be the preferred method because oxidative vapor concentrations can be difficult to maintain in runs of a few dozen feet or longer. Although hot, humid air or even steam may provide some additional decontamination, the increased risk of corrosion and secondary contamination makes successful execution difficult.

Whereas all of the recommended technologies may decontaminate impermeable and nonporous surfaces intended for reuse, they can leave greater residual concentrations on dirty, porous, or permeable surfaces. Gas or vapor decontamination can be used to decontaminate porous and permeable materials; however, items such as carpet or cushioned furniture are not recommended for reuse.

F.4.3. Decontamination of Sensitive Equipment and Items

Depending on the CWA or TIC involved, smaller items that are easily movable could be treated by hot-air ventilation, or special arrangements could be made to use a prototype solvent bath system. Ventilation of contaminated items with hot air needs more testing but should be cheaply and easily accomplished. The solvent bath system has had limited testing with real CWAs, and currently has limited availability, but would be useful for decontaminating persistent chemicals of concern. Larger items should be treated using hot-air ventilation for volatile contaminants, and consideration of gas/vapor technologies with ClO₂ or mVHP® may be appropriate, but given the limited evidence of efficacy for indoor surfaces it is recommended that pilot testing be conducted in order to demonstrate efficacy before reliance of these technologies for sensitive equipment.

Valuable artwork or irreplaceable personal possessions should be set aside for later decontamination. Decontamination of such items will depend on the materials in a particular item. Good ventilation of an item, especially at elevated temperatures for days or even weeks, may suffice for decontamination.

F.4.4. Operation of a Gas and Vapor Processes

In addition to monitoring a CWA or TIC to determine the efficacy of decontamination, it is important to monitor the decontamination reagent(s) themselves. Such monitoring is important for two reasons: (1) to ensure that the decontamination reagent was present at sufficient concentrations in various locations to inactivate the CWA or TIC, and (2) to ensure that, after the decontamination process is complete, no decontamination reagent remains at a concentration that would cause harm to human health.

The vendor providing decontamination services should, in most cases, be responsible for identifying and monitoring parameters related to the decontamination process. Responsibilities would include (if relevant) monitoring environmental conditions, such as ambient temperature,

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relative humidity, airflow, and decontamination reagent concentration as the decontamination proceeds. Real-time or near-real-time methods should be used concurrently by qualified individuals (possibly, but not necessarily, from the vendor providing decontamination) to monitor the CWA or TIC and to verify the progress of decontamination. Methods of analysis are discussed in Annex D.4.

In summary, during decontamination, both the CWA or TIC and the reagent(s) used for decontamination must be monitored. The methods used will depend on the questions being addressed and required detection limits. Real-time analytical methods will most likely be important for measurements taken as decontamination is ongoing to show that the decontamination is effective. Laboratory-based methods that provide optimum (i.e., the lowest or best) detection limits are important during the clearance process to show that no hazardous concentrations of chemicals remain.

F.5. Contractors

Remediation of a facility as complex and large as a major airport will most likely require multiple contractors for different aspects of the required work. Several contractors have assisted with gas or vapor decontamination of buildings contaminated with either explosives or *B. anthracis* spores. Their experience in containing and controlling gas and vapor flows is directly relevant to gas or vapor decontamination to clean up CWAs or TICs in buildings. For example, in remediating the Hart Office Building (*B. anthracis* contamination), the EPA had about 50 staff (on-scene coordinators) overseeing the work of 27 contractors and three state and Federal agencies. The EPA operated with the advantage of already having in place many existing, competitively awarded contracts as part of their Superfund Program. The EPA used ten of its existing, competitively awarded contracts and awarded two new competitive contracts. Most of the remaining 15 contracts were sole-source contracts for equipment and supplies costing less than \$200,000.

Most regional offices of the EPA Office of Emergency and Rapid Response Services contract with regional firms for quick remedial-response services for CERCLA, the Oil Pollution Act, and Underground Storage Tank programs. The EPA maintains a website listing its regional contractors at <http://www.epa.gov/superfund/programs/contracts/6errs.htm>. For example, two contractors are listed for Region IX. Table F-5 identifies contractors with experience in remediating facilities that have been contaminated with CWAs, BWAs, or explosives.

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Table F-5. Contractors with experience in remediating facilities.

Contracting agency	Type of contract	Task or role performed
Weston, Roy F., Inc.		
U.S. Army Environmental Center	Demonstrate hot-gas decontamination of explosives and mustard on munitions, process equipment and facilities at Hawthorne Army Depot and Rocky Mountain Arsenal.	Reported on results of operation of both a permitted, full-scale hot-gas decontamination system for explosives-contaminated equipment at Hawthorne Army Base and on the use of transportable hot-gas decontamination systems to decontaminate equipment across the country.
Parsons Engineering Science, Inc. and Battelle PNNL and Columbus Operations		
U.S. Army Environmental Center	Based on results of successful field demonstrations with explosive-contaminated buildings, prepare a design guidance manual for hot-gas decontamination.	Prepared a design guidance manual to assist installation personnel in determining the applicability and effectiveness of the technology at their site. Provided sufficient design information to move directly to detailed design, procurement, construction and operation of a hot-gas decontamination system. Presented the technical information necessary to develop a budgetary cost estimate for implementation at an installation.
IT Corporation (now Shaw Environmental and Infrastructure, Inc.)		
EPA	Conduct removal action (remediation-related) activities at the Hart Office Building ^a	Prepared buildings for decontamination. Conducted and supported decontamination operations, including fumigation with chlorine dioxide gas. Decontaminated interior surfaces of buildings, other structures, cars, and other vessels. Provided for collection, containment, transportation, and disposal of contaminated materials from site operations. Supported EPA sampling teams and other federal responders, including response technicians, to assist with decontamination activities.
U.S. Army Corps of Engineers Rapid Response Program		
U.S. Dept of State	Conduct removal action (remediation) activities at the Sterling Facility ^b	Project management.
Sabre Oxidation Technologies, Inc.		
EPA	Provide technical support to remediation activities at Hart Office Building. ^a Fumigation of Brentwood Postal Facility.	Provided engineering support during assessment of the feasibility and design of systems for fumigating air-handling return system. Fumigation of Brentwood Postal Facility using chlorine dioxide.

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Table F-5. (Continued)

Contracting agency	Type of contract	Task or role performed
Strategic Technology Enterprises (STERIS), Inc.		
U.S. Dept of State	Conduct removal action (remediation) activities at the Sterling Facility ^b	Fumigation of Sterling facility using vapor-phase hydrogen peroxide.
Tetra Tech EM, Inc.		
EPA	Provide technical support to remediation activities at Hart Office Building ^a	<p>Provided on-scene coordinator and incident commander fumigation design procedures, including details on decontaminant delivery; concentration; operating conditions, such as temperature and humidity; decontaminant containment and recovery; and monitoring of parameters. Provided detailed design for delivering decontaminant, equipment requirements and specifications, flow schematics, and schedules and operating procedures during fumigation. Provided chlorine dioxide specialist to help EPA oversee fumigation setup. Technical support to on-scene coordinator in developing chronology of events, including researching files to develop a comprehensive report. Monitored and assisted with oversight of chlorine dioxide fumigation. Assisted with health and safety at the site, conducted sampling, assisted and oversaw off-gassing, inventory, and returned treated items.</p> <p>Supported on-scene coordinator in presentations and briefings on post-treatment and design of chlorine dioxide use in HVAC system. Sampled critical items (plastic, leather, and polyester); determined how ethylene oxide and its derivatives are maintained in the materials and off-gas over time.</p>
Earth Tech, Inc.		
EPA	Conduct removal action (remediation) activities at the Hart Office Building ^a	<p>Provided decontamination services and other direct support to sampling teams. Decontaminated interior surfaces of buildings, other structures, and interior and exterior surfaces of cars and other vessels identified by the on-scene coordinator. Collected all expended cleaning agents and materials for treatment and/or disposal.</p> <p>Provided decontamination facilities and services for response personnel and their equipment. Inventoried items—segregating clean and contaminated materials and salvageable and expendable items—and provided documentation of inventoried items.</p> <p>Proposed a decontamination strategy for critical items (including personal items, such as photographs, framed diplomas, and equipment). Decontaminated critical and</p>

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Table F-5. (Continued)

Contracting agency	Type of contract	Task or role performed
		<p>salvageable items from the Capitol Complex, including setting up work zones for items to be decontaminated and for personnel decontamination.</p> <p>Returned property after decontamination.</p> <p>Provided contamination reduction and isolation facilities and operations that improved and ensured safe access to contaminated areas and items and prevented further spread of contamination.</p>
Environmental Quality Management, Inc.		
EPA	Conduct removal action (remediation) activities at the Hart Office Building ^a	<p>Provided personnel and equipment, including portable decontamination facility. Collected expended cleaning agents and materials for treatment and/or disposal.</p> <p>Disposed of materials or items that could not be decontaminated.</p>

^a GAO Report on the EPA (see GAO 2003).

^b <http://www.loudoun.gov/general/anthraxfaqs.htm#gen>

F.5.1. Indemnification

Decontamination contractors may require some sort of indemnification before responding to a CWA or TIC incident, especially if toxic materials or high temperatures are used for decontamination. Such was the case for remediation of facilities contaminated with BWAs. For example, numerous uncertainties about the use of chlorine dioxide gas for decontamination existed following the anthrax incidents of 2001. IT Corporation (now Shaw Environmental), which was tasked to fumigate the Hart Office Building using chlorine dioxide gas, would not start removal procedures without receiving indemnification from the EPA against liability for damages. CDM Federal Programs Corporation, whose responsibilities included placing the materials to test for the presence of anthrax during fumigation, received indemnification terms similar to those granted to IT Corporation, but with significantly smaller compensation amounts.

F.5.2. Homeland Security Safety Act

As part of the Homeland Security Act of 2002, Public Law 107-296, Congress enacted several liability protections for providers of anti-terrorism technologies. The Support Anti-Terrorism by Fostering Effective Technologies Act (SAFETY Act) provides incentives for developing and deploying anti-terrorism technologies by creating a system of risk and litigation management. More specifically, the SAFETY Act creates certain liability limitations for claims arising out of, relating to, or resulting from an act of terrorism when Qualified Anti-Terrorism Technologies (QATTs) have been deployed. All forms of technology, including products, software, services (including support

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services), and various forms of intellectual property (including information technology), may qualify for protection under the SAFETY Act.

The SAFETY Act authorizes the Under Secretary for Science and Technology to limit the liability of sellers of qualified anti-terrorism technologies to the amount of insurance coverage that they are required to maintain and also protects other entities in the supply and distribution chains. This is distinct from indemnification, which involves defending against claims brought against others and satisfying any resulting liability.

F.6. Selecting Decontamination Technologies and Sequencing Activities

The organization of multiple decontamination operations is an important part of remediation for all but small and relatively localized CWA or TIC incidents. Proper sequencing of remediation actions can reduce decontamination times and waste volumes. The sequence of actions typically includes initial disposal of items not intended for reuse, then decontamination of items and areas planned for reuse. The initial disposal of items requires physical removal of contaminated items, likely with treatment before or during waste storage. Decontamination for reuse may involve (1) hot spot source reduction, (2) isolation of sensitive equipment either onsite or offsite, (3) volumetric decontamination, and (4) decontamination of sensitive equipment. The various activities can be initiated at different times for different zones of a facility.

One way to generalize the sequencing activities and decontamination actions is through the use of contamination zones, and then within each zone through the material properties of items requiring remediation. Depending on the nature and magnitude of contamination, the activities in some contamination zones may need to begin with disposal and hot spot decontamination, whereas those in other zones may need to begin with volumetric decontamination or natural attenuation. Within each zone, two critical characteristics of material properties impact affinity, persistence, and resistance to decontamination; they are the chemical composition of materials (organic vs. inorganic) and the permeability of materials (porous or permeable vs. impermeable).

Table F-6 shows some examples of facility items in each of the above categories together with recommendations for how to decontaminate the items, depending on the magnitude of contamination. Most facilities have numerous features with items that fall into multiple material categories, such as escalators, computers, or baggage conveyors, and each material category needs to be considered independently when assessing decontamination requirements. In addition, most chemicals of concern have an affinity for, and persist in, grease, oil, and dirt on the surface of materials, and items can have increase permeability as a function of wear. Thus, the modification of material surfaces over time also warrants appropriate consideration.

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Table F-6. Material categories for typical facility surfaces and recommended decontamination approaches.

Material category	Reuse or disposal	Liquid hot spot decontamination	Vapor-phase volumetric decontamination	Other decontamination methods
Inorganic, impermeable				
Glass Metal	Typically available for reuse for both liquid and vapor exposure	Bleach or foams expected to be effective	Ventilation or hot air ventilation expected to be effective	mVHP or solvent bath not typically required
Organic, impermeable				
Epoxy Bakelite panels or countertops Sealed stone or ceramic	Should generally be available for reuse for both liquid and vapor exposure	Bleach or foams generally effective if liquid contact time is short	Ventilation or hot air ventilation expected to be generally effective with short desorption times	mVHP or solvent bath not typically required
Inorganic, porous or permeable				
Concrete Marble or granite Ceramic (unsealed) Terrazzo Grout Gypsum (inside sheetrock or wallboard) Fiberglass insulation Metal conduit	Difficult to reuse following liquid exposure; easier to reuse following vapor exposure	Difficult to decontaminate chemicals in deep porespace. Generally ineffective but may require numerous treatments or long contact times	Hot air ventilation expected to be generally effective because little adsorption expected; but longer desorption times are possible	mVHP may be beneficial for highly permeable but inaccessible locations
Organic, porous or permeable				
Carpet Vinyl tile Latex-painted surfaces Fabrics Food items Caulks and sealants Cushioned furniture Most rubber Most plastics	Typically requires disposal; generally not worth the effort to decontaminate	Difficult to decontaminate Will generally require disposal or very long contact times	Hot air ventilation expected to be generally effective, but may result in much longer decontamination time than is practical Easily movable items should be removed	mVHP generally not beneficial Solvent bath or nonaqueous decontamination liquid may provide enhanced waste decontamination compared to aqueous-based decontamination liquids
Sensitive items and equipment				
Computers X-ray units Electronics Artwork	Reuse requires significant effort; only worth the effort for high-value items	No bleach because of corrosion concerns	Ventilation or hot air ventilation may be sufficient	Solvent bath or mVHP for electronics should be considered Artwork requires special considerations

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In a zone containing substantial contamination, contaminated items that will require major efforts to decontaminate would generally be removed for disposal before the main decontamination activity commences. Such decisions will be site- and incident-specific, but in general such items include virtually all those in the organic porous/permeable category that are not of high value and many of the contaminated inorganic porous/permeable materials that can be easily removed. In zones with less contamination, it may be enough to remove only the easily removable organic porous/permeable materials before commencing with monitored natural attenuation or volumetric decontamination.

It should be emphasized that decontamination can proceed simultaneously in different contamination zones, even if the zones are at different stages of decontamination (e.g., hot spot cleanup vs. volumetric decontamination) as long as the zones are isolated so that contamination does not move from a more contaminated zone to a less contaminated one.

The decision framework for selecting the decontamination approach and sequencing activities according to the magnitude of contamination (contamination zones) and materials properties provides a rational basis for the decisions required for developing a Remediation Action Plan. Although Table F-6 is not comprehensive in listing all possible materials that might be encountered during remediation of a large facility, it does provide basic criteria so that materials not listed can be generally categorized into the bins shown. Ultimately, subject-matter experts will make appropriate decisions on the best approach to decontamination according to site- and incident-specific details.

F.7. Summary

This Annex discusses a variety of technologies that are available to decontaminate buildings after a release of CWA or TIC. The choice of decontamination technologies that are selected and applied during cleanup will depend on the specific chemicals of concern involved in a release, and different approaches will probably be necessary to decontaminate hot spots, volumetric spaces, and sensitive items. Many of the decontamination technologies that are currently available, however, are less effective on porous and permeable materials and have not yet been used in full-scale decontamination of a building and restoration to full service. Complete remediation of a large airport requires restoring the infrastructure necessary to support transportation services, such as ticketing and baggage checking. Such vital services are supported by sensitive equipment and by the wires and pipes running through inaccessible areas. Full remediation of such complex infrastructure has yet to be demonstrated.

A thorough understanding of interactions between the chemicals used in an attack (whether CWAs or TICs), decontamination reagents, and the materials found in airports (especially inaccessible areas) and in sensitive equipment is needed to make optimal recommendations for decontamination technologies. Confidence in evaluating the

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hazards will allow for better selection of decontamination alternatives that can quickly restore a transportation facility to full service.

No single, ideal decontamination technology exists; therefore, technology selection will be a site- and scenario-specific decision taking into account tradeoffs among availability, effectiveness, reuse requirements, material compatibility, and waste implications. In addition, the amount of contamination and properties of affected surfaces have a major impact on the efficacy of decontamination technologies. For example, current decontamination alternatives could damage some critical infrastructure by exposure to harsh chemicals or high temperatures. Rather than ripping out and replacing the cables in a facility, throwing out sensitive equipment, or subjecting the wiring and equipment to damaging decontamination procedures, studies may show that certain materials and equipment do not absorb and off-gas a particular chemical of concern for extended periods. If so, the materials and equipment could be returned to service with minimal monitoring and without treatment. If materials do off-gas at hazardous levels for extended periods, further consideration and development of decontamination technologies for volumetric spaces will be beneficial to quickly restore full services. Decontamination technologies for volumetric spaces, when appropriate, offer many improvements over technologies that require direct access to surfaces. The potential improvements include reductions in the time, expense, and risk to personnel to decontaminate a facility, as well as reductions in the amount of hazardous waste generated by decontamination activities.

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Annex G**Annex G
Development of Remediation Goals**

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G.1 Introduction

Remediation goals serve many purposes throughout a response to hazardous chemical contamination. Remediation goals are site- and situation-specific and should ensure use of the best available science while contributing to timely and economically responsible decision-making. It would be difficult to write such guidance to address every possible contamination circumstance. However, it is important to recognize that response to a CWA contamination incident in facilities that may be frequented by the general public (including adults, children, and the infirm) as well as those who must work in that environment daily be addressed carefully and conservatively.

Remediation goals are not only used to evaluate the effectiveness of a cleanup strategy but also to determine the extent of contamination and to judge the adequacy of tools (instruments, sampling plans, and analytical techniques) for determining where contamination may be located and whether it has been addressed sufficiently to ensure the absence of adverse health effects in those potentially exposed. The development of remediation goals is done early during response to provide the information necessary to make decisions regarding the tools and procedures needed for a specific scenario. The development of site- and situation-specific remediation goals should include participation by scientists knowledgeable in the chemistry and toxicity of the contaminant, chemists skilled in analysis and sampling, and engineers experienced in decontamination techniques. However, goal development must also include airport and local public health officials with responsibility for making difficult choices concerning aspects of an airport response and remediation and how the process will impact public health outcomes. It would seem a daunting task to bring a cadre of experts to the table for a timely discussion that will affect initial actions during a response. However, Federal agencies such as the DHS, EPA, and CDC have put into place and practiced plans that will enable the bringing together of experts from across the country at a moment's notice. Such agencies and others have worked together in previous national emergency responses, such as the World Trade Center attack, Katrina and Rita hurricanes, and Deep Horizon oil spill.

Annex G recommends a process that incorporates key factors that should be taken into consideration when site- and situation-specific remediation goals are developed. Many pre-existing exposure guidelines developed by a variety of agencies and organizations for an array of purposes are discussed. Most such guidelines were not developed for use as remediation goals.

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Rather, they were developed to monitor exposure (e.g., occupational exposures and accidental releases) or to assist in decision-making (e.g., evacuation, short-term re-entry into contaminated zones, and replacement of drinking water sources). Existing guidelines do not obviate the potential for developing site- and situation-specific remediation goals; rather, they can serve as initial indicators of ranges of exposures and environmental concentrations that can guide decision-making.

G.2 Framework for Clearance Decisions

Clearance decision-making is a process that includes situation-specific considerations and the most current understanding of relevant science and engineering information. It is a flexible process in which numerous factors, such as local needs, health risks, costs, and technical feasibility, are considered. Despite the existence of numerous standards and guidelines, no absolute cleanup approach or level can be universally applied to every chemical incident. Therefore, coordination among Federal, state, tribal, and local governments and a facility owner is critical to ensure that clearance decisions are effective and acceptable. The goals of clearance are:

- **Transparency**—The basis for cleanup and other decisions should be available to stakeholder representatives, and ultimately to the public.
- **Inclusiveness**—Representative stakeholders should be involved in decision-making activities.
- **Effectiveness**—Technical subject-matter experts should analyze remediation options, assess various technologies to assist in decisions that are optimal for the incident, and consider cleanup goals and clearance decisions.
- **Shared accountability**—The final decision for clearance will be made jointly by Federal, state, tribal, and local officials in the unified command.

The process brings together subject-matter experts who take into consideration the concerns of stakeholders to set clearance goals appropriate for site-specific circumstances.

G.3 Key Elements in Clearance Decision-Making

Many incident-specific factors (e.g., the types of chemicals released, their degradation byproducts, the amount and mode of release, collateral hazards, and final use/reoccupancy) will affect response decisions. The steps in developing clearance decisions are presented here sequentially; however, many can be performed concurrently during consequence management.

Conduct a Risk Assessment, and Estimate Clearance Goals

- Combine a toxicity assessment and exposure assessment to estimate site-specific risk.

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- Using site-specific information on chemical identity, the nature of the chemical (persistent or nonpersistent under different environmental conditions), and exposure and health effects, determine appropriate clearance goals.
- Consider stakeholder concerns and feasibility issues, including
 - Future use of the site, populations of concern, and types of health effects.
 - Feasibility issues (e.g., analytical detection and laboratory capacity).
 - Uncertainties and confidence [availability, confidence in, interpretation, and application of exposure guidelines (reference values); sampling methods and validation; and decontamination approach and effectiveness].
 - Time and resource concerns (extent of contamination, critical infrastructure and items, and economic impacts of cleanup options).
 - Other confounding factors (crisis management or first response, nature and toxicity of breakdown products, collateral hazards, and waste generation).

Verify Clearance

- Consider decontamination options (e.g., monitored natural attenuation or active decontamination methods) to determine which approach(es) will provide adequate cleanup efficacy.
- Consider the adequacy of verification that clearance goals have been achieved by evaluating clearance sampling and analysis of air, building surfaces, soil, surface water, groundwater, and drinking water, as needed.

Clear for re-occupancy and reuse

Consider ways to facilitate orderly reuse, including post-reoccupancy monitoring and any use restrictions, if appropriate.

G.4 Existing Exposure Guidelines

Many agencies and organizations have developed exposure guidelines for purposes such as occupational monitoring, escape warning, and preliminary remediation goals. Although only some of the exposure guidelines are intended as remediation or clearance goals, others can be used to inform clearance decision-making. Each exposure guideline targets specific environmental media or exposure pathways—air, water, soil, or dermal exposure. When decisions are made regarding which guideline or combination of guidelines to use, care should be taken to ensure that cumulative risk from multiple pathways of exposure is considered. An extra measure of caution should be applied to ensure that total exposure and risk are factored into the selection of a clearance goal.

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Four duration intervals can be used to differentiate among possible exposures. The durations are acute (<24 hr), short-term or sub-acute (1 to 30 days), sub-chronic (10 percent of a lifetime, or 7 years for humans), and chronic (up to a lifetime of continuous exposure).

Acute exposure guideline levels are often prescribed for use during emergency response decision-making, such as when personal protective equipment (PPE) is warranted, evacuation or sheltering-in-place warnings are issued, or for emergency drinking water guidance. In modeling, exercises, and other planning activities, the lowest of the acute (one-time, single exposure) guideline levels has often been used to demarcate the edge of the potential hazard zone. Such an approach is intended for use where fugitive emissions might escape from either a remediation operation or some other activity that is under other workplace restrictions. Acute guideline levels should not be applied to exposure durations and scenarios that are inconsistent with the exposure assumptions associated with the guidance level.

Chronic or long-term exposure guideline levels, which are based on lifetime or residential exposures, are at the opposite end of the exposure spectrum. Chronic guideline levels can be used as environmental screening levels or cleanup goals to evaluate chemical concentrations in different media and can assist in decisions regarding such issues as extent of contamination or as a starting point for developing a clearance decision. A variety of risk assessment methods can be employed to develop risk-based, chemical- and site-specific cleanup goals that can be used along with other site- and situation-specific information for making determinations concerning remediation and decontamination options.

Recommendations for guideline levels that are most appropriate for a given situation should be made by subject-matter experts who understand the complexities and uncertainties of such determinations and can use the available benchmarks most appropriately. Ideally, the full range of existing guideline levels should be evaluated in the context of the range of possible exposures, other site-specific information (population exposed, duration of exposure, and so forth), underlying assumptions, and other factors before determining the most appropriate exposure guideline level to apply.

Sub-acute or sub-chronic exposure durations exist between those that are acute and chronic. The definition of “intermediate exposure” can vary according to what agency or stakeholder group employs it. In general, however, intermediate exposures are between a few days to a month or up to a few years.

A wide array of quantitatively derived human toxicity and health-based exposure limits and guidelines exist for many substances and are appropriate for specific applications related to the phase of a response, potentially exposed population, and duration of exposure. Exposure guideline levels for CWAs have been developed for a variety of media (air, water, soil, and surfaces), for a variety of populations (general public and workforce populations) and for different exposure durations (acute, intermediate, and chronic). By far, the greatest number of guideline levels has been developed for the air exposure pathway. The following section

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provides definitions and descriptions of the guideline levels available for CWA and TICs, although the discussion is not exhaustive. No hierarchy is implied by the order in which the values are presented. To the extent possible and in an attempt to avoid misrepresentation, definitions of guideline levels are repeated verbatim from the literature and websites produced by the originating agency or stakeholder group.

G.4.1 Air Exposure Guidelines

Air exposure guidelines have been developed by both government and trade organizations. They can be generally segregated into those evaluating exposures to either the general public (which includes children and the elderly) and the workforce (generally healthy adults). Also included are military exposure guidelines. Military personnel are generally defined as relatively healthy and fit male and nonpregnant female adults. Table G-1, below, summarizes the various types of air exposure guidelines described in this section (exposure guidelines for cyanogen chloride are not included in the table because none are available). Permissible exposures change dramatically with minor changes in exposure duration. However, permissible exposures tend to begin to “level out” for exposure durations of 30 days to more chronic durations of 1 to 70 years.

G.4.1.1 General Public Air Guideline Levels

Acute Exposure Guideline Levels (AEGLs)

The AEGLs represent threshold exposure limits for the general public and are applicable to exposure periods ranging from 10 min to 8 hr. The AEGL-1 and AEGL-2, and AEGL-3 values have been developed for each of five exposure periods (10 and 30 min, and 1, 4, and 8 hr) and are distinguished by varying degrees of severity of toxic effects. Recommended exposure levels are generally considered to be applicable to the general population including infants and children, and other individuals who may be susceptible. The three AEGLs are defined as follows:

- **AEGL-1** is the airborne concentration (expressed as parts per million or milligrams per cubic meter (ppm or mg/m³)) of a substance above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic nonsensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure.
- **AEGL-2** is the airborne concentration (expressed as ppm or mg/m³) of a substance above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape.
- **AEGL-3** is the airborne concentration (expressed as ppm or mg/m³) of a substance above which it is predicted that the general population, including susceptible individuals, could experience life-threatening health effects or death.

Airborne concentrations greater than AEGL-1 represent exposure levels that can produce mild and progressively increasing but transient and nondisabling odor, taste, and sensory irritation or

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certain asymptomatic, nonsensory effects. With increasing airborne concentrations above each AEGL, there is an increase in the likelihood of occurrence and the severity of effects described for each corresponding AEGL. Although AEGL values represent threshold levels for the general public, including susceptible subpopulations, such as infants, children, the elderly, persons with asthma, and those with other illnesses, individuals subject to unique or idiosyncratic responses could experience the effects described at concentrations below the corresponding AEGL. AEGLs have been developed as guideline levels for once-in-a-lifetime, short-term (not repeated, chronic) exposures to acutely toxic, high-priority chemicals.

The National Research Council established the committee that develops AEGLs to guide emergency planning and response. The AEGL committee includes members from Federal agencies (EPA, DOD, and DOE) state agencies, national laboratories, academia, and private organizations (<http://www.epa.gov/opptintr/aeql/>).

Minimal Risk Levels (MRLs)

An MRL is an estimate of the daily human exposure to a hazardous substance that is likely to be without appreciable risk of adverse, noncancer health effects over a specified duration of exposure. These substance-specific estimates, which are intended to serve as screening levels, are used by the Agency for Toxic Substances and Disease Registry (ATSDR) health assessors and other responders to identify contaminants and potential health effects that may be of concern at hazardous waste sites. MRLs were not intended by the ATSDR to be used to define cleanup or action levels.

All MRLs are based on noncancer health effects only, not on a consideration of cancer effects. Inhalation MRLs are exposure concentrations expressed in units of ppm for gases and volatiles, and mg/m³ for particles. Oral MRLs are expressed as daily human doses in units of mg/kg per day.

MRLs are derived for acute (1 to 14 days), intermediate (>14 to 364 days), and chronic (365 days and longer) exposure durations and for the oral and inhalation routes of exposure. MRLs are generally based on the most sensitive substance-induced end point considered to be of relevance to humans. The ATSDR does not use serious health effects (such as irreparable damage to the liver or kidneys, or birth defects) as a basis for establishing MRLs. Exposure to a level above the MRL does not mean that adverse health effects will occur. The ATSDR MRLs were developed as an initial response to a mandate. The ATSDR chose to adopt a practice similar to that of the EPA's reference dose (RfD) and reference concentration (RfC) for deriving substance-specific health guidance levels for non-neoplastic endpoints (<http://www.atsdr.cdc.gov/mrls/>).

Provisional Advisory Level (PAL)

The PALs represent exposure advisory levels for the general public applicable to emergency situations. They are developed for use by Federal, state, and local emergency responders to

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inform and support decisions regarding evacuation from and/or temporary re-entry into or re-use of contaminated areas. PALs may be useful in planning and response efforts by homeland security, public health and law enforcement agencies, emergency response agencies, water utilities, and national and regional EPA offices. Three levels (PAL 1, PAL 2, and PAL 3) are distinguished by the degree of severity and type of toxic effects and are developed for 24-hr, 30-day, 90-day, and 2-year ingestion of drinking water and inhalation exposure durations. (Available PALs for drinking water exposure are presented in Section G.4.2.) Although PALs are developed with considerable attention to sensitive populations (e.g., asthmatics, age-dependent sensitivities, and so forth), PALs are not intended to protect hypersensitive populations or idiosyncratic responders within the general population.

- **PAL 1** represents a threshold concentration with assumed continuous exposure of a chemical in air or drinking water. Specific biomarkers for physiological responses or adverse effects in the general population could occur above the PAL 1 value. Concentrations at or below PAL 1 are not expected to be associated with adverse health effects. Increasingly greater concentrations above the PAL 1 value could cause a progressive increase in severity of harmful effects in the general population, including all ages and sensitive subpopulations.
- **PAL 2** represents the assumed continuous exposure concentration of a chemical in air or drinking water above which serious, irreversible, or escape-impairing effects could result. Increasingly greater concentrations above the PAL 2 value could cause a progressive increase in severity of harmful effects in the general population, including all ages and sensitive subpopulations.
- **PAL 3** represents the assumed continuous exposure concentration of a chemical in air or drinking water above which lethality in the general population, including all ages and sensitive subpopulations could occur.

The EPA policy demands that provisional PALs be intended for use in emergency situations. Their provisional nature does not imply a lack of scientific rigor in their development. PAL values for CWAs and some TICs are available through the EPA's National Homeland Security Research Center (NHSRC) (<http://www.epa.gov/nhsrc/index.html>).

General Population Limit (GPL)

The GPLs are developed by the CDC for the DOD. The values are used as the basis for risk management efforts to protect against exposure to the general population from CWAs during day-to-day operations of a CWA disposal facility. The GPL is the maximum concentration to which the general population may be exposed 24 hr, 7 days a week, for a 70-year lifetime. GPLs fall within the more general category of Airborne Exposure Limits (AELs). Although the traditional exposure duration for GPLs is for a 70-year lifetime, exceptions exist, for example, for VX. The CDC assumed that any spill at a DOD disposal facility of VX would be recognized

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quickly. Therefore, the GPL for VX assumes a 3-year exposure duration (<http://www.cma.army.mil/>).

Reference Concentration (RfC)

The EPA defines an RfC as an estimate (with uncertainty spanning perhaps an order of magnitude) of a continuous inhalation exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. It can be derived from a no-observed-adverse-effect-level (NOAEL), lowest-observed-adverse-effect-level (LOAEL), or benchmark concentration, with uncertainty factors generally applied to reflect limitations of the data used. Reference concentrations are generally used in EPA's noncancer health assessments (<http://cfpub.epa.gov/ncea/iris/index.cfm>).

G.4.1.2 Workforce Air Guideline Levels

Immediately Dangerous to Life and Health (IDLH)

NIOSH defines IDLH as a situation that poses a threat of exposure to airborne contaminants when that exposure is likely to cause death, or immediate or delayed permanent adverse health effects, or to prevent escape from such an environment. The purpose of establishing an IDLH is to ensure that a worker can escape from a given contaminated environment in the event of failure of respiratory protection equipment. The NIOSH respirator decision logic uses an IDLH as one of several respirator selection criteria (<http://www.cdc.gov/niosh/idlh/idlhintr.html#CNU>). Values for listed CWAs and TICs were obtained from USACHPPM (2008).

Short-Term Exposure Limit (STEL)

The NIOSH and OSHA STEL is a 15-minute, time-weighted-average (TWA) exposure that must not be exceeded at any time during a workday. The STEL is the concentration to which it is believed that workers can be exposed continuously for a short time without suffering from (1) irritation, (2) chronic or irreversible tissue damage, (3) dose-rate-dependent toxic effects, or (4) narcosis of sufficient degree to increase the likelihood of accidental injury, impaired self-rescue, or materially reduced work efficiency (NIOSH 2011) (<http://www.cdc.gov/niosh/npg/> and http://www.acgih.org/Products/tlv_bei_intro.htm). Values for listed CWAs and TICs were obtained from USACHPPM (2008).

Military Exposure Guidelines (MEG) for Air

The DOD developed MEGs to assist in assessing the significance of exposure to CWAs during deployments. A MEG is a chemical concentration that represents an estimate of the level above which certain types of health effects may begin to occur in individuals within the exposed population after a continuous, single exposure of specified duration. The severity of health effects and percentage of the exposed population demonstrating health effects increase as concentrations increase above the MEG, but the rate is chemical-specific, and therefore cannot

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be represented by the MEGs themselves. The MEGs are not designed for determining casualty estimates but are, instead, preventative-measures guidelines. The MEGs are based on the assumptions that deployed military populations consist of relatively healthy and fit male and nonpregnant female adults. For selected CWAs and TICs, air MEGs are provided for temporary and short-term exposure scenarios of 10 minutes and 1, 8, and 24 hr. MEGs are also distinguished by the degree of severity and type of toxic effects (i.e., negligible, marginal, critical, and catastrophic) (USACHPPM 2008).

Worker Population Limit (WPL)

The WPL is developed by the CDC for the DOD and is used to monitor identified areas where workers may be exposed to CWAs. The WPL is the maximum allowable 8-hr concentration that an unprotected chemical worker could be exposed for an 8-hr workday and 40-hr week for 30 years without adverse effects. The WPL falls within the general category of Airborne Exposure Limits (AELs) (<http://www.cma.army.mil/>).

Table G-1. Air exposure guidelines (mg/m³) for selected CWAs and TICs.

	Duration (hr)	VX	Tabun	Sarin	Soman	Cyclosarin	Sulfur mustard	Hydrogen cyanide	Phosgene
IDLH ^a	0.5	3×10 ⁻³	1×10 ⁻¹	1×10 ⁻¹	5×10 ⁻²	5×10 ⁻²	7×10 ⁻¹	NA	8.1
STEL ^a	0.25	1×10 ⁻⁵	1×10 ⁻⁴	1×10 ⁻⁴	5×10 ⁻⁵	5×10 ⁻⁵	3×10 ⁻³	NA	NA
AEGL-1 ^b	0.17	5.7×10 ⁻⁴	6.9×10 ⁻³	6.9×10 ⁻⁴	3.5×10 ⁻³	NA	4×10 ⁻¹	2.8	NA
AEGL-1	0.5	3.3×10 ⁻⁴	4×10 ⁻³	4×10 ⁻³	2×10 ⁻³	NA	1.3×10 ⁻¹	2.8	NA
AEGL-1	1	1.7×10 ⁻⁵	2.8×10 ⁻³	2.8×10 ⁻³	1.4×10 ⁻³	NA	6.7×10 ⁻²	2.2	NA
AEGL-1	4	1×10 ⁻³	1.4×10 ⁻³	1.4×10 ⁻³	7×10 ⁻⁴	NA	1.7×10 ⁻²	1.4	NA
AEGL-1	8	7.1×10 ⁻⁵	1×10 ⁻³	1×10 ⁻³	5×10 ⁻⁴	NA	8.3×10 ⁻³	1.1	NA
AEGL-2	0.17	7.2×10 ⁻⁴	8.7×10 ⁻²	8.7×10 ⁻²	4.4×10 ⁻²	NA	6×10 ⁻¹	19	2.5
AEGL-2	0.5	4.2×10 ⁻⁴	5×10 ⁻²	5×10 ⁻²	2.5×10 ⁻²	NA	2×10 ⁻¹	11	2.5
AEGL-2	1	2.9×10 ⁻³	3.5×10 ⁻²	3.5×10 ⁻²	1.8×10 ⁻²	NA	1×10 ⁻¹	7.9	1.2
AEGL-2	4	1.5×10 ⁻³	1.7×10 ⁻²	1.7×10 ⁻²	8.5×10 ⁻³	NA	2.5×10 ⁻²	3.9	0.33
AEGL-2	8	1×10 ⁻³	1.3×10 ⁻²	1.3×10 ⁻²	6.5×10 ⁻³	NA	1.3×10 ⁻²	2.8	0.16
AEGL-3	0.17	2.9×10 ⁻²	7.6×10 ⁻¹	3.8×10 ⁻¹	3.8×10 ⁻¹	NA	3.9	30	15
AEGL-3	0.5	1.5×10 ⁻²	3.8×10 ⁻¹	1.9×10 ⁻¹	1.9×10 ⁻¹	NA	2.7	23	6.2
AEGL-3	1	1×10 ⁻²	2.6×10 ⁻¹	1.3×10 ⁻¹	1.3×10 ⁻¹	NA	2.1	17	3.1
AEGL-3	4	5.2×10 ⁻³	1.4×10 ⁻¹	7×10 ⁻²	7×10 ⁻²	NA	5.3×10 ⁻¹	9.7	0.82
AEGL-3	8	3.8×10 ⁻³	1×10 ⁻¹	5.1×10 ⁻²	5.1×10 ⁻²	NA	2.7×10 ⁻¹	7.3	0.32

See footnotes at the end of table G-1.

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Table G-1. Air exposure guidelines (mg/m³) for selected CWAs and TICs—continued.

	Duration (hr)	VX	Tabun	Sarin	Soman	Cyclosarin	Sulfur mustard	Hydrogen cyanide	Phosgene
PAL-1 ^c	24	1.7×10 ⁻⁵	2×10 ⁻⁴	2×10 ⁻⁴	3.8×10 ⁻⁴	NA	8×10 ⁻⁴	NA	6.9×10 ⁻³
PAL-1	720	1.8×10 ⁻⁶	1.8×10 ⁻⁵	1.8×10 ⁻⁵	1×10 ⁻⁵	NA	1×10 ⁻⁴	NA	2.4×10 ⁻³
PAL-1	2160	NA	1.8×10 ⁻⁵	1.8×10 ⁻⁵	1×10 ⁻⁵	NA	1×10 ⁻⁴	NA	2.4×10 ⁻³
PAL-2	24	6.3×10 ⁻⁴	1×10 ⁻³	1×10 ⁻³	1×10 ⁻³	NA	1.3×10 ⁻²	NA	1.3×10 ⁻²
PAL-2	720	7.3×10 ⁻⁵	7.3×10 ⁻⁴	7.3×10 ⁻⁴	3.7×10 ⁻⁴	NA	2.9×10 ⁻³	NA	4.9×10 ⁻³
PAL-2	2160	NA	1.6×10 ⁻⁴	2×10 ⁻⁴	8×10 ⁻⁵	NA	9.7×10 ⁻⁴	NA	4.9×10 ⁻³
PAL-3	24	2.2×10 ⁻³	3×10 ⁻²	1.5×10 ⁻²	8.8×10 ⁻³	2×10 ⁻³	3.5×10 ⁻¹	NA	8.9×10 ⁻²
PAL-3	720	NA	NA	NA	NA	NA	NA	NA	NA
PAL-3	2160	NA	NA	NA	NA	NA	NA	NA	NA
MEG ^a	0.17	6×10 ⁻⁴	6.9×10 ⁻³	6.9×10 ⁻³	3.5×10 ⁻³	3.5×10 ⁻³	4×10 ⁻¹	NA	NA
MEG	1 day	1.7×10 ⁻⁴	2.8×10 ⁻³	2.8×10 ⁻³	1.4×10 ⁻³	1.4×10 ⁻³	6.7×10 ⁻²	2.2	0.4
MEG	30 days	7×10 ⁻⁵	1×10 ⁻³	1×10 ⁻³	5×10 ⁻⁴	5×10 ⁻⁴	8.3×10 ⁻³	1.1	0.4
MEG	90 days	2.4×10 ⁻⁵	3×10 ⁻⁴	3×10 ⁻⁴	2×10 ⁻⁴	2×10 ⁻⁴	3×10 ⁻³	NA	NA
MEG ^d	0.17	1.3×10 ⁻²	1.4×10 ⁻¹	1.4×10 ⁻¹	6.1×10 ⁻³	5.7×10 ⁻³	1.2	NA	NA
MEG	1	51×10 ⁻³	5.8×10 ⁻³	5.8×10 ⁻³	2.5×10 ⁻²	2.3×10 ⁻²	1.9×10 ⁻¹	7.8	1.2
MEG	8	1.8×10 ⁻³	2×10 ⁻²	2×10 ⁻²	0.9×10 ⁻³	0.8×10 ⁻³	2.4×10 ⁻²	NA	NA
MEG	24	6×10 ⁻⁴	6.7×10 ⁻³	6.7×10 ⁻³	3×10 ⁻³	2.7×10 ⁻³	8.1×10 ⁻³	NA	NA
MEG	0.17	2.2×10 ⁻²	2.2×10 ⁻¹	2.2×10 ⁻¹	8.9×10 ⁻²	8.9×10 ⁻²	1.7	NA	NA
MEG	1	9×10 ⁻³	9.1×10 ⁻²	9.1×10 ⁻²	3.7×10 ⁻²	3.7×10 ⁻²	2.8×10 ⁻²	16.6	3
MEG	8	3×10 ⁻³	3.2×10 ⁻²	3.2×10 ⁻²	1.3×10 ⁻²	1.3×10 ⁻²	3.5×10 ⁻⁴	NA	NA
MEG	24	1×10 ⁻³	1×10 ⁻²	1×10 ⁻²	4×10 ⁻²	4×10 ⁻²	1.2×10 ⁻²	NA	NA
MEG	0.17	10	11	5.6	5.6	5.6	2.2	NA	NA
MEG	1	1.7	4.6	2.3	2.3	2.3	0.9	NA	NA
MEG	8	2.1×10 ⁻¹	1.6	0.8	0.81	0.81	0.32	NA	NA
MEG	24	7×10 ⁻²	5.4×10 ⁻¹	2.7×10 ⁻¹	2.7×10 ⁻¹	2.7×10 ⁻¹	1.1×10 ⁻¹	NA	NA
MRL	24-336	NA	NA	NA	NA	NA	7×10 ⁻⁵	NA	NA
MRL	360-8760	NA	NA	NA	NA	NA	2×10 ⁻⁵	NA	NA
WPL ^a	219,000	1×10 ⁻⁶	3×10 ⁻⁵	3×10 ⁻⁵	3×10 ⁻⁵	3×10 ⁻⁵	4×10 ⁻⁴	NA	NA
GPL	613,200	6×10 ⁻⁷	1×10 ⁻⁶	1×10 ⁻⁶	1×10 ⁻⁶	1×10 ⁻⁶	2×10 ⁻⁵	NA	NA
RfC	613,200	NA	NA	NA	NA	NA	NA	3×10 ⁻³	3×10 ⁻⁴

Color key: Green = MEG negligible. Blue = MEG marginal. Orange = MEG critical. Red = MEG catastrophic.

Dark red MRL = acute. Blue MRL = intermediate.

NA = not available. See additional footnotes for Table G-1 on the next page.

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^a *The Medical CRPN Battlebook, Technical Guide 224* (USACHPPM 2008).

^b For U.S. EPA AEGLs, see <http://www.epa.gov/opptintr/aegl/>.

^c PALs available at <http://www.epa.gov/nhsr/index.html>

^d 24-hr MEGs derived from 8-hr AEGL by straight-line extrapolation, intended for healthy males or nonpregnant females ages between 18 to 55 (USACHPPM 2008).

Note that exposure guidelines for cyanogen chloride are not included in this table because none are available

G.4.2 Water Exposure Guidelines

G.4.2.1 General Population Guideline Levels for Water

Guideline levels for the CWAs and TICs identified in this *Remediation Guidance* for drinking water exposures to the general population do not exist. However, it is possible to use the toxicity values estimated by the DOD (USACHPPM 1999) and equations for drinking water Regional Screening Levels (EPA 1991) or other criteria to calculate general population guideline levels that can be used in screening assessment. See Table G-2, below, for a summary of estimated water exposure guidelines (RSLs, RCBs, MEGs, and PALs) for selected CWAs and TICs discussed in this section.

Maximum Contaminant Levels (MCLs)

The MCLs are derived by the EPA and are enforceable standards. They represent the maximum concentration of a chemical that is allowed in a public drinking water system. The EPA has not promulgated MCLs for CWAs. However, values can be calculated using DOD-derived toxicity values and EPA equations.

Regional Screening Levels (RSLs) for Drinking Water

The *Risk Assessment Guidance for Superfund, Part B* (EPA 1991) provides methodologies to calculate cleanup goals for environmental media such as drinking water. The same methodologies can be used with DOD-derived toxicity values to calculate residential drinking water RSLs for CWAs and TICs. These values are summarized in Table G-2 (http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/index.htm).

Provisional Advisory Level (PAL)

The PALs have been developed for drinking water ingestion and represent exposure advisory levels for the general public applicable to emergency situations. They are developed for use by Federal, state, and local emergency responders to inform and support decisions regarding evacuation from, and/or temporary re-entry into, or re-use of contaminated drinking water sources. The PALs may be useful in planning and response efforts by homeland security, public health and law enforcement agencies, emergency response agencies, water utilities, and national and regional EPA offices. Three levels (PAL 1, PAL 2, and PAL 3) are distinguished by the degree of severity and type of toxic effects and are developed for 24-hr, 30-day, 90-day, and 2-year ingestion of drinking water. Although PALs are developed with considerable attention to sensitive populations (such as asthmatics and those with age-dependent sensitivities), PALs are

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not intended to protect hypersensitive populations or idiosyncratic responders within the general population.

- **PAL 1** represents a threshold concentration with assumed continuous exposure of a chemical in air or drinking water. Specific biomarkers for physiological responses or adverse effects in the general population could occur above the PAL 1 value. Concentrations at or below PAL 1 are not expected to be associated with adverse health effects. Increasingly greater concentrations above the PAL 1 value could cause a progressive increase in severity of harmful effects in the general population, including all ages and sensitive subpopulations.
- **PAL 2** represents the assumed continuous exposure concentration of a chemical in air or drinking water above which serious, irreversible, or escape-impairing effects could result. Increasingly greater concentrations above the PAL 2 value could cause a progressive increase in severity of harmful effects in the general population, including all ages and sensitive subpopulations.
- **PAL 3** represents the assumed continuous exposure concentration of a chemical in air or drinking water above which lethality in the general population, including all ages and sensitive subpopulations, could occur.

As provisional values, EPA policy requires that PALs be intended for use in emergency situations. Their provisional nature does not imply a lack of scientific rigor during development. PAL values for CWAs and some TICs are available through the NHSRC (<http://www.epa.gov/nhsrc/index.html>).

G.4.2.2 Workforce Guideline Levels for Water

Military Exposure Guidelines (MEG)

The DOD developed MEGs to assist in assessing the significance of exposure to CWAs during deployments. A MEG is a chemical concentration that represents an estimate of the level above which certain types of health effects may begin to occur in individuals within the exposed population after a continuous, single exposure of specified duration. The severity of health effects and percentage of exposed population demonstrating health effects increase as concentrations increase above the MEG, but the rate is chemical-specific, and therefore cannot be represented by the MEGs themselves. The MEGs are not designed for determining casualty estimates but are instead preventative-measures guidelines. The MEGs are based on the assumptions that deployed military populations consist of relatively healthy and fit male and nonpregnant female adults (USACHPPM 2008).

Water MEGs were developed for short-term exposure scenarios with a maximum assumed duration of 7 days. Water MEGs are based on specific exposure conditions that are described by daily rates of water consumption that have been designated as typical standards for military

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deployment operations: 5 L per day for moderate climates and 15 L per day in dry, arid climates. Water MEGs are designed to indicate “thresholds” for minimal to no adverse health effects.

Table G-2. Water exposure guidelines (µg/L) for selected CWAs and TICs.

	Duration	VX	Tabun	Sarin	Soman	Cyclosarin	Sulfur mustard	Hydrogen cyanide	Cyanogen chloride	Phosgene
RSL ^a	Lifetime	NA	NA	NA	NA	NA	NA	1.6	1800	NA
RBC ^b	Lifetime	0.021	1.4	0.7	0.14	0.14	0.25	6.2	1800	NA
MEG ^c 5L/day	7 days	15	140	28	12	NA	140	NA	NA	NA
MEG 15L/day	7 days	5	46	9.3	4	NA	47	NA	NA	NA
PAL1 ^d	1 day	2.7	74	37	7.4	7	1400	NA	NA	NA
PAL1	30 days	0.21	16	8.1	1.6	1.6	250	NA	NA	NA
PAL1	90 days	0.21	4	2	0.44	0.44	250	NA	NA	NA
PAL2	1 day	8	220	110	22	22	5600	NA	NA	NA
PAL2	20 days	1	24	12	2.4	2.4	750	NA	NA	NA
PAL2	90 days	1	NA	NA	NA	NA	750	NA	NA	NA
PA3	1 day	39	1400	570	NA	NA	7000	NA	NA	NA
PAL3	30 days	39	NA	250	NA	NA	2100	NA	NA	NA
PAL3	90 days	NA	NA	NA	NA	NA	NA	NA	NA	NA

NA = not available.

^a RDLs see http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/pdf/restrap_sl_table_run_NOVEMBER2010.pdf

^b Risk-based concentration (RBC) values calculated for chronic exposure akin to MCLs.

^c *The Medical CRPN Battlebook, Technical Guide 224* (USACHPPM 2008).

^d PALs available at <http://www.epa.gov/nhsrc/index.html>

G.4.3. Soil Guideline Levels

General Population and Workforce Guideline Levels

Under direction of the DOD, the national laboratories—using models developed by the EPA and Army-approved interim chronic toxicity values—calculated health-based environmental screening levels for CWAs in soil. Both general population and workforce exposure scenarios were evaluated (USACHPPM 2008). The screening levels are risk-based concentrations, derived from standardized equations combining exposure assumptions with toxicity data from the EPA and other organization, such as the Army. They are considered by the EPA to be protective for humans (including sensitive subpopulations) as screening levels for contaminants in environmental media, triggers for further investigation, and provide an initial cleanup goal, if applicable.

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Soil MEGs have been derived for 1-year (deployment length), continuous exposures. Soil-MEG values are based on specific exposure assumptions that are described by daily rates of activity to include breathing rates, incidental soil ingestion rates, and dermal contact rates that are expected to be typical for military deployment operations. The soil guidelines are designed to indicate “thresholds” for no adverse health effects. As the parameters of soil MEG are exceeded (e.g., chemical concentrations exceed soil MEGs, or exposure durations increase), it becomes more likely that greater portions of individuals in the exposed population will experience adverse health outcomes.

Other Soil Guideline Levels (RSLs and PRGs)

The *Risk Assessment Guidance for Superfund, Part B* (EPA 1991) provides methodologies to calculate cleanup goals for environmental media such as soil. The same methodologies can be used with DOD-derived toxicity values to calculate residential and occupational soil RSLs for CWAs and TICs. RSLs are available for several TICs at

http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/index.htm.

Table G-3 shows soil exposure guidelines [residential and occupational Preliminary Remediation Goals (PRGs)] for selected CWAs and TICs. PRGs are risk-based concentrations derived from standardized equations combining exposure information assumptions with toxicity data from the EPA or other agencies such as CHPPM. They are considered by the EPA to be protective for humans (including sensitive subpopulations) as screening levels for contaminants in environmental media, triggers for further investigation, and provide an initial cleanup goal, if applicable. See http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/index.htm.

Table G-3. Soil exposure guidelines for selected CWAs and TICs.

CWA or TIC	Residential PRG (mg/kg) lifetime duration	Occupational PRG mg/kg 24 years
VX	0.0042	1.1
Tabun	2.8	68
Sarin	1.3	32
Soman	0.22	5.2
Cyclosarin	0.22	5.2
Sulfur mustard	0.01	0.3
Hydrogen cyanide	19	80
Cyanogen chloride	3,900	51,000
Phosgene	0.33	1.4

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G.4.4. Surface Guideline Levels

There are no peer-reviewed, published values for short- or long-term dermal toxicity for CWAs. Quantitative risk-based methods apply oral toxicity values to assess risks from dermal exposure. Depending on the studies from which a chemical's toxicity value was derived, one may need to adjust the oral toxicity value from an administered dose to an absorbed dose. The methodology is provided in EPA's *Risk Assessment Guidance for Superfund* (RAGS) (EPA 1989).

The *Risk Assessment Guidance for Superfund, Part B* (EPA 1991) provides methodologies to calculate cleanup goals for environmental media such as soil and water. More recently, the EPA recognized the need to expand its efforts to include building surfaces. Subsequent to the attack on the World Trade Center, the EPA became involved in efforts to develop risk-based surface cleanup goals (EPA 2003) using methodology similar to that provided by RAGS Part B to evaluate contamination from building debris in residential and commercial properties. Other available methods to derive surface cleanup goals have been developed by the California EPA (CalEPA 2009) that incorporate EPA's Stochastic Human Exposure and Dose Simulation (SHEDS) Model (EPA 2007).

Using the equations and assumptions presented by EPA (2003), surface cleanup goals can be calculated. Although cleanup criteria for environmental media have typically relied on the use of default exposure assumptions to characterize standard industrial or residential land-use assumptions for more chronic exposures, cleanup criteria for buildings and their internal surfaces cannot be grouped into such broad categories. Any implementation of the methodology should be situation-specific. Depending on the exposure scenario (e.g., small quantities of nonpersistent chemicals on nonporous surfaces), it may be possible to use exposure duration estimates that are shorter, resulting in higher screening levels. As a demonstration of the method, Table G-4 shows example surface clearance goals for a variety of CWAs and TICs on nonporous surfaces. The values shown in the table are not to be considered EPA policy or a recommendation of this *Remediation Guidance* document.

The pathways included in this model include dermal exposure and oral exposure (from hand-to-mouth activity). The model does not include the inhalation pathway (either inhalation of dusts or volatiles). It is recommended that buildings contaminated with significant amounts of contaminated dust be evaluated using models for surface soil inhalation exposures and with exposure parameters adjusted accordingly. As a means of comparison, Table G-4 shows risk-based surface screening levels for example exposure scenarios: an adult residential scenario, and an adult worker scenario. The equations and exposure assumptions used to derive these estimates are provided below.

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Table G-4. Solid-surface exposure guidelines for selected CWAs and TICs.

CWA or TIC	Residential PRG ($\mu\text{g}/\text{cm}^2$) lifetime duration	Occupational PRG ($\mu\text{g}/\text{cm}^2$) 24 years
VX	1.3×10^{-4}	3.6×10^{-4}
Tabun	8.6×10^{-3}	2.4×10^{-2}
Sarin	4.3×10^{-3}	1.2×10^{-2}
Soman	8.6×10^{-4}	2.4×10^{-3}
Cyclosarin	8.6×10^{-4}	2.4×10^{-3}
Sulfur mustard	8.1×10^{-5}	2.2×10^{-4}
Hydrogen cyanide	1.3×10	3.7×10
Cyanogen chloride	6.4	1.8×10
Phosgene	Not available	Not available

Calculation of Chemical-Specific Surface Cleanup Goals

Cancer risk from oral exposures:

$$Cancer\ Risk_o = \frac{SF_o \times ED \times EF \times MCF \times STF \times UC \times MSA \times MF \times SE \times ET}{BW \times AT_c \times TCF} \quad \text{Eq. 1}$$

Cancer risk from dermal exposures:

$$Cancer\ Risk_D = \frac{SF_D \times ED \times EF \times MCF \times STF \times UC \times CR \times ABS_D \times ET}{BW \times AT_c \times TCF} \quad \text{Eq. 2}$$

where:

$$SF_D = \frac{SF_o}{ABS_{GI}} \quad \text{Eq. 3}$$

Noncancer hazard from oral exposures:

$$Noncancer\ Hazard_o = \frac{1/RfD_o \times ED \times EF \times MCF \times STF \times UC \times MSA \times MF \times SE \times ET}{BW \times AT_c \times TCF} \quad \text{Eq. 4}$$

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Noncancer hazard from dermal exposures

$$\text{Noncancer Hazard}_D = \frac{1/RfD_D \times ED \times EF \times MCF \times STF \times UC \times CR \times ABS_D \times ET}{BW \times AT_N \times TCF} \quad \text{Eq. 5}$$

where:

$$RfD_D = RfD_O \times ABS_{GI} \quad \text{Eq. 6}$$

Risk-based surface goal for carcinogens:

$$\text{Risk-based Surface Goal}_C (\mu\text{g} / \text{cm}^2) = \frac{\text{Target risk}}{\text{Cancer risk}_O + \text{Cancer risk}_D} \quad \text{Eq. 7}$$

Risk-based surface goal for noncarcinogens:

$$\text{Risk-based Surface Goal}_N (\mu\text{g} / \text{cm}^2) = \frac{\text{Target hazard}}{\text{Noncancer hazard}_O + \text{Noncancer hazard}_D} \quad \text{Eq. 8}$$

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Parameters for Surface Cleanup Goal Equations

Parameter	Definition	Exposure Scenario		Ref.
		Worker	Adult Resident	
ED	Exposure duration (years)	25	24	a, b, c
EF	Exposure frequency (days/year)	250	350	a, b, c
MCF	Mass conversion factor (mg/μg)	0.001	0.001	
STF	Skin transfer factor (unitless)	0.25 nonporous 0.05 porous	0.25 nonporous 0.05 porous	d
UC	Unit concentration (μg/cm ²)	1.0	1.0	
MSA	Mouthing surface area (cm ² /event)	45	45	d
MF	Mouthing frequency (events/hour)	2	2	d
SE	Saliva extraction factor (unitless)	0.5	0.5	d
ET	Exposure time (hr/day)	8	16	a, b, c
BW	Body weight (kg)	70	70	a, b, c
AT _C	Averaging time for carcinogens (years)	70	70	a, b, c
AT _N	Averaging time for noncarcinogens (years)	25	24	a, b, c
TCF	Time conversion factor (days/year)	365	365	a, b, c
CR	Contact rate (cm ² /hr)	2000	2000	b
SF _O	Oral cancer slope factor ([mg/kg-day] ⁻¹)	Chemical specific	Chemical specific	
SF _D	Dermal cancer slope factor ([mg/kg-day] ⁻¹)	Calculated	Calculated	Eq. 3
ABS _{GI}	Gastrointestinal absorption factor (unitless)	Chemical specific	Chemical specific	e
ABS _D	Dermal absorption factor (unitless)	Chemical specific	Chemical specific	e
RfD _O	Oral reference dose (mg/kg-day)	Chemical specific	Chemical specific	
RfD _D	Dermal reference dose (mg/kg-day)	Calculated	Calculated	Eq. 6

a RAGS Part B (EPA 1991).

b RAGS Part E (EPA 2004).

c Soil Screening Levels for Superfund Sites (EPA 2002).

d World Trade Center Indoor Air Task Force Working Group (EPA 2003).

e ORNL (ORNL 2005).

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G.5 Considerations When Selecting Guideline Levels for a Specific Application

Selecting appropriate guideline levels can be a daunting task. Regulations, where present, will demand that a particular guideline level be used. In the absence of specific regulations, existing exposure guidelines can be adopted as a clearance goal, or site-specific values can be calculated. Previous national emergency responses (the World Trade Center attack, Katrina and Rita hurricanes, and Deep Horizon oil spill) are real-world examples of how experts from across the country have come together to peer review and develop exposure guidelines for site-specific situations and a variety of needs.

Consider Table G-1 in Section G.4, which summarizes many air-exposure-pathway guideline levels for VX. At first glance, this table shows what may be interpreted as a confusing array of guideline levels. Upon closer examination, however, it is possible to see trends that could assist in selecting an appropriate guideline level for a specific scenario. Acute exposure guideline levels are found at the higher end of the exposure concentration continuum. In toxicological terms, this makes sense because we recognize that, for noncarcinogens, humans have some capacity to tolerate doses (i.e., larger amounts over a shorter exposure period) of hazardous materials such as CWAs for short times. A comparison, however, of action levels such as the AEGL-1 values representing mild, reversible effects, and AEGL-2 values representing irreversible effects shows that these values are rather close. Uncertainties in measurement or other site-specific circumstances could result in harm if decisions are attempted at the AEGL-1 level for a particular CWA. Intermediate (30 days) to longer-term (1 to 70 years) exposure guideline levels for the general population and working population at the no-adverse-effect-level are found near 1×10^{-6} mg/m³. This is in comparison to exposure guidelines shown for sarin in Table G-1. Longer-term exposure guideline levels can be found between 1×10^{-3} and 1×10^{-6} mg/m³; however, the minimal effect levels for intermediate durations for the general population and for longer-term exposures for workers are found between 1×10^{-4} and 1×10^{-5} mg/m³. The very steep slope representing the line that connects one AEGL time point and another, and the narrow distance between one AEGL severity level and another, make decision-making more difficult at the acute exposure concentration range.

In other cases, such as for soil cleanups under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), the screening level goal is merely a starting point for decisions regarding remediation actions. Table G-3 shows that soil screening levels are established at the lower, more conservative end of the contaminant concentration spectrum and can be compared with action levels that are at the higher end of the concentration spectrum. The higher environmental concentrations are at levels that clearly warrant some response action. The term “screening level” denotes to some users the concept of less conservatism and, therefore, a higher concentration. On the contrary, screening assessments more correctly imply the lack of confirmatory data and, therefore, a greater level of uncertainty. Lack of certainty should promote a greater level of conservancy in decision-making to ensure the protection of public health and the environment. Final decisions regarding an ultimate cleanup level will include consideration

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not only of the exposure assumptions that underlie development of a risk-based screening level, but other considerations, such as technical feasibility, cost, regulatory mandates, short- and long-term effectiveness, and community acceptance.

Selecting cleanup levels intended for areas where children, the infirm, or even young and healthy adults are present needs the careful consideration of experts in a variety of fields, including facility operators, local officials, and local public health experts. The process should not be done in the absence of local sensitivities and considerations.

G.6 Spring Valley Case Study

The Spring Valley Formerly Used Defense Site (SVFUDS) consists of ~661 acres in the northwest section of Washington, DC. During the World War I era, the site was known as the American University Experiment Station (AUES) and used by the U.S. government for research and testing of chemical agents, equipment, and munitions. Today, the Spring Valley neighborhood encompasses ~1,600 private homes, including several embassies, foreign properties, American University, and Wesley Seminary. This case study is a summary of documents found on the Army Corps of Engineers (The Corps) website for Spring Valley <<http://www.nab.usace.army.mil/projects/WashingtonDC/springvalley/overview.htm>>. The website provides the Site-Wide Work Plan, Remedial Investigation (RI) reports, Engineering Evaluation/Cost Analysis (EECA) reports, and Sampling and Analysis Plans as well as public communication products, such as factsheets and news releases regarding the Spring Valley response and remediation activities.

The Superfund framework was followed for the SVFUDS investigation and remediation, which included input from representatives of The Corps, EPA, District of Columbia Department of the Environment (DDOE), and Spring Valley community. Site- and situation-specific decisions were made throughout the process per Superfund regulation and guidance. In the following summary, statements and resolutions regarding clearance decisions are in boldface.

G.6.1 Site-Wide Work Plan

The *Site-Wide Work Plan Spring Valley Formerly Used Defense Site* (March 2007) provides details of the procedures, methods, organization, and resources used to achieve project objectives. Objectives of the Spring Valley FUDS investigation were to:

1. Determine if chemical agent, agent breakdown products, or FUDS-related disposal areas exist in areas identified by the Spring Valley Partners.
2. Remove any munitions and explosives of concern or recovered chemical warfare material, munitions debris, laboratory wastes, and other debris attributed to past SVFUDS activities.
3. Resolve any anomalies or anomalous areas identified by the Spring Valley Anomaly Review Board.

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4. Collect data, as appropriate, to characterize investigated areas for the SVFUDS overarching Remedial Investigation/Feasibility Study (RI/FS).

G.6.2 Identification of Areas of Concern and Points of Interest

The first 36 points of interest (POIs) were selected from a review of historical records, including a 1918 aerial photograph. From additional information obtained during an expanded research effort, 17 additional POIs were identified for a total of 53 POIs. Continuing analyses and interpretation of new data and information was the responsibility of the Area of Interest (AOI) Task Force consisting of representatives of The Corps, EPA, and DDOE. Once an area was identified, a determination was made as to the type of investigation to be made. Investigations included test pits performed under the Site-Wide Work Plan, and/or geophysical investigations performed under the Site-Wide Work Plan or other SVFUDS work plans.

G.6.3 Data Quality Objectives for Site Investigations

Environmental investigations at the SVFUDS were conducted to ensure that data were collected of the right type, quality, and quantity to support defensible site decisions. Data quality objects (DQOs) for the project were developed using the guidance in *Data Quality Objectives Process for Hazardous Waste Site Investigations (QA/G-4HW)* (USEPA 2000).

The conceptual site model (CSM) for the SVFUDS was initially developed by The Corps. In general, the CSM focuses on encountering Ca or arsenic and other contaminants that may have resulted from AUES operations. Potential receptors include private residents, students, construction workers, and groundskeepers. Potential exposure scenarios with regard to surface soil, subsurface soil, and bottle contents involve dermal contact, direct ingestion, and inhalation of fugitive particulates.

For processing of contaminated solids or liquids, inputs for decision were the parameters, analytes, and “comparison values” included in EPA Region III Risk Based Concentrations (RBCs) for residential exposures and Health Based Environmental Screening Levels (HBESLs) (risk-based screening levels of CWAs) for residential exposures derived by the DOD. These are risk-based screening levels calculated for a 1×10^{-6} cancer risk or a hazard index of 1 for noncarcinogens. However, both RBCs and HBESLs based on a noncancer hazard index of 1 were adjusted downward by a factor of 10 to account for cumulative effects.

G.6.4 Site Investigation Decision Rules

The general decision rule for soil excavations is that if the concentration of any of the chemical agents of interest (including chemical agents, agent breakdown products, or ricin) exceeds the comparison value, then further vertical or lateral excavation is warranted in that grid. If those comparison values are not exceeded, the excavation is considered complete and may be backfilled.

The general decision rule for hazardous waste constituents in soil or water is that if the concentration of any hazardous waste analyte exceeds the comparison value (RBCs or HBSLs),

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then one of several actions may be taken. Actions include further vertical or lateral excavation, further sampling until the area is below the comparison value for that compound, or performance of risk-assessment calculations to evaluate future risk potential if that soil remains in place.

G.6.5 Initial Investigation (1993 to 1995)

While digging a utility trench in Spring Valley in 1993, a contractor unearthed buried military ordnance. The U.S. Army Technical Escort Unit initiated an emergency response that resulted in removal of 141 ordnance items (43 suspect chemical items) from a past burial pit. The action prompted a remedial investigation of the site. Using historical documentation from reports, maps, and photos, The Corps focused its investigation on specific sites that were determined to have the greatest potential for contamination. Such sites were referred to as POIs.

During the extensive, 2-year investigation that followed, POIs plus a selection of approximately 10 percent of all properties outside of the POIs were evaluated. The additional properties served as a check on historical information that had been gathered. A total of 492 properties were investigated.

G.6.5.1 Investigation Results

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

The risk-based criteria used to evaluate the samples were EPA Region III RBCs or site-specific background concentrations for inorganic chemicals. Region III RBCs were developed using EPA guidance for exposure estimates considering chronic exposures to the general public and chronic toxicity values. Similar RBCs were developed for CWAs. The DOD has developed HBESLs using the same methods and exposures assumptions (chronic exposures to the general public). The RBCs and HBESLs have been developed for both soil exposures and water exposures.

No chemical agents, CWA-unique breakdown products, explosives, or explosive breakdown products were found in any of the samples taken. However, several metals were identified that exceeded the EPA's RBCs. The metals were included in a quantitative baseline risk assessment, which found no elevated health risk requiring remedial action. Arsenic was not identified as a

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chemical of potential concern in the risk assessment because the sampling results were not significantly different from background concentrations.

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

G.6.5.2 Follow-Up Investigation

In 1996, the D.C. Health Department reported to EPA that they had uncovered new information regarding the Spring Valley site. The Corps responded to each of the issues raised by the D.C. Health Department. The Corps conducted field investigations of the area located along Glenbrook Road. An intrusive investigation of the area located two large burial pits. More than 600 items were recovered, including 288 ordnance-related items. Of those items, 14 were evaluated to have CWA, predominantly mustard agent. Following this work, soil samples were collected from the recovery site. Test results indicated elevated levels of arsenic were present in portions of the area. Following a comprehensive risk assessment, The Corps determined that the top 2 feet of soil in the affected areas should be removed and replaced with new soil. Work began in December 2000, was completed a few months later, and the property was restored.

The risk-based criteria used to evaluate these samples were EPA Region III RBCs, HBESLs, or site-specific background concentrations for inorganic chemicals. Region III RBCs and HBESLs were developed using EPA guidance for exposure estimates considering chronic exposures to the general public and chronic toxicity values. Follow-up evaluations used Region III RBCs or, in the case of CWAs, CHPPM residential HBESLs adjusted downward by 10 to account for cumulative toxicity.

G.6.6 Investigation Expanded

G.6.6.1 Soil Sampling and Cleanup

From the follow-up findings, it was determined in January 2000 that the area of investigation should be expanded. A plan was developed to conduct arsenic sampling on 61 private residences and the southern portion of American University. These areas are near the site of the disposal pits. Sampling was completed at 42 of the 61 properties. Eleven property owners would not grant permission, and attempts to reach eight others were unsuccessful. From the results of this sampling, nine properties and several lots on the American University campus were recommended for further detailed sampling. Such sampling was completed in January 2001.

One of the sampled locations involved the area around the American University Child Development Center. Given the sensitivity of this area, soil sampling around the center was expedited and the results provided to the university. Results identified arsenic levels higher than acceptable for a residential area. University officials relocated the Child Development Center to

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another area of the campus. Removal of contaminated soil began in the summer of 2001. New soil was placed on the site, and restoration activities were completed.

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

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

More than 1500 properties were sampled for arsenic. If a particular property was determined to have an elevated level of arsenic, then a more detailed grid sampling procedure was done. Following sampling to identify areas of contamination, results were evaluated to determine any elevated health risk. Working with the EPA and DDOE, The Corps agreed on a cleanup goal of 20 parts per million, and 150 properties were identified with one or more grids above 20 ppm of arsenic.

G.6.6.2 Sedgwick Trench

An investigation of 31 anomalies at two properties in the 5000 block of Sedgwick Street was completed in 2002. A trench system used by military personnel to test and explode munitions was once situated in this area. Three munitions fragments and several pieces of metal construction debris were removed. No intact munitions or laboratory-related materials were found. Air sampling did not detect CWAs or agent breakdown products.

G.6.6.3 Lot 18

The Lot 18 debris field is located on the southwestern edge of the American University campus and behind properties on Rockwood Parkway. In this area, The Corps discovered a debris area that contained domestic trash, laboratory glassware, and inert munitions debris. Excavation in the area started in 2002 and continued into 2003. Work was stopped temporarily at Lot 18 to focus the effort on other areas of the project when, in mid-2003, a bottle that had been recovered from Lot 18 was identified as containing a small amount of 0.3 percent lewisite. Discovery of the lewisite changed the low-probability dig to a high-probability dig. The Corps re-evaluated its site safety and work plans and returned to the site in 2004 with extensive safety measures in place. The dig continued under a pressurized and sealed tent with redundant filtration systems and air monitoring. Workers wore Level-B protective gear and were monitored by closed-circuit TV from an operations center.

At the end of September 2004, 474, 55-gallon drums of soil had been excavated and about 890 items recovered. Seven items required further analysis. All other items were "scrap." Fewer than

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30 were ordnance-related scrap, such as expended fuses, empty projectile casings, and broken pieces of munitions. Examples of the other types of items recovered included empty or broken test tubes and bottles, broken glassware and ceramic pieces, construction debris such as pipes and bricks, battery components, and horseshoes.

Work began November 15, 2005, with a larger sifting table and more workers to increase production. Workers recovered 18 suspect items amid the usual debris, including 15 sealed glass bottles and 3 ordnance related items. Breakdown products of sulfur mustard were identified during analysis of the liquid in one of the recovered bottles. Dithiane and thioxane were found in low quantities and concentrations. Both have a low toxicity and would not cause adverse effects to someone exposed, according to experts.

The site specific work plan for the Lot 18 investigation was further refined and incorporated the use of a much larger engineering control structure, additional chemical agent filtration systems, and a larger excavator. The method of sifting soil was revised from manual to mechanical sifting with the use of a mechanical sifting table and conveyor system. Sifted soil was transferred on a conveyor system into a covered roll-off dumpster, greatly increasing the efficiency of the operation. At the completion of the investigation, a total of 5,500 cubic yards of soil had been removed, 117 munitions debris items, 6 intact munitions items, and 31 intact containers. No munitions items were determined to be explosively or chemically configured. One intact container was determined to contain 0.28 ppm of sulfur mustard (the only CWA material detection during the Lot 18 investigation), and three contained agent breakdown products.

G.6.6.4 Test Pits at 4825 Glenbrook Road

Several investigations were carried out in and around Glenbrook Road following confirmation of burial pits containing ordnance-related items, acids, and other chemicals, including various volatile organic chemicals, semi-volatile organic chemicals, and metals (notably arsenic). In addition, sulfur mustard, lewisite, and agent breakdown products were detected in soils.

Pit characterization samples were collected from the center of the floor of each pit and from the midpoint of each pit outer sidewall, halfway between ground level and the pit floor (on the outer boundary of the excavation area), or near the elevation of scrap or any containers encountered. Samples were collected, analyzed, and evaluated according to the Site Investigation Decision Rules.

If it is determined that further excavation is required from the results of pit characterization sampling for CWAs and agent breakdown products, over-excavation of the pit is to be performed. If further excavation is required at the pit floor, the excavation is to proceed one foot deeper, or until bedrock, saprolite, or native soil is reached. If further excavation is required for a sidewall, excavation is to be taken one foot farther. Following over-excavation of the pit, additional pit characterization samples are to be collected and the process repeated until the pit is determined to be clear (according to Site Investigation Decision Rules) for CWAs or agent breakdown product, or until saprolite or native soil has been reached. If CWAs or agent

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breakdown products are not detected in pit characterization samples, but analysis indicates the presence of hazardous waste compounds, over excavation of hazardous-waste-contaminated soil may be carried out once the engineering control system (ECS), if present, has been moved.

All intrusive operations were conducted inside a negative-pressure ECS and with air monitoring for chemical agent. The ECS minimized exposure of onsite personnel and the nearby public in the event of a release of chemical agent. The ECS (tent) includes a vapor containment cover, combined with a chemical agent filtration system (CAFS). A containment cover is an impermeable fabric designed to prevent the release of any vapors outside the ECS. The ECS operates under negative pressure to contain a chemical release. The CAFS is specifically designed to monitor and remove chemical agent vapors and particulates.

Workers within the ECS were monitored for exposure to chemical agent at the level of WPLs and STELs, as previously defined in Section G.4.1. As a measure of assurance to the general population living nearby, perimeter monitoring was instituted and the AEGL-2 used as the perimeter monitoring action level. The AEGL-2 distance is the distance beyond which the public will not experience irreversible or other serious long-lasting health effects, or an impaired ability to escape associated with the unlikely event of a chemical release. The AEGL-2 distance calculation was based on meteorological conditions and the type and quantity of suspect, recovered chemical warfare materiel. The AEGL-2 distance for the test pits without engineering controls was determined to be 96 feet. However, investigation of the test pits included several engineering controls, including an ECS and CAFS, to reduce the effective AEGL-2 distance outside of the ECS to zero.

G.6.7 Other work

G.6.7.1 *Destruction of Munitions*

In 2003, The Corps used the Explosive Destruction System (EDS) to destroy chemical munitions that had been stored in Spring Valley. The mobile EDS is mounted on the bed of a trailer truck and contains special components to safely treat and neutralize chemical munitions. As an added measure of safety during the Corps' follow-up investigation in Spring Valley, engineers used a control known as the vapor containment structure. Delivered prefabricated and erected onsite, this dome-like structure was built over areas where excavation work was done at the Glenbrook Road site. Constructed of metal and outfitted with an activated carbon filtration system, the vapor containment structure had been tested and proven to contain and filter vapors from CWAs or chemical-filled munitions. It was also designed to safely contain the accidental detonation of small- and medium-sized military munitions. The vapor containment structure greatly reduces the number of residents potentially affected by this investigation. It also provides an increased measure of safety and protection to Spring Valley residents and workers at or near the site should any remnants of past defense activities be found.

During onsite EDS operations, the air within and around the EDS was monitored at the WPL for sulfur mustard and lewisite. As an extra measure of assurance to residents around the EDS, air

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monitoring was conducted, and an action level for evacuation in the event of an accident was set at an 8-hr AEGL.

G.6.7.2 Groundwater Investigation

The Corps installed 38 monitoring wells between 2005 and 2006 in locations agreed on by The Corps, EPA, and DDOE to help determine whether there is contamination in the groundwater and where groundwater is flowing. Sampling results identified elevated levels of perchlorate as high as 146 parts per billion in the project area. Further investigation is underway with more wells and sampling planned in 2009.

Groundwater and surface water analytical results were compared to EPA Region III RBCs for tap water and EPA MCLs.

G.6.8 ATSDR Health Consultation

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

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

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

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G.6.9 Remedial Investigation/Feasibility Study

In 2010, the Army found low-level agent (predominantly lewisite) in soil on a property where WWI disposal had occurred. At about the same time, there was a release of arsenic trichloride in the vapor containment structure over the work area. Work at the site was halted early in 2011. The Army is conducting a risk assessment and remedial investigation/feasibility study (RI/FS) to determine what to do with the property, and to test the efficacy of air filtration units for arsenic trichloride removal. The RI/FS is being assembled with the data gathered during removal actions. A human health risk assessment is being completed.

A soil cleanup goal is being developed for lewisite and mustard. The EPA will generally follow the process used to develop cleanup goals for any contaminants that do not have published values. The process will consider the exposure scenario (residential), toxicity, groundwater, potential for vapor intrusion, and ARARs, and conclude with the development of site-specific cleanup goals. A proposed plan and ROD are planned for this property and will likely be issued in the fall of 2011.

G.6.10 Conclusions

The SVFUDS was extremely complex and posed many challenges, including the search for burials of material that occurred almost 90 years ago and for which there are no documented locations. In addition, the environment has changed over the years because of extensive development of what was, in 1920, primarily open space.

In addition to the Data Quality Objective for environmental investigation detection limits [de facto cleanup goals: EPA Region III RBCs and HBESLs (0.1× screening levels for noncarcinogens to account for additivity)], the protective cleanup goal of 20 ppm for arsenic was agreed on by The Corps, EPA and DDOE, and approved by both the Mayor's Scientific Advisory Panel and the Spring Valley Restoration Advisory Board (SAB). The RAB includes area residents and representatives from each of the three partnering agencies. These cleanup goals were established to achieve a level determined to be very protective against long-term cancer and other noncancer risks for both children and adults. The Region III RRBCs for residential exposures and HBESLs of CWAs for residential exposures derived by the DOD used as cleanup goals are risk-based screening levels calculated for a 1×10^{-6} cancer risk or a hazard index of 1 for noncarcinogens. In many cases, both RBCs and HBESLs based on a noncancer hazard index of 1 were adjusted downward by a factor of 10 to account for cumulative effects. These cleanup goals also considered the natural background levels found in soils within the Washington, D.C. area. As part of the process for defining cleanup (clearance) goals for Spring Valley, EPA stated that "risk assessment and risk management should be conducted on a site-specific, not one-size-fits-all, basis and should incorporate all relevant scientific information to achieve this objective."

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G.7 ESS Pursuit Case Study

In June, 2010, a fishing and clamming vessel, the ESS Pursuit, encountered World War I-era munitions containing sulfur mustard during clam harvesting operations off the coast of New Bedford, MA. This section summarizes the initial response, decontamination, and clearance of the vessel, clam cages containing potentially contaminated clams, warehouse where clams were stored after off-loading from the vessel, and trucks used to transport the clams for disposal.

On June 7, 2010, EPA responded to a report of a fisherman in New Bedford, MA, who displayed symptoms of possible sulfur mustard exposure while on the ESS Pursuit. During clam-dragging operations, the crew pulled up a detonator and several World War I-era sulfur mustard munitions. One of the crew members attempted to throw the munitions overboard. At least one munition broke open, releasing material and exposing crew members and the vessel to sulfur mustard agent. A crew member began to display symptoms of exposure, requiring the captain of the vessel to return to New Bedford Harbor to remove the affected crew member, who then sought medical attention. A nurse at the hospital recognized the symptoms (blisters and respiratory distress) as possible sulfur mustard exposure and notified authorities. Blood tests confirmed exposure of the crew member to sulfur mustard.

While removing the affected crew member, the captain also off-loaded the catch of clams (~500,000 pounds), although potentially contaminated with sulfur mustard, to a refrigerated storage area in New Bedford, MA. After dropping off the affected crew member and the load of clams, the captain of the ESS Pursuit brought on a new crew and headed out to harvest another load of clams. Subsequently, the U.S. Coast Guard (USCG), now aware of the potential contamination on the vessel, ordered the captain to anchor offshore and placed the vessel into quarantine.

Federal, state, and local hazmat personnel responded to the scene and began making entries onto the vessel to investigate and identify any possible sulfur mustard contamination. The Federal On-Scene Coordinator (FOSC) for the response, the USCG, requested EPA support for decontamination and sampling of the fishing vessel, crew personal effects, clam storage areas, and clam disposal trailers. The USCG (with technical assistance from the EPA) provided for the transport in refrigerated food-grade trailers and disposal of approximately 500,000 pounds of potentially contaminated clams. Agencies involved in the response included EPA Region 1; EPA National Decontamination Team (NDT); EPA National Homeland Security Research Center (NHSRC); EPA Region 8; the USCG; USCG Atlantic Strike Team (AST); the DOD; U.S. Navy Explosive Ordnance Disposal Unit (EOD); the ATSDR; the CDC National Center for Environmental Health (NCEH); the Massachusetts National Guard 1st Civil Support Team (1st CST); the Massachusetts Department of Environmental Protection (MassDEP); the Rhode Island National Guard 13th Civil Support Team (13th CST); the Massachusetts Department of Public Health (DPH); the MA Division of Marine Fisheries (DMF); MA Department of Fire Services (DFS) hazmat teams; U. S. Customs and Border Patrol (CBP); the Port of Providence Chemical,

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Biological, Radiological, Nuclear (CBRN) Marine Strike Force; and the New Bedford Fire and Police Departments.

This response to a release of a CWA followed processes defined in the National Contingency Plan. Site-specific decision-making was accomplished within an Incident Command framework. Federal, state, and local agencies (as listed above) provided technical assistance and functioned within the Incident Command structure. The contaminant was identified, a sampling and analysis plan was devised and approved, a clearance process was agreed upon, sampling results were discussed and evaluated, and clearance and release of the vessel was determined by the Incident Command. This incident illustrates a highly successful response that brought together intergovernmental experts from across the country for site- and situation-specific decision-making related to a chemical release.

G.7.1 Response Activities

Planning began for sampling, vessel decontamination, and final disposition of the potentially contaminated clams as well as assessment of the refrigerated warehouse housing the clams. A Region 1 Regional Response Team (R1 RRT) incident-specific teleconference was held to discuss the incident. The R1 RRT was made up of representatives from 16 Federal departments and agencies and each of the New England States/Commonwealths. EPA developed the ESS Pursuit decontamination strategy for review and approval by the Unified Command (UC). The UC included representatives from the USCG and MassDEP, and the New Bedford Fire Chief.

The 1st CST assisted two remaining ESS Pursuit crew members in their departure from the vessel, personnel decontamination, and transferral for precautionary medical screening. Crew members were interviewed for additional information. The USCG reported the quantity of quarantined clams at approximately 250 tons.

On behalf of the USCG FOSC, the EPA OSCs and NDT were tasked with developing various sampling, analysis, and decontamination plans to address the contamination, which included:

- Vessel Decontamination Strategy.
- Decontamination of ESS Pursuit Crew Personal Effects Procedure.
- Post Decontamination Monitoring and Sampling Strategy.
- Clam Disposal Phase—Air Monitoring Strategy.
- Clam Disposal Phase—Decontamination Strategy.
- Clam Disposal Phase—Post-Decontamination Sampling Strategy.

G.7.2 Action Levels and Clearance Goals

Action levels (air concentrations used to monitor the response area to define the exclusion zone) and clearance goals (site-specific concentrations to define levels that would not result in adverse

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health effects associated with re-use or re-entry for populations of concern) were defined for the ESS Pursuit and associated materials and locations.

G.7.2.1 Action Levels

Exclusion Zone. The MassDEP Field Assessment and Support Team (FAST) mobile laboratory vehicle provided four AreaRAEs and monitoring support during clam disposal activities. The AreaRAE is a wireless multi-gas monitor that delivers real-time readings continuously to a computer located within the FAST vehicle located outside the exclusions zone. An AreaRAE multi-gas monitor with an ammonia and hydrogen sulfide sensor was deployed immediately within the exclusion zone where responders were conducting removal activities. A hand-held Photoionization Detector (PID) and combustible gas indicator (CGI) or Drager tubes were also used during removal activities within the exclusion zone. All activities conducted within the exclusion zone required Level-B PPE. Table G-5 summarizes the action levels for responders working within the exclusion zone:

Table G-5. Monitors, action levels, and required action.

Monitor	Action Level	Required Action
AreaRAE		Evacuate exclusion zone and reassess activities.
VOC	100 ppm	
Ammonia	100 ppm	
Hydrogen sulfide	50 ppm	
CGI	10 % LEL	

Monitoring with the handheld APD2000 was also conducted within the exclusion zone because of potential clam contamination with trace amounts of sulfur mustard. If a result was found on the APD2000, a Drager tube sample was taken for sulfur mustard. If the sample was positive, the exclusion zone and immediate area around the exclusion zone were to be evacuated to a predetermined muster area, and the situation reassessed as a potential hazardous materials response. Appropriate emergency response authorities were to be notified immediately, if necessary.

Exclusion Zone Perimeter Monitoring. Three AreaRAE multi-gas monitors were deployed along the northern, southern, and eastern perimeter of the exclusion zone. Two AreaRAE's were equipped with an ammonia and hydrogen sulfide sensor. The third AreaRAE was equipped with a hydrogen sulfide sensor. The purpose of air monitoring along the perimeter of the exclusion zone was to monitor potential offsite migration of ammonia and hydrogen sulfide during clam disposal activities. An action level of 5 ppm for an instantaneous result, or an average result of 1 ppm over a 15-minute period, was used for perimeter monitoring. If an AreaRAE produced an

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instantaneous reading of 5 ppm or a 15-minute, 1-ppm average at the perimeter, the following actions were to be taken:

- Immediately conduct air monitoring in areas downwind of the AreaRAE producing the elevated reading using a hand-held PID or chemical-specific Drager tubes for ammonia and hydrogen sulfide. For ammonia, if Drager tube sample results were greater than 25 ppm, personnel were to evacuate the exclusion zone and the immediate area and reassess operational procedures to attempt to mitigate the situation, including increasing the perimeter of the exclusion zone to ensure safety. For hydrogen sulfide, if Drager tube sample results were greater than 0.5 ppm, take similar actions to attempt to mitigate the situation.
- If the PID produced a reading of 1 ppm or greater, or ammonia and hydrogen sulfide were greater than 25 ppm and 0.5 ppm, respectively, on Drager tube samples, personnel were either to revise operations within the exclusion zone to prevent offsite migration, or they were to increase the perimeter of the exclusion zone to ensure the safety of the public.
- In the event of either situation, personnel were to report the incident immediately to the Site Safety Officer for consideration of additional safety measures for responders and the public.

G.7.2.2 Clearance Goals for Surface Wipes

The following summarizes a memo dated June 14, 2010, and entitled: Risk-based Surface Clearance Goals for Sulfur Mustard.

As part of the response to contamination of the ESS Pursuit and other property from an accidental release of sulfur mustard, risk-based clearance goals have been developed. These clearance goals can be used to inform decision-makers on the adequacy of analytical methods used to determine the presence or absence of sulfur mustard on inanimate surfaces and to estimate if residual contamination has the potential to cause adverse health effects to exposed individuals.

The methods used to estimate risk-based clearance goals for surfaces contaminated by sulfur mustard are consistent with those developed by the EPA's ATSDR, OSHA, the New York State Department of Health, and the New York City Department of Health and Mental Hygiene for calculation of risk-based surface clearance goals subsequent to the World Trade Center collapse (EPA 2003).

Clearance goals were calculated for two receptor types: adult workers and adult residents (general public). Workers were characterized as occupying a facility and touching surfaces for 8 hr a day, 5 days a week, for 25 years. Adult residents were characterized as occupying a facility and touching surfaces for 16 hr a day, 7 days a week, for 24 years. Although the ship is not a typical residential structure, the residential scenario was used to provide a more

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conservative clearance goal that would help to bracket a range of potential exposure scenarios and to account for voyages that may last longer than a typical 8-hr workday. The calculated clearance goals account for intake from both dermal absorption from touching contaminated surfaces and oral ingestion for incidental hand-to-mouth activity. Chronic toxicity values for sulfur mustard have been determined for both noncancer and cancer endpoints. Therefore, it is possible to calculate clearance goals that are based on both types of toxicity. Using the methodology and toxicity information described above, the following surface clearance goals were calculated for both adult worker and adult resident receptors.

Table G-6. Risk-based clearance goals for sulfur mustard.

Receptor	Noncancer goals ^a ($\mu\text{g}/\text{cm}^2$)	Cancer goals ^b ($\mu\text{g}/\text{cm}^2$)
Adult worker	0.0042	0.0022
Adult resident	0.0015	0.00081

^a A target noncancer hazard index of one used.

^b A target cancer risk of 1×10^{-5} used.

Surface wipe samples were collected from a variety of surfaces and analyzed by the EPA Region 1 laboratory. The reporting limit of those analyses was $0.0005 \mu\text{g}/\text{cm}^2$. Because the reporting limit for wipe samples was below the risk-based goals identified above, the analytical methods may be considered sufficient for risk-based decision-making regarding contaminant clearance.

G.7.2.3 Clearance Goals for Air Samples

Air sampling was conducted using a Hapsite direct-reading instrument (portable GC/MS with a detection limit for mustard agent of $0.00091 \text{ mg}/\text{m}^3$ or 0.14 ppb). Air sampling was to be conducted after the area sampled had obtained a temperature of 65°F or higher and maintained that temperature for at least 4 hr or longer. Air samples were collected by allowing sufficient time to run the analysis on the Hapsite (approximately 1 minute run time). The Hapsite detection limit of $0.00091 \text{ mg}/\text{m}^3$ is near the 90 day PAL-1 of $0.0001 \text{ mg}/\text{m}^3$ and the WPL of $0.0004 \text{ mg}/\text{m}^3$ and was, therefore, considered a reasonable goal for this site-specific situation. When the temperature stabilized at or above 65°F , air samples were taken from three locations in the room (one from the far ends of the room and one from the center of the room). All sample collection parameters and analysis data were documented by the sampling team.

G.7.3 Vessel Decontamination Strategy

The EPA, in consultation with its NDT, developed the following decontamination strategy to remediate sulfur mustard contamination.

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- Reconnaissance was conducted on the vessel by the 1st CST to determine locations requiring decontamination.
- From the reconnaissance information, the Coast Guard determined the decontamination locations. Required decontamination methods were as follows:
 - For noncorrosive surfaces, undiluted household bleach (5% sodium hypochlorite solution) was applied with a contact time of 15 minutes, followed by a water rinse. Any sulfur mustard product identified through visual inspection required a contact time of 1 hr on the affected area.
 - For corrosive surfaces, diluted household bleach (10% household bleach = 0.5% sodium hypochlorite solution: 1 part bleach, 9 parts water) was used with a contact time of 15 minutes, followed by a water rinse. Any sulfur mustard product identified through visual inspection required a contact time of 1 hr on the affected area.
 - For an ambient temperature greater than 65°F, the hold (clam storage) area, which contained potentially contaminated clams, was rinsed and agitated with sea water for ~15 to 30 minutes. If the temperature of the hold area was less than 65°F, a decontamination method involving undiluted bleach was to be implemented.
- According to the reconnaissance, the Coast Guard determined items that could not be effectively decontaminated and required proper disposal. The disposal plan contained further information.
- Diluted and undiluted sodium hypochlorite decontamination water generated was containerized and sampled before proper disposal. Sea water (containing no sodium hypochlorite) used to decontaminate the hold area was discharged back to the sea.
- After decontamination operations were complete, sampling and monitoring were conducted in accordance with the site sampling and analysis plan to ensure no further contamination above clearance criteria was present on the vessel.

G.7.4 Post-Decontamination Monitoring and Sampling Strategy

The following strategy to determine the effectiveness of decontamination activities was implemented after decontamination of the fishing vessel was complete:

- Two separate teams of three people (including both EPA and 1st CST personnel) boarded the fishing vessel. Air monitoring and sampling was conducted in areas potentially contaminated by crew members exposed to sulfur mustard during fishing activities, including the deck, galley, and berthing area.
- Monitoring was conducted using an APD2000 and an AP4C. The APD2000 detection limit for mustard agent was 0.220 mg/m³, or 33 parts per billion (ppb); the AP4C detection limit for mustard agent was 70 ppb. Monitoring was conducted throughout the fishing vessel, allowing for sufficient response time for each of the screening instruments. Monitored areas were documented.

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- Air sampling was conducted using a Hapsite portable GC/MS instrument. Air samples were collected by allowing sufficient time to run the analysis on the Hapsite (approximately 1 minute run time). Air sampling activities were documented, and a sampling area diagram was generated.
- Approximately 10 wipe samples were collected in areas that were potentially contaminated by crew members exposed to sulfur mustard. Samples were transported for laboratory analysis of sulfur mustard. Analytical data were released to EPA staff at the incident for immediate review and were then forwarded to the USCG FOSC.
- When monitoring and sampling activities on the vessel were complete, the two teams demobilized from the vessel and boarded the adjacent barge to undergo personnel decontamination.
- From the results of air monitoring and sampling, additional decontamination and monitoring activities were not conducted. Clearance of the vessel was determined by the USCG FOSC, in consultation with the EPA and CST entry teams, according to the results of the analytical data.

G.7.4.1 Sampling Locations

Post-decontamination air monitoring, air sampling, and wipe sampling were conducted in accordance with the *Post-Decontamination Monitoring and Sampling Strategy*. Personnel and equipment were mobilized by a New Bedford Fire and Police boat to a tugboat and barge moored to the ESS Pursuit in the outer New Bedford Harbor. The areas to be monitored and sampled were identified during previous reconnaissance entries, and included areas known or likely to have been directly impacted by the sulfur mustard agent release, as well as those areas where cross contamination by subsequent crew member movement was possible. Two entry teams, of three each, conducted air monitoring and air sampling, with one team assigned to below-deck areas and the other assigned to main deck areas, the wheelhouse, and a changing room off the main deck. Accompanying the two entry teams was one EPA observer and one 1st CST person who coordinated between the two entry teams. Air monitoring was conducted using the APD2000 and AP4Ce. Air sampling was conducted using the Hapsite portable GC/MS. Following completion of air monitoring, ten wipe samples were collected from areas identified during the air monitoring/sampling. Air and wipe sampling was conducted in accordance with the *Sampling and Analysis Plan for the New Bedford Mustard Agent Incident*, which was prepared as a separate document. Each wipe sample was collected from 100 cm² of surface area using sterile gauze wipes that were moistened with hexane. Air monitoring was conducted in three main locations on the deck, as well as locations in the wheelhouse and changing room, and below-deck areas including the galley, shower and bathroom, crew berthing area, and laundry room. Air monitoring was conducted allowing for approximately 30 seconds of response time for each of the screening instruments. All locations sampled by the Hapsite were also monitored using the APD2000 and the AP4Ce. The following is a summary of monitoring and sampling locations.

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Wheelhouse. Wipe sample WS-01 and the Hapsite air sample were collected from a couch cushion surface in the starboard rear section of the wheelhouse. Air monitoring locations within the wheelhouse were selected based on areas or items that were likely to have been used or to have come in contact with potentially contaminated crew members. Locations included hand rails leading up to the wheelhouse from the lower deck, cushion surfaces for a couch, the starboard side countertop, the chart table (port side), the Captain's chair and chair arms, the radio, the ship's wheel and throttle controls, and instrument panel countertop.

Galley. Wipe sample WS-03 and the Hapsite air sample were collected from the surface area of the dining table. Air monitoring locations included the handles of the galley entry door, the shower and bathroom door, the refrigerator, one overhead cabinet, two storage lockers, hand rails in the passageway and stairwell, the outer surface and inner sections of the first aid kit, the galley bench and tabletop, the counter surface, and faucet handles.

Shower and Bathroom. Wipe sample WS-05 and the Hapsite air sample were collected from the base of the shower stall. Air monitoring locations included the shower stall base, vanity counter surface, faucet handles, and storage cabinet handles.

Crew Berthing Area. Wipe sample WS-07 and the Hapsite air sample were collected from the base of the injured crew member's berth. Air monitoring locations included the entry door knob, the injured crew member's berth, the wall adjacent to the berth, and the storage locker handle.

Laundry Room. Wipe sample WS-09 and the Hapsite air sample were collected from the top of the clothes dryer. Air monitoring locations included the washer top, dryer top, and adjacent wall surfaces.

Changing Room. Wipe sample WS-08 and the Hapsite air sample were collected from the floor surface (which was still slightly damp) immediately to the left of the entrance hatch to the changing room. According to CST members, this was the location of mustard agent detection using the M256 kit. Air monitoring locations included the floor where sample WS-08 was collected, a bucket adjacent to the WS-08 sample location, the crew's foul-weather gear; the top of a plastic storage locker, the floor on the starboard and front sides of the changing room, the handle bottom edge and starboard side edge of the entrance hatchway to the changing room, and port and front walls of the changing room.

Main Deck. Wipe sample WS-02 and the Hapsite air sample were collected from the deck opposite the entrance hatchway leading from the main deck to the wheelhouse and main quarters. According to CST members, this was the reported location that the injured crew member's cushion was placed after being removed from below decks. Wipe sample WS-04 and the Hapsite air sample were collected from within the clam hopper/shaker unit for the conveyor belt system. According to CST members, this was the location where the canister was reportedly first noted and handled by crew members. Wipe sample WS-06 and the Hapsite air sample were collected from the starboard side of the ship, near the ship's rail, approximately parallel to the clam

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hopper/shaker unit and to the right of the starboard-side stack house. According to CST members, this was the approximate location where the crew member reportedly threw the canister and then tossed it overboard. Wipe sample WS-10 and the Hapsite air sample were collected from the port side of the ship near the ship's rail, approximately parallel to the clam hopper/shaker unit and to the left of the port-side stack house. It was observed to be the nearest location to the clam hopper/shaker unit from which to gain access to the sea, and therefore a potential point of disposal of materials overboard. Air monitoring locations on the main deck included hand railing and decking along the alleys adjacent to the clam storage area. These included four locations forward (two adjacent to the WS-02 sample location), four locations along both the starboard and port sides of the ship, and two locations along the rear section of the clam storage area. Other main deck air monitoring locations included the following: the outer alley side rail on the seaward side of the ship; opposite the four hand railing samples along the clam storage area locations along both the starboard and port sides of the ship; the metal hand rail, steps, and platform decking leading up to and adjacent to the clam hopper/shaker unit; the metal slide plate and conveyor track/belt within the top of clam hopper/shaker unit; the plastic sorting basket on the decking platform outside (left) of the clam hopper/shaker unit; the starboard side of the clam hopper/shaker unit (chest, elbow, and just above the decking heights); several locations along the floor decking in the vicinity of the clam hopper/shaker unit; the decking, outer rail, and seaward side stack house wall adjacent to sample location WS-06 at multiple heights including chest, elbow, and just above the decking heights; the decking and stack house wall between the clam hopper/shaker unit, the starboard side stack house, and the starboard side dredge hopper at the rear of the ship; the decking and stack house wall between the clam hopper/shaker unit metal stairs/platform, the port side stack house, and the port side dredge hopper at the rear of the ship; the decking, outer rail and stack house wall adjacent to sample location WS-10 at multiple heights (chest, elbow, and just above the decking heights); the rear gangway access swing door (handle, elbow, and just above the decking heights) on the starboard side of the ship; and the forward and rear gangway access swing doors (handle, elbow, and just above the decking heights) on the port side of the ship.

No elevated levels were detected on the APD2000, AP4Ce, or Hapsite GC/MS. Following completion of monitoring and sampling, all wipe samples were delivered to the EPA Office of Environmental Measurement and Evaluation (OEME) laboratory in North Chelmsford, MA for analysis. All wipe sample analytical results were nondetections for sulfur mustard agent.

Following completion of decontamination, monitoring, and sampling activities, the ESS Pursuit was escorted by the USCG to the pier at Hervey Tichon Avenue in New Bedford Harbor. The ESS Pursuit was secured at the pier until laboratory results provided by OEME could confirm that all samples collected from the vessel were below specified clearance criteria. Site-specific risk-based clearance goals used for the site were taken from the document entitled *Risk-Based Surface Clearance Goals for Sulfur Mustard*, dated 14 June 2010.

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G.7.5 Clam Disposal Phase Post-Decontamination Sampling Strategy

The UC developed the following sampling strategy implemented during the clam disposal phase of the response. The clams were embargoed before sale and stored within a refrigerated facility. The embargo on the potentially contaminated clams was lifted by Massachusetts Department of Public Health on June 14, 2010, prior to commencement of the loading of clams onto refrigerated trailers for disposal at incineration facilities in El Dorado, AR. and Deer Park, TX. Loading activities were anticipated to be completed on June 17, 2010. Decontamination activities commenced upon completion of the emptying of clams from the cages onto refrigerated trailers for disposal. Decontamination of 180 clam cages and the refrigerated storage room consisted of wash with a 10% bleach solution with a 15-minute contact time and clean water rinse. After the completion of decontamination activities, sampling was conducted to confirm decontamination effectiveness. For wipe samples, a risk-based clearance goal for noncancer, adult residential exposure of $0.0015 \mu\text{g}/\text{cm}^2$ was used in accordance with the EPA document, *Risk-based Surface Clearance Goals for Sulfur Mustard*, dated June 14, 2010. If wipe samples exceeded the clearance goal, a full decontamination would be required of all clam cages and/or the refrigerated storage room and re-sampled following the same procedures as outlined in this document. For air samples, a clearance goal was indicated as nondetect on a Hapsite Instrument ($0.00091 \text{ mg}/\text{m}^3$, or 0.14 ppb). If any concentration for sulfur mustard was detected, a full decontamination was required of all clam cages and the refrigerated storage room and re-sampled following the same procedures as outlined in this document.

G.7.6 Sampling of Refrigerated Storage Room

G.7.6.1 Wipe samples

Eight samples were taken within the refrigerated storage room. Four samples were taken on the floor at the location of floor drains, and four additional samples were taken at random locations on the floor. Each sample was taken using a 3- × 3-in. gauze pad treated with hexane as a wetting agent. A 100-cm^2 area was sampled with the gauze pad and then placed in a 40-ml VOA vial. The vial was placed inside a plastic bag, which was decontaminated with a 10% bleach solution and then double-bagged and placed in coolers no greater than 14 inches wide by 15 inches high by 15 inches deep. Samples were processed through chain of custody before being delivered to the New England Regional Laboratory (NERL) in Chelmsford, MA for analysis of sulfur mustard. Three quality control samples were also taken.

G.7.6.2 Air samples

Air handling and refrigeration units used to cool the clam storage room were turned off, and the room was allowed to warm. An equilibration period of at least 4 hr (or longer) was begun. When the temperature stabilized at or above 65°F , air samples were taken with a Hapsite GC/MS, with a detection limit for mustard agent of $0.00091 \text{ mg}/\text{m}^3$, or 0.14 ppb. Air samples were taken from three locations in the room, one from the far ends of the room, and one from the center of the room. All sample collection parameters and analysis data were documented by the sampling team.

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G.7.7 Release of Vessel

All sampling and monitoring results were nondetections. On June 15, 2010, the vessel was released by the Coast Guard. On June 26, 2010, all cages, refrigerated storage units, and other equipment were released for reuse.

G.8 Annex G References

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Annex H. Templates for Preparing Incident-Specific Sampling Plans

This Annex contains a checklist and three templates for developing sampling plans. The major topics by section are:

- **Section H.1.** A checklist for initial information gathering and assessments based on Sections 2.1 and 2.2 of the *Remediation Guidance*.
- **Section H.2.** A generic template for the data quality objectives process for time-critical response to transportation facility sampling following contamination with a CWA or TIC.
- **Section H.3.** A template for an emergency response and time-critical quality-assurance sampling plan (QASP).
- **Section H.4.** Guidance and a template for a sampling and analysis plan that combines, in a short form, the basic elements of a QASP and a Field Sampling Plan (FSP).

The checklist in Section H.1 is intended to help environmental remediation responders gather information and make initial assessments of the environmental consequences of a release. It is not intended prescriptively, that is, there is no implied requirement to “check off” every item before proceeding. The first two templates are intended to be appropriate for use by EPA On-scene coordinators (OSCs) when they arrive an incident, to rapidly develop a sampling plan to support immediate source reduction activities (Section 2.2.4) or other time-critical sampling needs that they may identify. The two templates are intended to be used together. The third template in Section H.4 is intended for a more thorough, and perhaps facility-wide, characterization sampling effort.

All three templates are adapted for a CWA or TIC incident from templates offered by EPA Region 9. An EPA original of the third template is referenced as Annex VI in the EPA document *Incident Command System, Job Aid for Environmental Unit Leader* (accessed May 2009 from http://epaossc.net/doc_list.asp?site_id=963).

The checklist and templates will be made available as separate electronic documents.

As described in Annex D., Section D.2, a good sampling plan includes the following information:

- Project objectives.
- Data-quality objectives.
- Sample collection requirements.
- Analysis and testing requirements.
- Quality control (QC) requirements (Quality Assurance Project Plan, Quality Assurance Sampling Plan, and so forth).
- Required project documentation.
- Identification of organizations conducting laboratory and field operations.

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Interested readers should consult the following sources for additional information:

EPA (March 2000), U.S. Environmental Protection Agency, *Sampling and Analysis Plan Guidance and Template*, version 2, document R9QA/002.

USEPA Region 9, *Emergency Response and Time-Critical Quality Assurance Sampling Plan for Air Sampling*, available from USEPA Region 9 staff.

Training, preparation, and certification are pre-requisites for all personnel charged with sampling activities, field analytical monitoring, and sample analysis. Time-critical technical responders must be familiar with the following:

- Operating real-time CWA monitoring instruments (e.g., AP2C Chemical Agent Monitor, APD2000 Chemical Agent Monitor, and various chemical agent detector kits). See Annex D for more discussion of such instruments.
- Monitoring procedures.
- Making time-critical environmental monitoring design decisions.
- Measurement methods.
- Surface, bulk, air, and soil sampling procedures for CWAs and TICs.
- Making time-critical surface, bulk, air, and soil sampling design decisions.
- Executing planning, mobilization, and communications functions pertinent to critical-response situations.

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H.1 Checklist for Initial Information Gathering and Assessments

Gather available information (refer to Sections 2.1 and 2.2 of the *Remediation Guidance*)

Potential sources of information include, but are not limited to:

- Documentation from first response
 - Maps and drawings created during first response
 - Photographs
 - Surveillance cameras
 - Interviews of or written reports from first responders
 - ICS forms
 - Any walking through the release area
 - Any visible contamination
 - Information about the release device
 - Interviews of witnesses (probably second-hand from first response)
 - Observed the device
 - Movements of people (e.g., rapid exiting) or equipment
 - Sign and symptom reports (severity, location)
 - Containment actions, if any
 - Firedoors closed?
 - Other interior doors, especially any between major sections: opened or closed?
 - Entry locations (estimate how much time open)
 - Other doors to outside (were any left open?)
 - Windows open? (e.g., in-transit lounge balconies in TBIT)
 - Source reduction actions, if any
 - Was anything removed (e.g. carpet, rubber mats)?
 - Was any kind of decontaminant applied (e.g., bleach applied to visible contamination)?
- HVAC management
 - HVAC settings at time of release (% recirculation, other)
 - HVAC changes since then (left on or turned off; if changes, when?)
 - Estimated air flow directions at time of incident and since; if changed, estimates of when
 - Normal rate of outside air exchange, any changes since incident
 - Estimate of constituent of concern “purge” rate
- Interior environment at the time of incident (and since, if available)
 - Temperature
 - Humidity
 - Other
- Exterior environment at time of release and since
 - Temperature
 - Humidity
 - Wind
- Sampling by first responders (fire department, HazMat)
 - What type of sampling (handheld, air)?

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- Results: map of bar readings (when and where reading was made)
- Agent information
 - Agent identity
 - General properties of the agent (not incident specific) e.g., volatility, persistence, vapor density, propensity to sorb, and so forth.
 - Formulation of this particular agent (are there variations from “normal”?)
 - Any way to estimate amount released?
- Facility information
 - Common building materials (e.g., floors, walls). Is there carpet, rubber mats, bare concrete, escalators, elevators, acoustic (porous) ceiling tile, at or near release location
 - Critical equipment

Initial assessments (based on information gathered from first response)

- Rough estimate of extent (and confidence in estimate)
- Agent entered HVAC?
- Locations and materials confirmed to be contaminated?
- Are there sources of out-gassing?
- Is it possible that agent vapors have largely vented out of the building by now?

Containment, isolation, and source reduction (refer to Sections 2.2.4, 3.3, and 3.4.1 of *Remediation Guidance*)

- Seek opportunities for improved or additional containment and isolation, and do them
- Seek opportunities for (additional) source reduction, and do them
- Should HVAC be turned on (if off) or off (if on)? Throughout the building or just in some sections?
- Should NAUs be used?
- Install air monitoring inside to assess effectiveness of source reduction and containment, as well as future uses

Inputs to planning and decisions

- Appropriate sampling and analytical methods (list, pros and cons)
- Potential decontamination methods (list, pros and cons (see Section 3.4.2 of *Remediation Guidance*))
- Clearance goals (see Section 2.3 of *Remediation Guidance*)
 - Are they immediately available, or do they need to be developed?
 - Can sampling and analysis methods measure below them?
- Waste disposal options
- Staging locations
- Worker protection requirements
- Available laboratories
- Data management options (e.g., EPA Scribe)
- Facility information
 - Drawings (floor plan, drainage, HVAC, other)

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- Facility staff, especially engineering, environmental, and operations
- Coordination with other agencies (such as law enforcement agencies engaged in additional evidence collection)

Conceptual site model and data quality objectives

- Review zones from pre-incident planning, if any, or define zones
- Assess each zone with respect to likelihood of contamination (see Section 2.2.9.1 and Annex I). Identify the following types of likelihood:
 - Confirmed
 - Highly likely (but not confirmed)
 - Possible (but unknown)
 - Very unlikely (but not confirmed clean)
- Select a sampling goal for each zone
 - Immediate support for decontamination
 - Attempt to confirm contamination
 - Attempt to confirm contamination, or determine if not contaminated
 - Attempt to “clear” the zone
- Select one or more of the suggested sampling options per zone
 - Judgmental sampling of permeable or porous materials
 - Grid sampling of surfaces for hot spots; design grid to have high (e.g., 95%) probability of detecting a small (e.g., 5% of available surface area) hotspot
 - Random sampling to show with high confidence (e.g., 95%) that a large (e.g., 95%) portion of surfaces is below clearance goals
 - Percentages are decision-maker selected based on risk-management decisions.

Other (nonlocal) resources

- EPA NDT, ERT, NHSRC, other
- Dispersion modeling (CST or national laboratory)
- Other. See Table 1-2 in Section 1 of this *Remediation Guidance*, and the EPA Region 9 *Compendium of Special Teams, Assets, and Capabilities*.

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H.2 Time-Critical, Generic, Data Quality Objectives For CWA or TIC Transportation Facility Sampling

This data quality objectives (DQOs) document is intended to be used with the template Time-Critical, Generic, Quality Assurance Sampling Plan for CWA or TIC Transportation Facility Sampling. This template views the EPA environmental sampling response as consisting of several phases. The first phase, from first arrival of EPA personnel through perhaps a few days, consists of numerous time-critical decisions. This phase focuses on information gathering, including identification and characterization of the CWA or TIC, and on sampling to support source reduction and containment, because such actions need to be implemented as quickly as possible to minimize the spread of contamination. The second phase occurs when there is a need to develop a comprehensive plan to characterize all or most of the facility. The third phase consists of sampling to support clearance decisions. This template is intended for the initial time-critical response phase. Section H.4 contains a separate QAPP/FSP template for use in the later phases. This template assumes that first responders (fire, police) will collect samples according to their own protocols, but that their first priority is on protecting and saving lives and controlling and stabilizing the situation, not on environmental issues.

The generic DQOs presented in this document are based on typical technical and project directives encountered by the EPA in time-critical responses that involve releases of hazardous chemicals. This document implements a planning process for an emergency response involving CWA or TIC contamination in a (large) public transportation facility. The term, “CWA or TIC,” is used to refer to the chemical that was released, whether CWA or TIC. This document, coupled with site-specific output statements as documented in the associated time-critical response Quality Assurance Sampling Plan, is intended to meet the EPA’s DQO process requirements. The following requirements and preconditions must be fulfilled to implement these DQOs:

- Emergency responders must be familiar with all types of miscellaneous matrix sampling procedures and possess sufficient emergency response experience and training to make emergency sampling design decisions.
- Emergency responders must be sufficiently prepared and organized for emergency response situations to implement the planning, mobilization, and communications necessary to support expeditious sampling, analyses, and decision-making.
- Emergency responders must be familiar with EPA QAPP and QMP requirements.
- Emergency responders must be familiar with the EPA’s DQO process and the information and objectives indicated in this generic DQO document. Emergency responders must document any additional DQO information and DQO modifications.
- Before any sample collection, emergency responders must determine site-specific assessment parameters as indicated in Section 2 of the associated Quality Assurance Sampling Plan for CWA/TIC Transportation Facility Sampling.
- All DQO-related information not specified in this DQO document or the associated Quality Assurance Sampling Plan for CWA/TIC Transportation Facility Sampling must be recorded in other project documentation (e.g., sampling plans, logbooks, action memos, or pollution reports).

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Step 1. The Problem

Background for a Time-Critical Transportation Facility CWA Sampling Project

The EPA was notified of the confirmed release of a CWA or TIC in a transportation facility. Because of the nature of the threat, the investigation must proceed immediately. There may be no available data regarding the extent or magnitude of contamination. This template assumes that the specific agent may or may not yet have been identified, and that the affected facility has been evacuated.

The primary purpose of this DQO document is to support time-critical sampling in a major transportation facility (e.g., international airport) following a terrorist release of a CWA or TIC. This sampling response is time-critical because it can be used to support immediate source reduction or containment actions, which, if undertaken, will help minimize the extent of contamination and reduce the subsequent duration, difficulty, and cost of remediation. This document assumes that a longer-term response will follow (e.g., a traditional characterization, remediation, and clearance process; see the Requirements section of this template).

The Planning Team is as follows:

- The primary decision-maker is the responding EPA On-Scene Coordinator (OSC).
- Plan development is provided by the OSC and ICS Environmental Unit.
- Plan approval is done by the responding OSC and ICS UC.
- On-scene assistance is provided by local first responders.
- Supplemental remote or on-scene support is provided by the EPA Regional Incident Management Team (EPA IMT), certified analytical laboratory for TIC, or OPCW certified for CWA, regional equipment resources, and contractors.

The names and affiliations of the actual planning team will be documented in the field logbook or in the emergency-response sampling plan.

Conceptual Site Model

A CWA or TIC has been released somewhere in the interior of a major transportation facility. The CWA or TIC has begun to spread via the air. There may be local surface contamination at the release site from CWA or TIC condensation, spatters, or similar. Contaminated matrices may include surfaces, the air, or porous or permeable building materials (e.g., polymeric materials, carpet, concrete, acoustic tile, and so forth). Emergency responders are on site, have secured the facility, and rescue operations may still be taking place.

Exposure Scenario

The site is being evaluated by the EPA, Region (x), to determine whether it poses an imminent threat to human health and/or the environment. Concerns include migration of contaminants to other media within or outside the facility, and direct exposure of human or environmental receptors to the CWA or TIC, and possibly also exposure to degradation products.

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Resources

The planning and preparation for emergency response situations that involve environmental data collection in EPA, Region (x), are administered and implemented at the direction of the EPA OSC. This is an emergency response under the technical direction of the EPA. Labor resources include:

- The responding OSC, who will typically oversee all data collection operations related to this project. A responding OSC must be capable of responding immediately.
- EPA Regional Incident Management Team (EPA IMT).
- Sampling teams or contractors, who should be capable of responding immediately.
- Local first responders.
- Federal, regional, state, or local responders.
- The ERRS contractor, who must be capable of responding immediately.

Analytical service resources include:

- Laboratory assignment according to site location or specific analytical requirements.
- A certified analytical laboratory for TICs, or an OPCW certified for CWAs.

EPA-owned equipment resources are readily available and accessible for mobilization to an emergency response through the given EPA Region (Region 9 example: Eagle Warehouse, 888-447-5602 for the San Francisco office and 562-705-4900 for the Long Beach office). Use of EPA equipment can only be authorized by the EPA. Such emergency equipment is accessible 24 hours per day, seven days per week. EPA emergency response equipment is continuously maintained in a response-ready condition. Additional emergency sampling equipment and field analytical instruments may be available from the Region (Region 9 examples: United States Coast Guard Pacific Strike Team in Novato, California), National Guard Civil Support Team, an OPCW Laboratory, and from the EPA ERT and its emergency response contractor in Edison, New Jersey.

Resource Constraints

The EPA Region (x) QA Office resources, regional laboratory resources, and Contract Laboratory Program laboratory resources are typically not readily available for emergency response. Leased or rented equipment is not readily accessible for emergency response situations. The abilities and availability of other (nonEPA) resources will depend on the situation, location, and time frame of the response.

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Step 2. The Decision

Principal Study Questions

General questions:

- 1 What is the specific CWA or TIC?
- 2 What are its characteristics (physical properties, purity, and so forth)?
- 3 Could there have been more than one type of CWA or TIC released?
- 4 Have the release device and its location been identified?
- 5 What was the release method (aerosol, liquid)?
- 6 What is the general initial area (areal extent) of contamination?
- 7 Has contamination migrated beyond the area of the release?
- 8 What are the estimated contaminant concentrations within the contaminated area?
- 9 Has contamination entered the facility's HVAC system? (Are HVAC returns located near the release location?)
- 10 Are eyewitness accounts or security camera system recordings available, and if so, do they provide information about the potential release quantity or areal extent?
- 11 What porous and permeable materials are in the general release area (e.g., carpet, gypsum wall board, nonsealed brick)?
- 12 Is there an available action level for the CWA or TIC?
- 13 Other?

Decontamination Planning Questions

- 1 From answers to the general questions, are there immediate source reduction actions that, if implemented, could substantially reduce the potential for continued additional contamination? (e.g., CWA or TIC in porous or permeable materials that could become a source for additional contamination).
- 2 From answers to the general questions, what is the rough estimated volume of contaminated facility material?
- 3 Other?

Actions that Could Result from the Resolution of Study Questions

- The EPA would initiate no further action on the site in relation to the contamination.
- The EPA would initiate an immediate (or as soon as permitted by law enforcement) removal action in the vicinity of the release to minimize the subsequent spread of contamination, especially to underlying structural elements (e.g., concrete floor underneath carpet).
- The EPA would initiate a further investigation of the contamination, potentially including a full-scale characterization, remediation, and/or clearance process.

Decision Statements (Directives)

- Determine the CWA or TIC and the action levels for the CWA or TIC.
- Roughly estimate the lateral extent and concentrations of contamination.
- Roughly estimate the volume of material that might contain CWA or TIC above action levels.
- Determine if an expeditious sampling and analysis protocol can be used to screen for contaminant(s).
- Document contamination to support project decisions and future legal activities.

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- Visually determine whether the CWA or TIC might have migrated (or is migrating) to other media. Provide documentation to support the determination.

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Step 3. Decision Inputs

Specific Data Required

- Identity of the CWA or TIC(s) released in the facility.
- Physical, chemical, and physiological properties of the CWA or TIC.
- Action levels for the CWA or TIC(s).
- Analytical data capable of providing a rough estimate regarding the extent and concentration levels of contamination.
- Analytical data capable of legally documenting specific contamination of selected samples.
- Facility drawings, including floor plans, HVAC system information, and drainage systems.
- Access to facility staff, especially engineering and maintenance.
- Physical characteristics of the site.
- Chemical and physical properties and characteristics of the CWA or TIC.
- Analytical data for the CWA or TIC that are capable of documenting and supporting emergency decisions.
- Specific data needs will be indicated in the site's emergency response sampling plan.

Sources for Study Information

- Verbal or written information from witnesses, first responders, and other on-scene personnel.
- Site information collected during the emergency response.
- Screening data generated during the emergency response.
- Definitive analytical data generated during the emergency response.
- Chemical reference books and databases.
- Spill report information from first responders (if a liquid release).

Information Needed to Establish Action Level

- Because time-critical decisions during the initial response are likely to be based on presence or absence of the CWA or TIC, the analytical reporting limits for the CWA or TIC are needed.
- State and Federal regulations and definitions of hazardous substances, material, and waste are values that are typically used as action levels, which may be appropriate for a TIC.
- If available, the local applicable or relevant and appropriate requirements for each CWA or TIC.

Confirm that Measurement Methods Exist to Provide Data

- EPA 8270D for cyclosarin, hydrogen cyanide (AC), phosgene (CG), sarin, soman, sulfur mustard, tabun, VX; 8260C for cyanogen chloride
- Appropriate sample preparation methods must be used in the laboratory.
- Note that such methods are not currently (as of June 2011) validated. EPA is working on developing validated methods. This template must be updated when validated methods are released.

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Step 4. Study Boundaries

Specify Characteristics that Define the Population Being Studied

- The presence or absence of CWA or TIC throughout the area of concern (AOC), especially in easily removed permeable or porous materials.

Geographic Boundary of Investigation

- The geographic boundary of time-critical sampling is the facility interior.
- The geographic boundary of sampling will be determined during emergency response according to the professional judgment and experience of the responders.
- The sampling area should include at least the area in and around the release location, which becomes a de facto “release zone.”
- If time and resources permit during this time-critical response, a more extensive zone-based approach can be used, if zones can be quickly defined. (Otherwise a zone approach can be deferred for a later, more comprehensive characterization or clearance plan.)

Temporal Boundary of Investigation

Data must be generated promptly to facilitate the on-scene emergency decision-making process. Unless otherwise specified and documented, the temporal boundaries are as follows:

- Sample planning will take place just before sample collection.
- Sample collection will generally take place immediately following OSC verbal directives or approval.
- Analytical field data (i.e., data generated on scene using field-screening techniques) that are needed to make on-scene emergency decisions must be generated and reported immediately.
- Analytical data (definitive or nondefinitive) used for on-scene emergency decisions must be generated within 24 to 48 hours after samples are collected.
- Estimations derived from field-generated data that are used for on-scene emergency decisions must be generated and reported immediately.
- All other preliminary definitive and nondefinitive data will be reported within 4 weeks of sample collection.
- Validated data will be reported approximately 8 weeks after sample collection.

Other Constraints on Data Collection

- It may not be possible to generate high-quality data that are thoroughly documented in an expeditious time frame.
- The turn-around times for data are always estimated and cannot be ensured. Sample and system problems may indiscriminately increase data turn-around times.
- Because some analytical data may be required immediately to facilitate the on-scene emergency decision-making process, it may be necessary to forgo some QA measures, including data review, to meet this requirement.
- Definitive data will be validated before final reporting.
- All other data used to make decisions will be reviewed before final reporting.
- Physical constraints, such as lack of lighting or inability to access portions of the facility, may exist and will be addressed on scene according to the experience and professional judgment of responders.

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- Civil constraints, such as legal site access, permit requirements, or limitations on access because of crime scene status, may exist and will be addressed on scene according to the situation.

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Step 5. Decision Rule

Statistical Parameter

Unless otherwise specified and documented, this investigation is interested in the worst-case values for each “decisional unit” within the release zone. The baseline assumption is that a decisional unit is contaminated unless shown to be clean. Potential, discrete, decisional units could be, for example:

- Easily removable furniture, especially if it has permeable or porous covering.
- Polymeric building materials (e.g., caulking, escalator hand rails, earthquake joint covers, vinyl tile).
- Porous materials (e.g., wallboard, acoustic ceiling tile, carpet).
- Exposed concrete building structure.
- Fire-retardant material (typically sprayed-on girders, piping, especially above ceiling tile).

Action Levels

Action Level Case 1: The Action Level is specified in the associated time critical QASP.

Action Level Case 2: The Action Level will be the laboratory-achieved analytical reporting limit.

Decision Rules

If a CWA or TIC concentration at a sample location:

- Is less than the action level, then the material represented by that sample will be considered “not contaminated” and may not be subject to any removal action.
- Exceeds the action level, then the material represented by that sample will be considered “contaminated and may be subject to additional investigations.”
- Exceeds the action level, then the material represented by that sample will be considered “contaminated and may be subject to an EPA removal action.”
- Exceeds the action level, then the material represented by that sample will be considered “contaminated and the EPA may defer additional action to regional, state, or local regulators.”

During an on-scene, time-critical response or before data reporting, the OSC could develop additional decision rules that could involve additional actions. Additional decision rules will be recorded with the project documentation (e.g., sampling plan, logbook, OSC action memo, or pollution report). If a decision unit is represented by multiple samples, then the decision rules below may be considered.

Decision Rule Case 1

- If all individual sample values are less than the Action Level the decision unit is considered clean.
- If any individual sample value equals or exceeds the Action Level, the decision unit is considered contaminated.

Decision Rule Case 2

- If all individual sample values are less than the laboratory analytical reporting limit (i.e., all sample values are nondetected/nonreported), the decision unit is considered clean.

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- If any individual sample value equals or exceeds the laboratory analytical reporting limit, the decision unit is considered contaminated.

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Step 6. Limits on Decision Errors

Range of the Parameters of Interest

The CWA or TIC concentrations may range from nondetectable to well above the action level. However, for this time-critical response phase, concentrations indicating a need for source reduction or the potential for additional spread of contamination are of principal concern.

The Null Hypothesis or Baseline Condition

At least some portion of the decisional unit exceeds the action level.

Alternative Hypothesis

The decisional unit as a whole is below the action level.

Decision Errors for CWA or TIC Time-Critical Response		
Decision Error	F(+): Erroneous indication of contamination. Deciding that the decisional unit as a whole exceeds the action level when it does not.	F(-): Failure to detect contamination. Deciding that the decisional unit as a whole does not exceed the action level when it does.
True Nature of Contamination	The decisional unit does not exceed the action level.	The decisional unit does exceed the action level.
Consequences of Error	Materials represented by the sample will be immediately removed or treated. Such action would cost additional, unnecessary resources of time, money, and manpower.	Exposure could continue to be a threat within the facility. The CWA or TIC in areas with contaminated materials could migrate to additional materials in the same area or elsewhere within the facility. The CWA or TIC could migrate to sensitive environments (e.g., outdoors). Exposure could be a threat outside the facility.
Severity of Error	Less severe.	More severe. May result in an unrecognized health threat.
Error Type based on Consequences	Practical: F(+) Statistical: False negative	Practical: F(-) Statistical: False positive
See the EPA document titled <i>Guidance for the Data Quality Objective Process</i> , Chapter 6, (EPA QA/G-4) for additional guidance regarding decision error.		

The above hypotheses are for Decision Rule Case 1 in Step 5. For Decision Rule Case 2, substitute “reporting limit” for “action level” here and in Step 7.

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Step 7. Design for Obtaining Data

All sampling, analytical, and QA activities will take place under an established EPA Regional (emergency response) QAPP and documents referenced therein. All site-specific planning and activities will be documented either in a plan developed using the template Time-Critical, Generic, Quality Assurance Sampling Plan for CWA or TIC Transportation Facility Sampling, or within a bound field logbook. A record of sampling activities as they are conducted must also be documented in a bound field logbook. For sampling that is not time-critical, i.e., that may occur later in the response or requires more extensive planning, see the companion document *Sampling and Analysis Plan Guidance and Template for CWA/TIC Transportation Facility Sampling* (Section H.4).

The sampling plan will be completed before sample collection. In all cases, it will be completed within 30 days of the time-critical sampling event. The time-critical QASP comprises four sections: (1) Introduction and Background, (2) Objectives, (3) Sampling and Analysis Methodologies, and (4) Project Organization and Responsibilities. The time-critical QASP, the QAPP, and these DQOs are intended to meet EPA Region (x) planning requirements for emergency response situations. Before sample collection, emergency responders should review sampling procedures and relevant QA/quality control (QC) requirements for selected analytical methods.

General Design

The collection of replicates (collocated duplicates) and field blanks is recommended but not required. All analytical QA/QC and documentation specified in the START QAPP is recommended; however, such QA/QC and documentation may be considered secondary to the expeditious generation of data.

For the purposes of source reduction and containment, statistical measurement and determination of sampling error are not practical or necessary. For the purpose of detecting the presence of contamination in areas where it is suspected, but not confirmed, judgmental sampling based on agent-material interaction will be primary, followed by statistically based sampling if judgmental sampling does not provide sufficient (qualitative) confidence. For statistically based sampling, see the sample size tables below under Simple Random Sampling. To the extent possible, sampling and analytical measurement error will be estimated and reported with the data validation report.

Because of the emergency nature of the response, the specific sampling methodology and emergency response sampling design must be chosen in the field according to the experience, training, and professional judgment of the responders.

Emergency response decisions will be made by the OSC according to professional judgment and training using analytical and nonanalytical information. The analytical information initially generated by sampling will comprise discrete sample data and not statistical data. Representativeness of samples will be based on the professional judgment of responders (e.g.,

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one sample from carpet near the release location might be used to make a decision about hundreds of square feet of nearby carpet). The type of decision requiring the most confidence is a decision that a material or area is not contaminated.

Representativeness will be maximized and sampling error minimized when possible by increasing the number of sampling points, by compositing, or both. Where obtaining surface samples, and concentrations are expected to be low, consider increasing the likelihood of detection by sampling a large surface area. When possible, analytical measurement error will be minimized through the use of proper QA/QC practices and conformance to QA limits.

The OSC will consider data uncertainty when making decisions based on discrete sampling data and estimated values. For most standardized CWA or TIC methods, the greatest uncertainty is assumed to lie within reported ranges 60 to 100% of the action level. For unqualified and validated definitive data, the range will be 75 to 100% of the action level. The uncertainty range for field-screening methods depends on the method and will be determined and considered before the data's use for decisions. The uncertainty for estimated data (i.e., data based on extrapolations and interpolations) is typically greater than that for discrete data. The use of standard methods and procedures could mitigate all other false positive and false negative decisions.

Data validation, independent of the laboratory, will be performed on all enforcement data and all definitive data that are used in decision-making. Data review, independent of project management, will be performed on all nondefinitive and screening data used in the decision-making process. Because of the nature of emergency response activities, validation will be performed after the decision-making but before final reporting.

Hot Spot and Grid Sampling

Because the primary objective of sample collection in an emergency response is to expeditiously identify the significant contaminant threats, the initial sampling approach will concentrate on the search for and identification of contamination areas and materials that are sufficiently above the action level that source reduction or containment is indicated. Systematic grid and search sampling can provide a probabilistic approach to finding contamination in areas where there is insufficient information for judgmental sampling to guide the selection of sampling locations. When such an approach is used, the responder must determine the search parameters before sampling. This information will be specified in the associated time-critical sampling plan (Section 3.1). The lateral extent and concentrations of contamination will be extrapolated and interpolated from sampling grid data.

Biased and Judgmental Sampling

Additional sampling approaches will generally include sample collection at locations expected to exhibit the worst-case contamination. Biased sampling may be based on direct visual observations or the results of field-screening instruments and techniques. If physical information

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suggests that contamination may have migrated to other media, then limited judgmental sampling of those media, when practicable, should be included.

Enforcement Sampling

Biased samples may be collected from selected locations and analyzed to document the presence and magnitude of contamination at those locations for legal enforcement. Such sampling would include complete documentation regarding the sampling and analysis performed. The samples would be analyzed in a non-time-critical manner to ensure maximum analytical quality and documentation.

Field Methods

Portable field methods can be used to more precisely delineate contamination boundaries, provided that they have sufficiently low detection limits and a sufficiently rapid response. The EPA Portable TAGA system is one such method, but this system would probably not be available immediately. Other systems under development may be useful, but would not be immediately available. Contact the EPA National Decon Team for more information.

Simple Random Sampling

If statistically based (simple random) sampling is selected, the $F(-)$ error rate (the chance of failing to discover contamination) is recommended to be set no larger than 0.01. Tables 7-1 and 7-2 show the number of samples required for $F(-) \sim 0.01$ and ~ 0.001 , respectively, for a range of degrees of contamination. For example, if “chance individual sample $<AL$ ” is set at 0.95, then about 95% of the decisional unit is below the AL.

Table 7-1. $F(-) \approx 0.01$.

	Increasing Contamination				Decreasing Contamination			
Chance individual sample $<AL$	0.500	0.750	0.825	0.900	0.950	0.990	0.995	0.999
Number needed (n)	7	17	24	44	90	459	919	4603

Table 7-2. $F(-) \approx 0.001$.

	Increasing Contamination				Decreasing Contamination			
Chance individual sample $<AL$	0.500	0.750	0.825	0.900	0.950	0.990	0.995	0.999
Number needed (n)	10	25	36	66	135	688	1379	6905

Because the degree of contamination is unknown, it will have to be estimated (judgmentally) based on incident information. When contamination above the AL is extremely rare (“chance that individual sample $<AL$ ” = 0.999, equivalent to 0.1% of the unit above the AL), it takes a huge number of samples to have a good chance of discovering that the decisional unit is contaminated. This is the “finding the needle in the haystack” problem, and is a reason that

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judgmental sampling based on agent–material interactions is recommended during the time-critical phase.

Annex H**H.3 Time-Critical, Generic, Quality Assurance Sampling Plan for CWA or TIC Transportation Facility Sampling****Response Location:****(Facility name)****Date:****Prepared by:****Reviewed by:****Approved by:****(EU Leader, Planning Section Chief, Unified Command)**

This template views the EPA environmental sampling response as consisting of several phases. The first phase is from arrival of EPA personnel through perhaps a few days and consists of numerous time-critical decisions. This phase focuses on information gathering, including identification and characterization of the CWA or TIC, and on sampling to support source reduction and containment, because such actions need to be implemented as quickly as possible to minimize the spread of contamination. The second phase occurs when there is a need to develop a comprehensive plan to characterize all or most of the facility. The third phase consists of sampling to support clearance decisions.

This template is intended for the initial, time-critical response phase. Section H.4 contains a separate QAPP/FSP template for use in the later phases. This template assumes that first responders (fire, police) collect samples according to their own protocols, but that their first priority is on protecting and saving lives and controlling and stabilizing the situation, not on environmental issues.

This sampling plan has been designed to assist field responders in their preparation for collecting, analyzing, shipping, storing, and handling samples collected during an emergency response. The use of this generic sampling plan will involve forethought and planning that should help direct the sampling and analytical work. It is meant to be used in the case of emergency responses or time-critical responses when sampling teams may not have the opportunity to write a more thorough sampling plan. Sampling teams should always reference standard quality procedures, standard operating procedures, and standard methods for sampling and analytical guidance.

This generic plan will improve the documentation, communication, planning, and overall quality associated with the sampling and analysis by:

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- Encouraging field teams to consider their goals and objectives before generating environmental data.
- Documenting predetermined information in a standardize format.
- Increasing the communication between sampling personnel and decision makers.
- Detailing expectations and objectives before samples are collected.

For the remainder of this template, the term “CWA or TIC” is used to refer to the chemical that was released, whether a CWA or TIC.

1.0 Introduction and Background. *Describe the affected facility, and specify the geographic boundaries for the response and any specific areas of concern. What is the problem, what precipitated the response, which agencies and other entities (e.g., contractors) are on site, who has taken the lead for the response and for environmental cleanup actions? Include incident information that may be useful, such as typical or current airflow in the facility, interior air temperature and humidity, interviews with first responders or witnesses, and so forth.*

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2.0 Objectives. *Write a brief statement on the general project objective. What is the overall goal or objective? Specific objectives are selected in Section 2.1; see also Table D.*

2.1 Data Use Objectives

How will the data that are generated be used? Select appropriate boxes. Transcribe from Step 2 of the time-critical DQO document (Section H.2), or reference (by number) study questions from Step 2 of the time-critical DQO document. Make sure that this section and Step 2 of the DQO document are consistent.

- 1 ☐ To identify the CWA or TIC that was released (if not yet identified).
- 2 ☐ To obtain definitive identification of the CWA or TIC, given a preliminary identification by first responders.
- 3 ☐ To develop information about the properties of the CWA or TIC (e.g., formulation, purity).
- 4 ☐ To be compared with an available detection or quantification level.
- 5 ☐ To assist in determining the presence or absence of the CWA or TIC at levels above an available detection or quantification level.
- 6 ☐ To assist with determining the area of impact from the release. (i.e., horizontal and vertical extent, intrusion into air ducts, elevator shafts, and so forth).
- 7 ☐ To be compared with site-specific action levels or risk-based action levels (e.g., EPA Health Screening Level) to assist in determining if a health threats exist.
- 8 ☐ As definitive confirmatory data for confirmation of nondefinitive (screening) data.
- 9 ☐ To make preliminary estimates of the volume of contaminated facility material.
- 10 ☐ To decide whether immediate source reduction actions should be implemented.
- 11 ☐ To decide whether additional containment measures should be implemented.

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- 12 ☐ To collect samples for enforcement purposes, if requested by law enforcement agencies.
- 13 ☐ Transcribe or reference by number one or more study questions from Step 2 of the DQOs (Section H.2).
-
- 13 ☐ Other objectives. Specify here.
-

2.2 Sampling Objectives (What are you proposing to do?)

- 1 Sampling to estimate:
- ☐ contamination levels within the area of concern (vicinity of release).
 - ☐ contamination area(s) within the facility.
- 2 ☐ Sampling to determine the location of hot spots within the area of concern.
- 3 Sampling to estimate the extent of contamination (both horizontal and vertical):
- ☐ of specific source area(s) or areas of concern
 - ☐ over an entire facility
- 4 Sampling offsite to determine:
- ☐ HazMat warm and cold zones (or verify or review those developed by first responders)
 - ☐ Safe locations for staging areas

2.3 Sample Matrices

- 1 ☐ Surface wipe samples
- 2 ☐ Surface swab samples
- 3 ☐ Bulk samples. Specify (carpet, wallboard, caulking, and so forth)
- 4 ☐ Liquid samples. Specify (water, wastewater, agent if present in liquid phase, and so forth).

Note: Use a separate QASP for assessing air concentrations throughout the response.

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2.4 Data Types

In general, data types and data needs should be decided prior to data generation. Data types can be generally divided into three categories: definitive methodology data (generally data generated using standardized methods), nondefinitive methodology data (also referred to as screening data), and screening data with at least 10% definitive confirmation. The generation of definitive data is preferable; however, in emergency and time-critical situations where definitive data are not available, nondefinitive data should be generated. The data type is not an indicator of precision, accuracy, documentation completeness, or quality. Reported data should be verified (by a party other than the laboratory) as meeting specific quality control and data category requirements by following a verification or validation procedure. Check the appropriate box(es):

- 1 ☐ Screening data will be generated. The screening data may not be verifiable. Because of the time-critical situation, the data must be reported and may be used to make decisions.
- 2a ☐ Screening data with at least 10 percent definitive data will be generated and may be used to make decisions prior to availability of definitive data. Data using nondefinitive analytical methodologies will be generated. Because of the time-critical situation, the data must be reported and may be used to make decisions prior to generation of definitive data. The screening data may not be verifiable until definitive data results are available. Screening data will be evaluated and reported with definitive data at a later time. If the definitive data confirm the screening data, then the original decisions will stand. If the definitive data do not confirm the accuracy of the screening data, then the decisions will be reevaluated.
- 2b ☐ Screening data with 10 percent definitive data will be generated but will not be reported until evaluated against definitive data. Data using nondefinitive analytical methodologies will be generated. Such data will not be reported until they are evaluated against definitive data.
- 3a ☐ Definitive data will be generated, and may be used for comparisons without validation, but not for decision making. The sampling and analysis must be done on an emergency basis. Because of the time-critical situation, preliminary results must be reported and used for comparison, but not decision-making, without validation. Analytical data packages will be required. Because the data are not to be used for decision-making, validation of the data package need not be performed. (Document generic DQO deviation in Section 4.4.)
- 3b ☐ Definitive data will be generated and may be used to make decisions without validation. The sampling must be done on an emergency basis. Because of the time-critical situation, preliminary results must be reported and may be used to make decisions without validation. The generated analytical documentation packages will later be reviewed and validated. If the validation confirms the preliminary results, then the original decisions will stand. If the validation does not confirm the preliminary results, then the decisions will be reevaluated. Qualified data will be reported after validation.

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- 3c ☐ Definitive data will be generated and will be reviewed and validated before making comparisons or decisions. Full documentation will be required. Analytical data packages will be reviewed and validated prior being reported or used.

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2.5 Chemicals of Concern

The chemicals of concern, proposed analytical methods, proposed action levels, and available reporting limits are summarized in Table A. (Select the appropriate row; delete other rows.) See also Table C.

Table A. Chemicals of Concern				
CWA	Sample mass (solid) or area (wipe) ^a	Proposed analytical method ^a	Proposed action level (see notes)	Detection limit ^e (approximate)
Cyanogen chloride (CK)	5 g	EPA 8260C		
	(b)	(b)		
Cyclosarin (GF)	10 g	EPA 8270D		
	10 to 30 g	EPA 8270D		
	2" × 12"	EPA 8270D		
Hydrogen cyanide (AC)	(c)	(c)		
Phosgene (CG)	(d)	(d)		
Sarin (GB)	2 to 3 g	EPA 8270D		
	5 g	EPA 8270D		
	2" × 12"	EPA 8270D		
Soman (GD)	10 to 30 g	EPA 8270D		
	2" × 12"	EPA 8270D		
Sulfur mustard (HD)	5 g	EPA 8270D		
	2" × 12"	EPA 8270D		
Tabun (GA)	10 to 30 g	EPA 8270D		
	2" × 12"	EPA 8270D		
VX	5 g	EPA 8270D		
	2" × 12"	EPA 8270D		

^a As specified in EPA (2011).

^b Cyanogen chloride (CK) is a gas at $T \geq 56.8^{\circ}\text{F}$ (13.8°C), so surface/solid contamination might not be of concern.

^c Hydrogen cyanide (AC) is a gas at $T \geq 78^{\circ}\text{F}$ (26°C), so surface/solid contamination might not be a concern.

^d Phosgene (CG) is a gas at $T \geq 47^{\circ}\text{F}$ (8.2°C), so surface/solid contamination might not be of concern.

^e Estimated method detection limits, based on expected instrument detection limits and recommended preparation methods.

Sampling and analytical information in Table A is derived from EPA (2011). Methods are not yet validated for CWAs, but validated methods currently (as of June 2011) are being developed.

Annex H**3.0 Sampling and Analysis Methodologies****3.1 Sampling Approach**

Indicate sampling approaches to be used (select the approach from the list below). Include justification for the selection. Refer to or incorporate from Step 7 of the associated time critical DQO document.

- 1 ☐ Because of the lack of site information, the approach will be determined in the field according to professional judgment.
- 2 ☐ Judgmental (Biased)
- 3 ☐ Random
- 4 ☐ Systematic
- 5 ☐ Transects
- 6 ☐ Search-grid

If a search-grid is to be used, specify the grid type (circle one): Square Triangle
Rectangle

Size of contamination hot spot to be detected:

Shape of hot spot (circle one): Circle Elliptical Elongated-Elliptical

Required Grid Spacing:

Acceptable probability of missing hot spot (circle one): 5% 10% 20% 40%

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3.2 Field Analysis Equipment

Field analysis equipment options for surface measurements are summarized in Table B1.

Table B1. Field Analytical Equipment				
Analysis equipment. Specify the field analytical procedures to be used. Select the appropriate boxes.	Model	Analyses	Matrix	Resource or Contractor
<input type="checkbox"/> CBMS II (applicability is under research)			Surface	
<input type="checkbox"/> LISA manned portable			Surface	
<input type="checkbox"/> TAGA portable			Air	EPA
<input type="checkbox"/>				
<input type="checkbox"/>				
<input type="checkbox"/>				
<input type="checkbox"/>				
<input type="checkbox"/>				
<input type="checkbox"/>				
<input type="checkbox"/>				
<input type="checkbox"/>				

Notes: Equipment-specific information (such as the date of last calibration, serial number, and so forth) should be recorded in a field log book.

The TAGA portable unit samples air but has sufficient spatial resolution that it can be used to find surfaces that are off-gassing.

Annex H**3.3 Field Sampling Equipment**

Field equipment requirements for samples destined for an analytical laboratory are summarized in Table B2.

Table B2. Field Sampling and Decontamination Equipment				
Analyses and Matrix	Sampling Equipment	Dedicated or Reusable	Decontamination Solution	Resource or Contractor

Add additional pages if necessary.

List equipment types here. If appropriate, record the specific instrument used (i.e., by serial number) in a field logbook.

3.4 Sampling Locations, Methods, and Procedures**3.4.1 Sample Locations**

Indicate the sampling location name, describe location, and indicate rationale for each sample location chosen. Document sample locations in an electronic data management system if available.

Add additional pages if necessary.

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Provide a map of the site indicating the release location and any additional areas of concern. Use a scale that is meaningful for the sampling work covered under this plan. Show where samples will be collected, and include sampling location names. Include sufficient facility landmarks to clearly locate the sampling area within the facility. Attach a local area map if one is available. Sketch by hand only if electronic facility drawings are not yet available.

Figure A.
Sample Location Map

Add additional maps if necessary (e.g., if sampling more than one floor level or section of the facility).

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3.4.2 Sample Labeling and Documentation

Sample Container Labels

Sample labels will clearly identify the particular sample and should include the following:

- Site name.
- Time and date samples were taken.
- Sample preservation.
- Analysis requested.
- Sample location, identification number, or both.
- Sampler name or initials.

Sample labels will be securely affixed to the sample container.

Chain of Custody Record

A chain of custody record will be maintained from the time the sample is taken to its final deposition. Every transfer of custody must be noted and signed for, and a copy of this record kept by each individual who has signed. When samples (or groups of samples) are not under direct control of the individual responsible for them, they must be stored in a secured container sealed with a custody seal.

The chain of custody record should include (at minimum) the following:

- Sample identification number.
- Sample information.
- Sample location.
- Sample date and time.
- Names(s) and signature(s) of sampler(s).
- Signature(s) of any individual(s) with control over samples.

Electronically generated labels and forms can be used if available.

Custody Seals

Custody seals demonstrate that a sample container has not been tampered or opened. The individual in possession of the sample(s) will sign and date the seal, affixing it in such a manner that the container cannot be opened without breaking the seal. The name of this individual, along with a description of the samples' packaging, should be noted in the field logbook.

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All sample documents will be completed legibly in ink. Any corrections or revisions will be made by lining through the incorrect entry and by initialing the error. Such documents include the logbooks, chain of custody forms, this field QASP, and any other tracking forms.

Field Logbook

The field logbook is essentially a descriptive notebook detailing site activities and observations so that an accurate account of field procedures can be reconstructed in the writer's absence. All entries will be dated and signed by the individuals making the entries and will include the following:

- Site name and project number.
- Names of sampling personnel.
- Subcontractor information and names of onsite personnel.
- Descriptions of all site activities, especially sampling start and ending times. Include site entry and exit times.
- Noteworthy events and discussions.
- Environmental conditions (e.g., air temperature, relative humidity, wind speed and direction).
- Identification and description of samples and locations.
- Date and time of sample collections, along with chain of custody information.
- Record of photographs.
- Site sketches and field observations.
- Deviations from standard procedures or methods and the rationale for the deviations.
- Field method equipment serial number(s), calibration dates, and other instrument specifications as appropriate.

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3.4.3 Sample Containers, Sample Mass, Preservation, and Hold Time

Surface wipes are placed in a 1 × 40-mL VOA or 8-oz wide-mouth glass jar. Bulk samples are placed in an 8-oz wide-mouth glass jar. Sample preparation, sample mass for bulk samples, and preservatives are summarized in Table C. (Select appropriate row, and delete others.)

Table C. Sample Size, Preparation, and Storage			
Analyte	Sample Mass (solid) or Area (wipe) ^a	Sample Preparation ^a	Sample Storage ^a
Cyanogen chloride (CK)	5 g	EPA 5035A	< -7°C for up to two weeks
	(b)	(b)	(b)
Cyclosarin	10 g	EPA 3541	4°C for up to two weeks
	10 to 30 g	EPA 3545A	4°C for up to two weeks
	2" × 12" ^f	EPA 3570 (extraction)	4°C for up to two weeks
Hydrogen cyanide (AC)	(c)	(c)	(c)
Phosgene (CG)	(d)	(d)	(d)
Sarin	2 to 3 g	EPA 3570	4°C for up to 2 weeks
	5 g	EPA 3571	Add 1 mL glacial acetic acid to 1g sample; extract within 3 days; analyze within 14 days
	2" × 12" ^f	EPA 3570 (extraction)	4°C for up to 2 weeks
Soman	10 to 30 g	EPA 3545A	4°C for up to 2 weeks
	2" × 12" ^f	EPA 3570 (extraction)	4°C for up to 2 weeks
Sulfur mustard	5 g	EPA 3571	Add 1 mL glacial acetic acid/NaCl per 1 g sample; extract in 3 days; analyze within 14 days
	2" × 12" ^f	EPA 3570 (extraction)	4°C for up to two weeks
Tabun	10 to 30 g	EPA 3545A	4°C for up to two weeks
	2" × 12" ^f	EPA 3570 (extraction)	4°C for up to two weeks
VX	5 g	EPA 3571	Extract within 3 days Analyze within 14 days
	2" × 12" ^f	EPA 3570 (extraction)	4°C for up to two weeks

^a as specified in EPA (2011).

^b Cyanogen chloride (CK) is a gas at T ≥ 56.8°F (13.8°C), so surface/solid contamination might not be of concern.

^c Hydrogen cyanide (AC) is a gas at T ≥ 78°F (26°C), so surface/solid contamination might not be a concern.

^d Phosgene (CG) is a gas at T ≥ 47°F (8.2°C), so surface/solid contamination might not be of concern.

^e Estimated method detection limits, based on expected instrument detection limits and recommended preparation methods.

^f The 2" × 12" area is from Appendix A of EPA 8290A method description

Note: this information is derived from EPA (2011) (see footnote to Table A). Methods are not yet validated for CWAs, but validated methods are currently (as of June 2011) being developed.

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3.5 Analytical Methods and Procedures

The analytical methods per sample and sample location are presented in Table D. General field QC considerations and requirements are presented in Table E. See Section 2.1 and Table A for options.

Table D. Sample Locations and Data Objective Summary					
Sampling Locations and Identifiers should correspond to location indicated on Figure A					
Sample Location(s) (should match with 3.3.1 and Figure A)	Sample Identifiers	Analytical Method Refer to Table A	Data Use Objective(s) ^a Refer to Section 2.1	Data Category Refer to Section 2.3	Samples Matrix

Add additional pages if necessary.

^a Objectives from Section 2.1 may be referenced by number or by short summary. Reference DQO Step 2 study questions (by number) if data use objectives are linked to the DQO study questions.

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3.6 Quality Assurance and Quality Control

General field and laboratory QA/QC considerations and requirements are presented in Table E.

Table E. Quality Control Samples and Measurement Performance Criteria			
QC Sample	Number and Frequency	Measurement Performance Criteria	Comments and Exceptions Incident-specific remarks
Field-Specified QA/QC			
Background or reference sample	At least one sample should be collected from an area believed to be unaffected by source contamination.	Source samples should be at least 3 times background.	CWA very unlikely to be present from other sources. (Check site history for prior military use.) If used, sample some other facility of the same kind.
Field Blanks	1 per SDG ¹ , per matrix, per method	Source samples should be at least 3 times the blank.	Include with wipe or swab sampling
Trip Blanks	1 per SDG, per matrix, per method	Source samples should be at least 3 times the blank.	Trip blanks are a low priority due to limited utility in assessing cross-contamination.
Equipment Blanks	1 per SDG, per matrix, per method	Source samples should be at least 3 times the blank.	Include when nondedicated equipment must be decontaminated in the field.
Collocated Samples	1 per SDG, per matrix, per method	Wipe - 35%RPD ² Swab - 50%RPD ²	As needed by sampling objectives. The procedure for collecting duplicate samples can greatly affect the reproducibility.
Performance Standards	1 per project, per matrix, per method	75–125%R ³	If available.
Selected Laboratory QA/AC			
Method Blank	1 per SDG, per matrix, per method	Standards and samples should be at least 3 times the blank.	Mandatory.
Matrix Spike	1 per SDG, per matrix, per method on field designated sample.	75–125%R	Designate sample on COC.
Matrix Spike Duplicate or Replicate	1 per SDG, per matrix, per method on field designated sample.	≤50 RPD	Designate sample on COC.
Reference Standards	1 per SDG, per matrix, per method	75–125%R	If available.
Internal Standards	All samples	50–200%R	All GC/MS and some GC analyses only.
Laboratory Control Standards	1 per SDG, per matrix, per method	75–125%R	Per method for organic analyses.
Surrogates	All samples	70–130%R	Surrogate standards for CWA may change when validated methods for CWA are issued.

¹ SDG = Sample delivery group (maximum 20 samples).

² RPD = Relative percent difference.

³ %R = Percent recovery.

Note: review laboratory's QC criteria for whether they meet project requirements.

Annex H**4.0 Project Organization and Responsibilities****4.1 Schedule of Sampling Activities**

Sampling activities are summarized in Table F.

Table F. Proposed Schedule of Work For Sampling Activities		
Activity	Start Date	End Date

Add additional pages if necessary.

4.2 Project Laboratories

Laboratories used for this project are summarized in Table G. CWAs may go to OPCW-certified laboratories; TICs may go to conventional contract laboratories. Additional CWA-certified laboratories may become available after validated methods are issued.

Table G. Laboratories	
Lab Name and Location	Methods

Add additional pages if necessary.

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4.3 Project Personnel and Responsibilities

Personnel and responsibilities are summarized in Table H. Names are also recorded in field log book.

Table H. Sample Team(s) Personnel				
Name	Title	Affiliation	Contact (phone and email)	Responsibility

Add additional pages if necessary.

4.4 Modification or Additions to the Generic Data Quality Objective for Emergency and Time-Critical Sampling

Project-specific modifications to the generic DQO statements are summarized in Table I. Indicate which DQO step corresponds to the addition or modification.

Table I. DQO Modifications and Additions	
Additions or Modifications to Generic DQO Output Statements	DQO Step

Add additional pages if necessary.

5.0 Reference

EPA (2011), U.S. Environmental Protection Agency, *Standardized Analytical Methods for Environmental Restoration following Homeland Security Events*, Revision 6.0, available at: <<http://www.epa.gov/nhsr/sam.html>>, updated 5/13/2011; accessed 6/16/2011.

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H.4 Sampling and Analysis Plan Guidance and Template for CWA or TIC Transportation Facility Sampling

This Sampling and Analysis Plan (SAP) guidance and template has been developed to help document the procedural and analytical requirements for sampling to characterize contamination by a CWA or TIC in the interior of a major transportation (or similar) facility. This template includes surface, bulk, and water or liquid sampling. A separate SAP is recommended for air sampling.

This template views the EPA environmental sampling response as consisting of several phases. The first phase is from arrival of EPA personnel through perhaps a few days and consists of numerous time-critical decisions. This phase focuses on information gathering, including identification and characterization of the CWA or TIC, and on sampling to support source reduction and containment because they need to be implemented as quickly as possible to minimize the spread of contamination. The second phase occurs when there is a need to develop a comprehensive plan to characterize all or most of the facility. The third phase consists of sampling to support clearance decisions.

This template is intended for the second and third phases, characterization and clearance. A separate template for time-critical sampling has been developed for the first phase. This template assumes that the release is confirmed and that the specific CWA or TIC has been identified. It also assumes that first responders (fire, police) collect samples according to their own protocols, but that their first priority is protecting and saving lives and controlling and stabilizing the situation, not on environmental issues.

This template combines, in a short form, the basic elements of a Quality Assurance Project Plan (QAPP) and a Field Sampling Plan (FSP). Once prepared and approved, it will meet the requirements for any EPA-led project in which environmental measurements are to be taken. An extensive resource for QAPP development is the *Workbook for Uniform Federal Policy for Quality Assurance Project Plans, Evaluating, Assessing, and Documenting Environmental Data Collection and Use Programs, Part 2A: UFP-QAPP Workbook*, available at http://www.epa.gov/fedfac/pdf/Wkbk_Mar05.doc.

This template assumes that the work will be done in the context of an Incident Command System (ICS) set up as described in the EPA *Incident Management Handbook* (2007). Within the ICS system, the Environmental Unit in the Planning Section is responsible, among other things, for site characterization strategies and sampling and analysis plans.

The template format assumes that a qualified laboratory will perform chemical-specific analyses of samples. At present, an OPCW-certified laboratory would be best for CWAs. A conventional contract laboratory can be used for TICs. Other potential laboratory resources include, for example, a state laboratory, a research laboratory, or an in-house laboratory. More complete information is provided in the sections, below, describing sampling procedures than those

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describing analytical methods because it is assumed that a qualified laboratory will be used (see Table A-1 and Section 3.3).

This template provides item-by-item instructions for creating a SAP and includes example language that can be used verbatim or modified to reflect project-specific requirements. The electronic version of the template is a Microsoft Word file and is recommended as a starting point for the SAP.

The format of the template is as follows:

- Tutorial information is presented in *shaded grey italic* type. Such information includes definitions and background information pertaining to a given section of the SAP and is to be deleted from the final document.
 - Specific instructions to the preparer are given inside brackets [in shaded normal type]. Brackets and instructions inside the brackets should be deleted from the final document.
 - Suggested text that can be included in the SAP is presented in normal type. This text can be used, modified, or deleted, depending on the nature of the project. For example, delete the discussion of trip blanks if only field blanks and equipment blanks will be used.
 - If the use of an SOP is appropriate, the SOP should be included as an Annex to the final SAP and referenced in the appropriate section of the SAP.
 - An underlined blank area _____ indicates that text should be added. So does a section of multiple empty underlines, as in
-
-
-

- Added text should not be underlined.
- Underlined areas are not meant to imply how much text should be added; only that it is a place that the plan writer should add information. Adjust the space or number of lines provided as necessary to completely address each section.
- Examples or choices are given in [brackets] following the blank; where alternative choices are offered, they are separated by slashes, as in [option 1 / option 2 / option3]. Select as many as are appropriate, and delete the others, or replace with appropriate text.
- If a given section does not apply, it is recommended (but not required) that the section state “Not applicable,” or “Does not apply,” under the section heading. By not deleting the section, the writer avoids having to renumber sections. However, sections can be removed altogether and the remaining sections renumbered if the preparer prefers.

Annex H**Sampling and Analysis Plan for**

[Title of Project]

Date[Prepared by]

Expedited review requested? ☐ Yes ☐ No

Approvals:

Quality Assurance Coordinator (EU):

Date:

Environmental Unit Leader:

Date:

Planning Section Chief:

Date:

Operations Section Chief:

Date:

Unified Command:

Date:

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1.0 Introduction provide page numbers here

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7.0 Sample Containers, Preservation, and Storage

9.0 Sample Documentation and Shipment.....

10.0 Quality Control.....

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12.0 Field Health and Safety Procedures

Attachments

References.....

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1.0 Introduction

[Briefly describe the project, including the history, problem to be investigated, scope of sampling effort, and types of analyses required. The topics will be covered in depth later; therefore, do not include a detailed discussion here.]

1.1 Facility Name or Sampling Area

[Provide the most commonly used name of the facility.]

1.2 Facility or Sampling Area Location

[Provide a general description of the facility and its surroundings. More facility information is provided in Section 2. Detailed sampling location information should be provided in Section 4.]

1.3 Responsible Agency

[Provide a description of the organization conducting the sampling.]

1.4 Project Organization

This template assumes that the overall project will be managed using an Incident Command Structure, and that EPA's project organization will be based on the EPA Incident Management Handbook (currently, the 2007 edition). The table below lists key positions within the ICS directly related to this SAP. Other organizations (e.g., DHS, local and municipal officials, airport staff) having a decision-making or oversight role can be represented on the UC.

[Fill out the table. Key positions in the EPA ICS are shown; add or remove as needed. Airport personnel who take an active role (e.g., HVAC or facility engineers) can be added. Provide the name and phone number(s) of the person(s) or contractor working on the sampling project as listed in the table. The table can be modified to include titles or positions appropriate to the specific project. Delete personnel or titles not appropriate to the project.]

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Title/Responsibility	Name	Phone Number	Email
Planning Section Chief			
Environmental Unit Leader			
Staff			
Quality Assurance Coordinator			
Operations Section Chief			
Contractor (Company Name)			
Contractor Staff			

The Quality Assurance Coordinator (QAC) is responsible for overseeing the implementation of the Sampling and Analysis Plan or QA Plan (if one has been prepared). The responsibility includes determining whether specified quality control (QC) procedures are being followed as described. Preferably, the QAC should not be involved in data collection, analysis, interpretation, or reporting, except in a review or oversight capacity. If the project is small, another technical person may fulfill this role.

1.5 Statement of the Specific Problem

[Provide a brief description of the incident and the reason that this plan is needed. More detailed information is to be provided in Section 2.2.]

On _____ [date and time] _____ emergency responders were called to an incident at [facility] with reports of sudden, severe physical distress. Upon arrival, they found _____ [description] _____. US EPA On-Scene Coordinators arrived at _____ [date and time] _____ and after speaking with first responders determined that the facility had become contaminated with _____ [CWA or TIC] _____. A time-critical sampling plan was developed and executed in to provide an initial scoping of the degree of contamination. Additional detail is in Section 2.2.

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2.0 Background

Provide currently available information about the incident (e.g., from emergency responders and any time-critical response sampling already conducted by the EPA). This information is the basis for an initial conceptual model of the contamination.

2.1 Site or Sampling Area Description

[At least one, and possibly two, maps of the facility should be included in this section. The first map (Figure 2.1), on a larger scale, should identify the facility within its geographic region. The second map (Figure 2.2), on a smaller scale, should identify the features of the site including structures, roads, and bodies of water. Both maps should include a directional North arrow and a scale. Facility engineering staff should be able to provide appropriate drawings or detailed electronic (CAD) drawings of the facility. Include spatial coordinate information, such as longitude or latitude, a state plane coordinate system (in feet or meters), or local facility-specific coordinate system for the general site location. Provide a detailed description of the facility, including the number of terminals, parking garages, and outbuildings; include information about tunnels, active transportation lines, and water features as well. Additional site or facility information, such as HVAC zones, drainage lines, access points (doors), and interior or exterior features including walls, stairways, escalators, utilities, and outside prevailing winds, may be included on additional maps here or in Section 4, as needed. Blueprint drawings showing sampling locations will be shown in Section 4.]

[Fill in the blanks.]

The site is located at _____ [include street address, city, state, zip code] and occupies _____ [e.g., acres or square feet] in a _____ [e.g., urban, commercial, industrial, residential, agricultural, or undeveloped] area. The site is bordered on the north by _____, on the west by _____, on the south by _____, and on the east by _____. The specific location of the facility is shown in Figure 2.1.

Provide detailed written descriptions of the facility (all relevant attributes), consistent with what is presented in Figure 2.2.

[Insert Figures 2.1 and 2.2 here, and additional figures if needed.]

[Depending on the nature of the project, some of the following sections may not be applicable. If such is the case, do not delete the section. Instead enter "Not Applicable" or other text to indicate that the section does not apply or that the information is not available.]

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2.2 Incident History

To develop data quality objectives and a conceptual model, collect as much information as possible about the incident.

[Report available information about the nature of the incident, i.e., from first-responder actions and law enforcement investigations. Especially include information that may indicate the spread or severity of contamination, such as reports of liquid contamination and locations where symptoms or health effects were reported. Include information regarding the types and physical states (solid, liquid, or gas) of the CWA or TIC present in the facility originally and now.]

2.3 Previous Investigations and Regulatory Involvement

[Summarize first-responder sampling, forensic sampling (if available), and any time-critical response sampling already conducted by the EPA. Include the sampling date(s); name of the party(ies) that conducted the sampling; agency for which the sampling was conducted; a rationale for the sampling; type of media sampled (e.g., air, surface, building materials); laboratory methods used; and a discussion of what is known about data quality and usability. Summarize information in subsections according to the media that were sampled (e.g., air, surface, soil) and chronologically within each medium. Attach reports or summary tables of results, or include in appendices if necessary.]

This information is to be factored into the preparation of the SAP.

2.4 Structural Information

[Summarize relevant information on the structure of the facility. Include, at a minimum, summaries of the types of material from which the facility is constructed (concrete, steel beam); finishing materials (gypsum wallboard, carpet, terrazzo tiles, vinyl tiles, wood, brick, stainless steel, glass) and their approximate distribution and quantities; information about HVAC systems and their operating parameters; air handling zones and life safety zones; locations of elevators, escalators, stairwells, doorways to the outside, and interior doorways); any other aspects that might affect the extent and patterns of dispersal of CWA or TIC within the facility.]

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2.5 Environmental and Human Impacts

[Discuss what is known about the possible and actual impacts of the CWA or TIC contamination on human health or the environment. Discuss persistence of the CWA or TIC in the indoor environment (because this template is for interior characterization). See Section 2.3 of the *Remediation Guidance* for information.]

[If an action level or clearance goal is available, state it here. If different exposure pathways have different levels, state them here.]

The [action level / cleanup level / clearance goal / (other)] for the CWA or TIC of concern [on surfaces / in bulk material _____] is _____. The source of or basis for this action level is _____.

3.0 Project Data Quality Objectives

Data Quality Objectives (DQOs) are qualitative and quantitative statements for establishing criteria for data quality and for developing data collection designs. This section is crucial to SAP approval because it defines what the data will be used for and what quality of data is needed to make decisions. EPA's Guidance for the Data Quality Objectives Process (EPA QA/G-4, Final, February, 2006) should be consulted for more information.

DQOs should:

- *Concisely describe the problem to be studied.*
- *Identify what questions the study will attempt to resolve, and what actions (decisions) may result.*
- *Identify the information that needs to be obtained and the measurements that need to be taken to resolve the decision statement.*
- *Define study boundaries and when and where data should be collected.*

Most projects using this template are small so that defining action levels measurement quality objectives (MQOs) for the field and laboratory measurements used on the project are sufficient. MQOs define criteria for calibration and QC for field and laboratory methods. MQOs are discussed more thoroughly below.

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3.1 Project Task and Problem Definition

[Describe the purpose of the environmental investigation in qualitative terms and how the data will be used. The discussion should usually be brief and generic. Include all measurements to be made on an analyte-specific basis in whatever medium (wipe, swab, bulk, etc.) is to be sampled. The discussion should relate to how this sampling effort will support the specific decisions described in Section 3.2 DQOs, below.]

3.2 Data Quality Objectives

DQOs establish the types of decisions that the data will support, therefore the type and quality of data required for the project. DQOs may involve testing statistically defined hypotheses and calculating confidence intervals, depending on project decision-making needs.

For a CWA or TIC incident in a transportation facility, this template suggests a zone-based approach, in which different zones might have different decision-making needs. Zone-specific DQOs should be documented in the zone-specific sections of the plan (4.1, 4.2, etc.). In addition, DQOs are expected to be different for characterization sampling than for clearance sampling, and the zone-specific DQOs of Sections 4.1, 4.2, etc. should reflect the difference. Data quality indicators and measurement performance criteria (MQOs) are used to determine whether analytical data have sufficient quality to support the required decisions, as discussed in the next section.

This section should describe decisions to be made based on the data and provide criteria on which the decisions will be made. Inclusion of one or more tables is recommended: tables that list all the chemicals of concern, their associated action levels or clearance goals, and the source of the action levels or clearance goals (regulation, incident-specific health based criteria, etc.) If a chemical of concern does not have an action level or will not be used in decision-making, the text should discuss how data will be used (but this circumstance is not anticipated in a CWA or TIC incident in a transportation facility). In a CWA or TIC incident in a public facility, it is anticipated that a technical working group or equivalent will be convened to develop incident-specific clearance goals. In that case, users of this template will have to wait until that work is done before clearance goals become available. Section 2.3 of the Remediation Guidance lists some sources that can be consulted while waiting.

The use of "...if...then" statements is recommended. Decisions do not have to involve regulatory or legal action. Some examples: "If the CWA or TIC or a degradation product is found above the levels specified in Table ___, but below 10× the levels, the area in the vicinity of the sample will be marked for decontamination, and additional sampling to identify the boundary of contamination above the action level will be conducted," or, "If the CWA or TIC is found above 10× the action level, then the area will be marked for decontamination, but no further sampling in the immediate vicinity is warranted." Such if-then statements might be different for different zones, as described in Section 4.

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[Discuss overall project Data Quality Objectives, action levels, and decisions to be made on the basis of the data.]

3.3 Data Quality Indicators and Measurement Performance Criteria

Measurement Performance Criteria (MPCs) are quantitative and qualitative criteria that establish the level of uncertainty associated with a set of data. They answer the question: How sure are you that the value of the data is what the analyses have determined them to be? All the elements of the sampling event, from the sampling design through laboratory analysis and reporting, affect the quality of data. Depending on what the chemicals of concern are, what effect they may have on human and environmental health, and at what level, measurement quality may need to be legally defensible.

Data Quality Indicators are usually considered as the PARCCS parameters [precision, accuracy, representativeness, completeness, comparability, and sensitivity (method detection limits)]. Depending on how these parameters are determined, criteria, termed “measurement performance criteria” are defined to determine whether analytical data meet project-specific needs. Measurement performance criteria consist of ranges of acceptable values for DQIs that should be met to support project decisions.

The Environmental Unit Leader or other decision-maker identified earlier in the project organization section must make the decision as to what level of uncertainty is acceptable or appropriate.

This template assumes users are familiar with DQIs and measurement performance criteria. Table 3-1, which lists DQIs that should be considered, is adapted from Figure 14 in the IDQTF UFP-QAPP Manual. For information about the meaning and use of these DQIs see Section 2.6.2 of the IDQTF UFP-QAPP Manual. Example measurement performance criteria in Table 3-1 should be replaced with project-specific measurement performance criteria. One way to select measurement performance criteria is to find out from the analytical laboratory what criteria it can meet or routinely uses, and if they are acceptable, adopt them for the project. In general, the lower the true concentration in the sample, the greater the analytical uncertainty.

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Table 3-1. Measurement Performance Criteria.

DQI	Measurement Performance Criteria	QC Sample Type	Assesses variability in Sampling (S), Analytical (A)
Precision-overall	$RPD \leq 40\%$	Collocated	S+A
Precision-lab	$RPD \leq 30\%$	Laboratory duplicate	A
Accuracy-lab	Recovery 70–130%	Single-blind PT	A
Accuracy/Bias	Recovery 70–130%	Surrogate spike	A
Cross-contamination	<MDL	Blanks	S+A
Sensitivity	$\pm 40\%$ at QL	Lab-fortified blank at QL	A

Detection limits for the methods currently available for CWAs are given in Table A-1. Note that these methods are not validated for CWAs. Validated methods are under development by the EPA; Table A-1 will need to be updated when validated methods are released.

At present (September, 2009), the best available methods for CWA or TICs are EPA 8270 (most CWAs) or 8260C (CK), so MPCs normally used for those methods should be appropriate.

Acceptable values for the quantitative data quality indicators, and statements concerning the qualitative indicators, are determined by the answers to the questions in Section 3.2. In particular, the criterion for sensitivity depends on the relation between the QL and a project-specific action level or other level of interest. The fundamental requirement is that measurements have sufficient sensitivity at the QL to reliably distinguish whether a result near the QL is above or below an action level or other level of interest. The Quality Assurance Coordinator must approve the MPCs.

[Copy Table 3-1 and include it here; replace example criteria with project-specific criteria.]

The following discussion is intended to assist in setting acceptable values for DQIs for collocated (collocated field duplicate) and field split (subsample field duplicate) samples.

Collocated samples

Collocated samples are used to assess small-scale spatial variability, consistency of sampling technique, and laboratory variability. Sample results are typically interpreted as representative of some area around them; if there are large variations over short distances then that area may

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be relatively small. Collocated sample results should not show systematic differences (e.g., collocated sample results are consistently higher (or lower) than the standard sample result). If differences are not systematic, calculate the relative percent difference between all pairs and establish a variability goal, such as “90% of the RPD values should be less than 30%. Consult with the laboratory regarding what is realistic, especially at very low concentrations, and especially below the laboratory’s practical quantitative limit for the method being used. Take into account the way data will be used; for example, if splits indicate a 30% uncertainty in reported concentrations, but reported concentrations are 3 times greater than an action level or clearance goal, 30% uncertainty is acceptable.

Field split samples

Split samples assess sample heterogeneity and inter- or intra-laboratory variability. If split sample results are markedly different, then the source of variability should be investigated and resolved before results are used for decision-making. This is especially important if the splits are being sent to different laboratories, and the differences are systematic, i.e., one laboratory consistently reports higher (or lower) results than the other. If differences are not systematic, calculate the relative percent difference between all pairs, and establish a variability goal, such as “90% of the RPD values should be less than 30%.” Consult with the laboratory regarding what is realistic, especially at very low concentrations, and below the laboratory’s practical quantitative limit for the method being used. Take into account the way data will be used; for example, if splits indicate a 30% uncertainty in reported concentrations, but the reported concentrations are 3 times greater than an action level or clearance goal, 30% uncertainty is acceptable.

Splitting a wipe sample is done by cutting a wipe in half. Side effects include contaminating the cutting tool (which would then require decontamination) and reducing the detection capability associated with the sample. For such reasons, it is probably better not to use field splits, but to collect collocated samples as close together as possible. Bulk samples can be split by collecting additional material from the same location and then splitting it. When bulk material is extracted as discrete “chunks” or “chips,” it should be placed alternately into the two sample containers to avoid inadvertent bias.

3.4 Data Review and Validation

At present, validation for CWAs should use the same standards as would be used for other chemicals for the methods described in Table A-1. Validation standards may change when (new) validated methods for CWAs are released.

This section should discuss data review, including what organizations or individuals will be responsible for what aspects of data review and what the review will include. The SAP should discuss the process by which the evaluation of data quality will be made. Describe how data that do not meet data quality objectives will be designated. Assistance is available from the Quality Assurance Coordinator.

If data need to be legally defensible, data packages and data validation may be required. If necessary, results may go through the EPA CLP system. Data reviewed include raw data, such as standards logbooks, extractions logs, instrument printouts, chromatograms (if applicable), mass spectra (if applicable), and so forth. Calibration data, sample analysis data, and quality

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control data are all evaluated. There is no requirement that all data be validated to the same level; the project can mix and match depending on DQOs. It is recommended that, if validation will be a part of the data review process, validation SOP(s) from the validating organization be attached. Alternatively, the Quality Assurance Coordinator can be requested to review the validating organization's validation SOP on a generic basis. Once reviewed to ensure it is consistent with EPA protocols, it can be referenced in future SAPs associated with the incident.

The IDQTF UFP-QAPP Manual (2005) references

<http://www.epa.gov/region9/qa/pdfs/ldrdrdv.pdf> as a good example for data validation methods.

The currently available methods for CWAs are 8260C (CK) and 8270D (others); the referenced document includes validation for 8260 and 8270.

[Discuss data review and data validation here, including what organizations or individuals will be responsible for what aspects of data review and what the review will include. This section should also discuss how data that do not meet data quality objectives will be designated, flagged, or otherwise handled. Possible corrective actions associated with the rejection of data, such as reanalysis and resampling, also need to be addressed.]

3.5 Data Management

[Provide a list of the steps that will be taken to ensure that data are transferred accurately from collection to analysis to reporting. Discuss measures that will be taken to review the data collection processes, including field notes or field data sheets; to obtain and review complete laboratory reports; and to review the data entry system, including its use in reports. A checklist is acceptable. If an electronic system is to be used, describe it here. Provide its name and the organization or individuals responsible for managing the system. If the system includes electronic data transfers with the analytical lab, mention it here. This section can be prepared by the Data Management Specialist in the Planning Section.]

3.6 Assessment Oversight

[Describe the procedures that will be used to implement the QA Program. Include oversight by the Quality Assurance Coordinator in the Environmental Unit or a QA specialist under the authority of an Area Command Environmental Unit Leader. Indicate how often a QA review of the different aspects of the project, including audits of field and laboratory procedures, use of performance samples, review of laboratory and field data, etc., will take place. Describe what

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authority the QA Manager or designated QA person has to ensure that identified field and analytical problems will be corrected and the mechanism by which correction will be done.]

4.0 Sampling Design

For each sampling event, the SAP must describe the sampling locations, type of samples to be collected, and analytes of concern at each location. This template assumes that the specific CWA or TIC that was released has been identified and that it was named in Section 1 or 2 (or both). This section is crucial to plan approval and should be closely related to previously discussed DQOs.

Zone-based planning: Major public transportation facilities are typically large, with a complex structure. They include large, open public areas, often with high ceilings, as well as office spaces, storage rooms, mechanical rooms, baggage handling areas and systems, and so forth. Connections between sections of the facility may consist of relatively small, enclosed corridors, tunnels with trams or trains, elevators, and stairwells. Therefore, and depending on the estimated extent of contamination, it is likely to be expedient to divide the facility into zones. This template assumes zones are used, but such use is not a requirement. If zones are used, then include Sections 4.1, 4.2, etc., one for each zone. If only a single zone is used, then only Section 4.1 need be provided. Each section is subdivided on a media-specific basis among surface and bulk samples. Other media can be added as needed.

This template assumes that first-responder reports are available, or will be made available as they are completed. The responding OSC may have been present for much of the first response phase and may be able to provide first-hand information to corroborate any first-responder reports. Such information is summarized in Section 2.3 and used here as needed.

[Describe the rationale for identifying zones (or zone boundaries).]

[List all zones in Table 4-1. Add rows as necessary. Add or remove columns as appropriate.]

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Table 4-1. Zone descriptions.

Zone name	Floor or level number	Brief Description	Approx. floor area (sq ft)	Approx. volume (cu ft)
Ex: Ticketing	Ex: 3	Ex: Ticketing and baggage check in for departing passengers.	Ex: 50,000	Ex: 1,500,000
Add a row for each zone				

More complete zone descriptions, and sampling design information for each zone, are included in the following subsections.

Some aspects of sampling design and rationale may be the same throughout the facility. For example, if a statistical sampling design is selected, it might be decided that the confidence level should be the same in all zones. If that is the case, document it here. Similarly, criteria used to identify appropriate judgmental sampling locations, such as material type, proximity to release location, or proximity to doors or air supply registers, are likely to be similar throughout. If so, document the criteria here. You can repeat them in each zone's section.

Some aspects of sampling design and rationale will be unique to each section. Zone-specific decisions, designs, and rationale are described in each zone's section (4.1, 4.2, and so forth).

[Describe sampling rationale common to all zones.]

Prior to decontamination, each zone is classified according to the following criteria.

[Suggested zone classifications are:]

- Class 1:** Known or assumed to be contaminated above guideline levels (the release location and its immediate vicinity; direct air flow path connected to the release location).
- Class 2:** High likelihood of being contaminated above guideline levels. (Contamination seems likely because of proximity to release or known dispersion mechanisms, but definitive evidence of contamination does not [yet] exist; all areas served by the same AHU as the release location, including other floors of the building, and all AHU zones sharing a common return plenum with the release zone).
- Class 3:** Low likelihood of being contaminated above guideline levels (contamination is possible, but seems unlikely because of the distance from release point, building layout, or absence of known dispersion mechanisms; AHU zones adjacent to the release zone).
- Class 4:** Extremely low likelihood of being contaminated above guideline levels (all remaining areas not connected via a direct air flow path to the release zone).

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[Include one of the two of the following sets of rationale (characterization or clearance) and delete the other.]

For each type of zone, the basic sampling rationale is as follows:

[Suggested characterization sampling rationale for each class; use as is or modify]

- Class 1:** Judgmental samples to support decontamination planning and possibly additional source reduction.
- Class 2:** Judgmental samples to confirm the expected contamination as quickly as possible; followed by statistical sampling (likely a grid) if not found in initial judgmental samples. Judgmental samples are suggested to be of materials expected to retain agent (permeable or porous), preferably in locations within a transport pathway.
- Class 3:** Judgmental samples to quickly find contamination if present, but because contamination is considered unlikely, also sample to begin to develop confidence the zone does not need decontamination, if that is in fact the case.
- Class 4:** Expected to be clean, therefore sample to develop confidence it is clean (in essence, attempt to “clear” the zone now).

[Suggested clearance sampling rationale for each class; use as is or modify]

- Class 1:** Judgmental samples to support decontamination planning and possibly additional source reduction.
- Class 2:** Judgmental samples to confirm the expected contamination as quickly as possible; followed by statistical sampling (likely a grid) if not found in initial judgmental samples. Judgmental samples are suggested to be of materials expected to retain agent (permeable or porous), preferably in locations within a transport pathway.
- Class 3:** Judgmental samples to quickly find contamination if it is present, but because contamination is considered unlikely, also sample to begin to develop confidence the zone does not need decontamination, if that is in fact the case.
- Class 4:** Expected to be clean, therefore sample to develop confidence it is clean (in essence, attempt to “clear” the zone now).

[Create Sections 4.1, 4.2, 4.3, etc.; one for each zone.]

4.1 Zone _____ (fill in zone name)

[Create an abbreviation (zone code) to be used in naming samples. For example: “Ticketing” and “TK.”]

[Include additional information specific (or unique) to this zone (e.g., air handlers serving the zone; zone use, such as public, offices, controlled access, food court, ticketing, boarding; summary of materials present).]

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[Describe any sampling rationale specific to this zone, i.e., not covered by the general rationale above.]

[If the sampling plan specifies exact locations ahead of time, provide them in Table 4-1 and show them in Figure 4-1.]

[Characterization: if this is a characterization SAP, include the following, and delete the clearance SAP section below.]

[Describe the expected likelihood and levels of contamination in this zone.]

The _____ zone [is confirmed to be / is highly likely to be / may be / is unlikely to be] contaminated, because

Class 4 examples: far from the release location, on a different floor, there are no records indicating that first responders traveled from the release area to this zone (i.e., no evidence of tracking), does not share any air handling units.

[From the generic DQOs in Section 3.2, select one of the following sampling goals or DQOs for this zone, and explain why it is appropriate. Edit as needed. Delete the others. If none apply, describe sampling goals in this zone based on the previously discussed DQOs]

[Class 1 Zone (contamination confirmed or assumed)] Contamination has been confirmed to be present in this zone, as a function of ____ [first-responder sampling / presence of release device / reports of (severe) symptoms / other] _____. Sampling requirements are determined entirely by information necessary to develop the decontamination process.

[Class 2 Zone (contamination likely but not confirmed)] Characterization sampling is designed to detect contamination, if it is present, as quickly as possible. Judgmental sampling will be used. Sample materials and surfaces where the CWA or TIC is expected to still be present. Include permeable materials that, if contaminated, may be out-gassing.

If judgmental samples fail to find contamination greater than specified clearance goals, random sampling should be used. Random sampling will be _____[simple random / grid sampling]. Grid spacing will ensure a ____[95%] probability of detecting a contaminated area larger than ____[1%] of the available surface.

If contamination is detected, this zone is reclassified as a Class 1 Zone.

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If contamination is not detected, the area should be protected from cross contamination, if possible, set aside for later clearance sampling as deemed necessary, and documented in a clearance sampling plan.

[Class 3 Zone (contamination possible but unlikely)] A combined judgmental and random sampling approach (available in VSP software) will be used. The number of random samples will be such that if contamination is not detected, there will be _____ [95%] confidence that contamination is not present in the zone. Judgmental sampling includes materials and surfaces where contamination is expected to persist and permeable materials that, if contaminated, are likely to be out-gassing.

If contamination is detected, this zone is reclassified as a Class 1 Zone.

If contamination is not detected, the area should be protected from cross contamination, if possible, and set aside for a later review of the confidence achieved during characterization.

[Class 4 Zone (contamination highly unlikely)]

If the available information provides sufficient confidence, no sampling is done. Otherwise, the goal of sampling is to confirm with high confidence the hypothesis of no contamination.

Use a purely judgmental approach (sampling in locations where the contaminant is expected to persist, or air sampling), or combined judgmental with random sampling approach (available in VSP software).

If contamination is detected, this zone is reclassified as a Class 1 Zone.

If contamination is not detected, the area should be protected from cross contamination, if possible, and set aside for a later review of the confidence achieved during characterization.

[Clearance: if this is a clearance SAP, include the following, and delete the preceding characterization SAP section.]

[Decision criteria will be _____ [judgmental / statistical / both].

Judgmental sampling: resample all locations where contamination was found during characterization. If any sample result is above the clearance goal, decontamination is considered unsuccessful.

Statistical sampling: The number of samples must be sufficient to support a statement of the form, "We are _____ [95%] confident that less than _____ [1%] of the surface area contains concentrations of contamination greater than the clearance goal."]. If the statistical analysis does not support the statement, decontamination is considered unsuccessful.

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4.1.1 Surface Sampling

Surface sampling provides information for contact hazard analysis.

[Provide a general overview of any surface sampling to be conducted in this zone. Present a rationale for choosing each sampling location in the zone. If exact sampling locations are to be determined in the field, and their criteria are unique to this zone, include them here (i.e., a decision tree to be followed). Otherwise reference the location criteria at the beginning of Section 4.]

[Show sampling locations in Figure 4-1 below, and list samples in Table 4-1 below.]

4.1.2 Bulk Sampling

Bulk samples can detect the presence of sorbed CWA or TIC in permeable and porous materials. Bulk sampling generally causes some damage to the surface or material being sampled. Included in bulk sampling is soil sampling. Although soil sampling is not expected to be a large component of the sampling plan, it is an option.

[Provide a general overview of any bulk sampling to be conducted. Present a rationale for choosing each sampling location in the zone. If exact sampling locations are to be determined in the field, and their criteria are unique to this zone, include them here (i.e., a decision tree to be followed). Otherwise reference the location criteria at the beginning of Section 4. Include sampling locations in Figure 4-1 or equivalent.]

4.1.3 Water Sampling

Because of the chemical and physical interactions between CWAs or TICs and typical airport materials, including water, water is not expected to be the most useful matrix for characterization sampling for a CWA or TIC incident. Where concentrations are low (i.e., distant from a release location) it will be difficult to collect enough water to reach detection limits, and better materials are available for sampling. Where water concentrations may be high (i.e., near a release location), water sampling is unlikely to answer questions that other types of sampling cannot. Nonetheless, water sampling can be done, for example, during clearance to assure stakeholders that there is no potential for exposure from water (e.g., drinking water, hand washing, cooking).

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[Provide a general overview of any liquid or water sampling to be conducted. Specify the procedures used to collect the samples in Section 6.0 of this document. Present a rationale for choosing each sampling location in the zone. If exact sampling locations are to be determined in the field, and their criteria are unique to this zone, include them here (i.e., a decision tree to be followed). Otherwise reference the location criteria at the beginning of Section 4. Include sampling locations in Figure 4-1 or equivalent.]

4.1.4 Sample Maps and Table of Samples

[Add rows for samples and columns for additional types of information].

Table 4-1. Samples in Zone _____.

Sample ID	Location coordinates	Description	Method	Composite
Ex: TK-001	Ex:	Ex: Flexible earthquake joint material to each side of central metal strip, center of north wall.	Ex: wipe	No
Ex: TK-002	Ex:	Ex: Carpet in entrance to bookstore.	Ex: bulk	No

[Insert Figure 4-1 here, a map or floor plan for this zone, showing sampling locations and sample types (wipe, swab, bulk, water or liquid) at each location. Contact the staff of facility engineering for floor plans. Floor plans should show, at a minimum, walls, doors, and major features, such as stairs, elevators, and escalators. Additional information, such as use and areas of rooms and spaces, will be useful.]

*Figure showing sample locations in this zone,
exact or approximate, depending on the planning process.*

Figure 4.1 Sampling locations in the _____ zone.

Section 4.1 ends here. Add additional Sections (4.2, 4.3, 4.4, and so forth) for each zone, with subsections for each type of sample. Sections 4.2, 4.3, and so forth should include corresponding Tables 4-2, 4-3, etc. listing the samples in each zone.

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5.0 Request for Analyses

Discuss analytical support for the project, depending on several factors, including the analyte of concern, analytical method(s) requested, turnaround time, available resources, available laboratories, and so forth. The specific analyte should already be known by the time this template is being used. If samples will be sent to more than one laboratory, it should be clear which samples go to which laboratory. Field methods should be discussed in the sampling section. Field measurements in a mobile laboratory should be discussed here and differentiated from samples to be sent to a fixed laboratory. Field screening tests (for example, using portable ion-mobility spectrometers or flame photometric detectors) should be discussed in the sampling section. Analytical methods for CWA or TIC analyses are given in Table A-1. The information in Table A-1 is based on EPA (2011). Validated methods for CWAs do not currently exist, but they are being developed by the EPA. Table A-1 should be updated when validated methods are released.

Specific instructions to a laboratory regarding each sample are specified on the Chain of Custody document (Section 9.3).

[Complete the following narrative subsection concerning the analyses for each matrix (surface wipe, swab, bulk, or liquid).

5.1 Analyses Narrative

[Fill in the blanks. Delete inapplicable information below, as appropriate. Include any special requests, such as fast turnaround time (2 weeks or less), specific QC requirements, or modified sample preparation techniques, in this section. Repeat for each matrix (surface or bulk). An example of the narrative follows. Summarize the complete set of planned analyses in Table 5-1. Transfer the relevant sample storage, preparation, and analytical method information from Attachment Table A-1 to Table 5-2. This information should also be included on the Chain of Custody.]

As enumerated in Table 5-1, ____ [indicate matrix, e.g., surface or bulk] samples will be taken at ____ [indicate total number of locations] locations. ____ ["single" or "double" depending on laboratory requirements] volume ____ [matrix] samples will be supplied to the laboratory for use as QC samples: ____ [QC sample numbers]. Duplicate ____ [matrix] samples will be collected at ____ locations. As shown in Table 5-1, each ____ [indicate matrix] sample (including laboratory QC samples) will be analyzed for ____ [identify analyte(s) of interest]. Table 5-2 summarizes sample storage, holding, and analyses.

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Table 5-1. Summary of Samples and Requested Analyses for [CWA or TIC and degradation product(s)].

	Number of Samples of Each Type						
Matrix	Regular Samples	Collocated Field	Equipment Blank	Field Blank	Turnaround time	Field screening samples	Confirmation samples
Surface wipe							
Surface swab							
Bulk material							
[add or delete rows as needed]							

Table 5-2. Summary of Requested Analyses for [CWA or TIC and degradation product(s)].

Matrix	Analyte	Sample Storage	Sample Preparation	Determination
Surface wipe				
Surface swab				
Bulk material				
[add or delete rows as needed]				

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5.2 Analytical Laboratory

At present, an OPCW-certified laboratory is best for the analysis of CWAs. A conventional contract laboratory can be used for TICs.

[Complete the following narrative subsection concerning the analytical laboratory. Identify the laboratory or laboratories to be used. Include documentation showing that laboratory analyses will meet the measurement performance criteria described in Section 3. Such documentation may include, for example, a QA Plan from the laboratory, or SOPs for the methods to be performed. The EPA does not approve or certify laboratories; however, it will review the laboratory's QA Plan and provide comments to the SAP's originator concerning whether the laboratory's QA/QC program appears to be adequate to meet project objectives. It is recommended that any issues be discussed with the laboratory and resolved before work commences. Refer to Attachment Table A-1 for information about appropriate analytical methods.]

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6.0 Field Methods and Procedures

In the general introductory paragraph to this section, describe the methods and procedures that will be used to accomplish the sampling goals, e.g., "...collect surface, water, and bulk samples." Aseptic procedures must be followed, i.e., samplers must wear clean, disposable gloves of the appropriate type and change them between every sample. Field personnel should be trained in the sampling protocols. The sampling discussion should track the samples identified in Section 4. A general statement should be made that refers to the sections containing information about sample tracking and shipping (Section 7). Provide a description of sampling procedures. As of this writing, procedures appropriate for CWAs are under development by the EPA; use updated procedures if they have become available.

[If computerized systems for sampling location are to be used for locating samples in the field, describe their use here.]

6.1 Field Equipment

6.1.1 List of Equipment Needed

[List all the equipment that will be used in the field to collect samples, including decontamination equipment, if required. Discuss the availability of backup equipment and spare parts. List equipment types here. If appropriate, record the specific instrument used (i.e., by serial number) in a field logbook.]

6.1.2 Calibration of Field Equipment

[Describe the procedures by which field equipment is prepared for sampling, including calibration standards used, frequency of calibration, and maintenance routines. Indicate where equipment maintenance and calibration record(s) for the project will be kept.]

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6.2 Field Screening with Fixed Laboratory Analyses

In some projects, a combination of field screening using a less accurate or sensitive method may be used along with confirmation samples analyzed in a fixed laboratory. Describe any such methods or reference attached SOPs in this section.

To use field screening results for decision-making in lieu of or in addition to fixed laboratory results, the correlation between them must be good. This template recommends a statistical analysis of the correlation, with a requirement that field screening results can be used to predict fixed laboratory results to within, at most, plus or minus 20% with 95% confidence within the range of concentrations of interest.

[Describe any field-screening methods to be used on the project here, including how samples will be collected, prepared, and analyzed in the field. Include in an Annex, as appropriate, SOPs covering the methods. Confirmation of screening results should also be described. The role of the field screening in decision-making for the site should be discussed here if it has not been covered previously. Specify the desired correlation between field and fixed results, and the confidence level of that correlation.]

6.3 Surface Sampling

6.3.1 Surface Wipe and Swab Sampling

Use a standardized procedure for each sampling method. When in areas where lower concentrations are expected, wiping a larger surface area will increase the likelihood of detecting the CWA or TIC if it is present. Samplers should strive to wipe the defined surface area as consistently and precisely as possible to minimize error when converting from per-sample (mass per sample) results to concentration (mass per area) units.

A 2007 literature review of wipe sampling methods (downloaded August 2009 from <http://www.epa.gov/nerlesd1/cmb/pdf/epa-600-r-07-004.pdf>) did not identify a definitive or “best” method for wipe sampling for CWAs. In a variety of studies, wipes were usually wetted; IPA, DCM, and methanol were the most commonly used wetting agents. Wipe materials were typically either lint-free cotton or a woven polyester–cotton blend.

[In this subsection, describe the collection of surface wipe or swab samples, or refer to an attached SOP. See Attachment A-3 for an example wipe or swab protocol. EPA method 8290 includes some information on wipe sampling.]

[If an electronic sample-tracking system is being used, follow its procedures. Record the sampling event in the field logbook. Include: sample locations, a sketch of the sample location with any physical reference points labeled, and if possible, distances to reference points. Take photographs if possible. At least two photographs of every sampling location is recommended, as

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follows: (1) a close-up photo showing the exact sampling location, and (2) a photo that shows the sampling location in context, preferably including easily identified landmarks.]

[Describe the wipe or swab sampling protocol. The protocols for wipes and swabs are similar, but if necessary write separate descriptions.]

Don a sterile pair of sampling gloves. Attach a sample template (if being used) to the selected surface. Document the surface area to be wiped. Open a new sterile package containing a wipe or swab, or remove a new wipe or swab from the container. Wet the wipe with _____ [solvent name and quantity]. Wipe the designated surface area inside the opening of the template (or the selected area if not using a template). Wipe twice vertically, then horizontally, using an S-shaped pattern, to ensure complete surface coverage. For wipes, fold the wipe with the exposed side inward. Place the wipe in a clean sample container (1- × 40-mL VOA or 8 oz wide mouth glass jar). Cap and seal the container, attach a label and custody seal, and triple seal in sealable bags. Place sample container in a chilled (4°C) shipping container. Don new sterile gloves before collecting the next sample.

6.4 Bulk Sampling

6.4.1 Bulk sampling of building materials

[Use this subsection to describe the collection of bulk samples of building materials (e.g., wallboard, vinyl tile, elastomeric materials, etc.). Specify the method (e.g., chisel, scoop) that will be used to collect the samples and use the language below or reference the appropriate sections of a bulk sampling SOP. If tools need to be reused then they must be decontaminated with a solvent between samples; see Section 10.1.1.1.]

[If an electronic sample tracking system is being used, follow its procedures. In addition record the sampling event in the field logbook. This should include: sample locations, a sketch of the sample location with any physical reference points labeled, and if possible, distances to reference points. Take photographs if possible; at least two photographs of every sampling location are recommended: (1) a close-up photo showing the exact sampling location, and (2) a photo that shows the sampling location in context, preferably including easily identified landmarks.]

[Provide a brief description of how to collect a bulk sample of a building material such as carpet, wallboard, sealant, escalator handrail, etc.]

For each sample, don a new pair of sterile gloves. Decontaminate sampling equipment prior to use. Collect the specified volume of material using sterile scissors, knife, chisel, or other appropriate tool. Place the material into a sterile sample container (1- × 40-mL VOA or 8-oz wide-mouth glass jar). Close and seal the container, attach a label and custody seal, and triple-seal in sealable bags. *If off-gassing after collection and before extraction is a concern, consider using a hermetically sealed container.* Place the sample container in a chilled (4°C) shipping

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container. Don new sterile gloves, and decontaminate sampling tools before collecting the next sample.

6.4.2 Bulk sampling of soils

[Use this subsection to describe the collection of soil samples from, for example, planter boxes. Specify the method (e.g., hand trowels) that will be used to collect samples and use the language below or reference the appropriate sections of a soil-sampling SOP. If tools need to be reused, then they must be decontaminated with a solvent between samples; see Section 10.1.1.1].

[If an electronic sample-tracking system is being used, follow its procedures. In addition, record the sampling event in the field logbook. Include: sample locations, a sketch of the sample location with any physical reference points labeled, and if possible, distances to reference points. Take photographs if possible. At least two photographs of every sampling location are recommended: (1) a close-up photo showing the exact sampling location, and (2) a photo that shows the sampling location in context, preferably including easily identified landmarks.]

[Brief description of how to collect a bulk sample of a soil.]

For each sample, don a new pair of sterile gloves. Decontaminate sampling equipment prior to use. Collect the specified volume of material using a sterile spoon, trowel, or spatula. Place the material into a clean sample container (1- × 40-mL VOA or 8-oz wide-mouth glass jar). Close and seal the container, attach a label and custody seal, and triple-seal in sealable bags. Place the sample container in a chilled (4°C) shipping container. Don new sterile gloves and decontaminate sampling tools before collecting the next sample.

6.4.3 Water or Liquid Sampling

As discussed in Section 4.4, water or liquid sampling is not expected to be a priority. However, if water or liquid samples are desired, describe their collection in this subsection, and see Appendix A of EPA (2010) for information on sample preparation and analytical methods. Potential locations include, for example, drinking water, standing water in toilets, and wet countertops. (Sampling of spent decontamination solutions should be documented in the Remediation Action Plan.) Specify the method that will be used to collect samples, and use the language below or reference the appropriate sections of a soil-sampling SOP.

If an electronic sample-tracking system is being used, follow its procedures. In addition, record the sampling event in the field logbook. Include: sample locations, a sketch of the sample location with any physical reference points labeled, and if possible, distances to reference points. Take photographs if possible. At least two photographs of every sampling location are

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recommended: (1) a close-up photo showing the exact sampling location, and (2) a photo that shows the sampling location in context, preferably including easily identified landmarks.

[Brief description of how to collect a water or liquid sample.]

For each sample, don a new pair of sterile gloves. Decontaminate sampling equipment prior to use. Collect the specified volume of material directly into the container using a syringe, Teflon tubing, or other device. Place the water or liquid into a clean sample container (1- × 40-mL VOA, or 1-L amber glass jar). Close and seal the container, attach a label and custody seal, and triple-seal in sealable bags. Place sample container in a chilled (4°C) shipping container. Don new sterile gloves and decontaminate sampling tools before collecting the next sample.

7.0 Sample Containers, Preservation, and Storage

Sample containers, preservation, and holding times should be consistent with those of EPA's Standardized Analytical Methods for Environmental Restoration Following Homeland Security Events, Revision 6.0 (or subsequent update). See Table A-1. If no specific guidance is available, samples should be stored, refrigerated without preservatives, and analyzed as soon as possible after sample collection (preferably within 7 days). Large volumes of sample material requiring multiple containers are not anticipated for CWA or TIC sampling of a transportation facility, so this section is expected to be brief.

[Describe the types of sample containers to be used and sample preparation. Preservatives should not be used. If the information is given in the request for analyses tables in Section 5, reference them in the appropriate section below.]

The number of sample containers, volumes, and materials are listed in Section 5.0. The containers are pre-cleaned and will not be rinsed prior to sample collection.

7.1 Surface Samples

[Include this subsection if collecting surface samples; otherwise delete it.]

Surface wipes will be placed in a 1- × 40-mL VOA or 8-oz wide-mouth glass jar. As described in Section 6, the sample container is immediately placed in a chilled (4°C) shipping container. Preservatives are not used. Storage time should be minimized.

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7.2 Bulk Samples

[Include this subsection if collecting bulk samples of building materials, soil, water, or other liquids; otherwise delete it.]

Bulk samples will be placed in a 1- × 40-mL VOA or 8-oz wide-mouth glass jar. As described in Section 6, the sample container is immediately placed in a chilled (4°C) shipping container. Preservatives are not used. Storage time should be minimized.

8.0 Disposal of Residual Materials

[Describe the type(s) of investigation-derived wastes (IDW) that will be generated during sampling. The EPA recognizes that IDW may not be generated in all sampling events, in which case this section would not apply. Use the language below, or reference the appropriate sections in a Disposal of Residual Materials SOP, and state in which Annex the SOP is located. Depending on site-specific conditions and applicable Federal, state, and local regulations, other provisions for IDW disposal may be required. If any analyses of IDW are required, discuss them. If IDW are to be placed in drums, labeling for the drums should be discussed in this section.]

In the process of collecting environmental samples at the _____[site or sampling area name] during the site investigation (SI) [or name of other investigation], the _____[name of your organization or agency] sampling team will generate different types of potentially contaminated IDW that include the following:

- Used personal protective equipment (PPE).
- Disposable sampling equipment.
- Decontamination fluids.
- Excess bulk sample matrix.

The EPA's National Contingency Plan (NCP) requires that management of IDW generated during sampling comply with all applicable or relevant and appropriate requirements (ARARs) to the extent practicable. The sampling plan will follow the *Office of Emergency and Remedial Response (OERR) Directive 9345.302* (May 1991), which provides guidance for managing IDW. In addition, other legal and practical considerations that may affect the handling of IDW will be considered.

[Listed below are the procedures that should be followed for handling IDW. The procedures have enough flexibility to allow the sampling team to use its professional judgment as to the proper method for disposal of each type of IDW generated at each sampling location.]

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[The following bullets for TICs are generally appropriate for site or sampling areas with low levels of contamination or for routine monitoring. If higher levels of contamination exist at the site or sampling area, other disposal methods (such as drumming of wastes) should be used to dispose of used PPE and disposable sampling equipment.]

- Used PPE and disposable equipment will be double-bagged and placed in a municipal refuse dumpster. Such wastes are not considered hazardous and can be sent to a municipal landfill. Any PPE and disposable equipment that is to be disposed of, which can still be reused, will be rendered inoperable before disposal in the refuse dumpster.
- Decontamination fluids that might be generated during sampling will consist of solvent. The volume and concentration of the decontamination fluid will be sufficiently low to allow its disposal at the site or sampling area. Pesticide-grade solvents will be allowed to evaporate from the decontamination bucket.

[IDW for CWAs should be collected and stored with other wastes generated by the remediation effort (for example, building materials removed for the purpose of source reduction) and handled in the same manner as those materials.]

9.0 Sample Documentation and Shipment

The Sample Documentation Team Leader should review and approve the procedures described in this section. The Sample Tracking Team Leader is responsible for ensuring that procedures are followed.

9.1 Field Notes

Discuss recordkeeping in the field, for example, through a combination of logbooks, preprinted forms, photographs, or other documentation. Information to be maintained is provided below.

If an electronic sample-tracking system is used that includes field tracking (i.e., a handheld PDA-type device), then field notes are still essential. They represent (1) a backup to the electronic system, and (2) a way to record additional information, if any, not in the electronic system.

9.1.1 Field Logbooks

Use field logbooks to document where, when, how, and from whom any vital project information was obtained. Logbook entries should be complete and accurate enough to permit the reconstruction of field activities. Maintain a separate logbook for each sampling event or project. A separate logbook for each sampling zone is recommended. Logbooks should have

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consecutively numbered pages. All entries should be legible, written in black ink, and signed by the individual making the entries. Use factual, objective language.

[Describe how field logbooks will be used and maintained.]

At a minimum, the following information will be recorded during the collection of each sample:

[Edit this list as relevant.]

- Sample location and description.
- Sample identification numbers and any explanatory codes, chain of custody, and request for analysis form numbers.
- Site or sampling area sketch showing sample location and measured distances.
- Sampler's name(s).
- Date and time of sample collection.
- Designation of sample as composite or grab.
- Type of sample (wipe, swab, bulk).
- The type of surface or material sampled.
- Type of sampling equipment used.
- Field instrument readings and calibration.
- Field observations and details related to analysis or integrity of samples (e.g., evidence of visible contamination, stains, colors, and so forth).
- Lot numbers of the sample containers.
- Shipping arrangements (overnight air bill number).
- Name(s) of recipient laboratory(ies).

In addition to the sampling information, record the following specific information in the field logbook for each day of sampling:

[Edit this list as relevant.]

- Team members and their responsibilities.
- Time of arrival and entry onsite and time of departure.
- Other personnel onsite.
- Summary of any meetings or discussions with facility, contractor, or local, state, or Federal agency personnel.
- Deviations from sampling plans, site safety plans, and QAPP procedures.
- Changes in personnel and responsibilities, with reasons for the changes.
- Levels of safety protection.
- Calibration readings for any equipment used, and equipment model and serial number.

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[A checklist of the field notes, following the suggestions above, using only those that are appropriate, should be developed and included in project field notes.]

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9.1.2 Photographs

[If photographs will be taken, the following language may be used as is or modified, as appropriate.]

Photographs will be taken at the sampling locations and at other areas of interest onsite or at the sampling area. Photos serve to verify information entered in the field logbook. At least two photographs of every sampling location is recommended: (1) a close-up photo showing the exact sampling location, and (2) a photo that shows the sampling location in context, preferably including easily identified landmarks. For each photograph taken, enter the following information in the logbook, or recorded it in a separate field photography log:

- Time, date, location, and any relevant environmental conditions.
- Description of the subject photographed.
- Name of person taking the photograph.
- Photograph number or id code (for digital cameras).

9.2 Labeling

[The following paragraph provides a generic explanation and description of the use of labels. It may be incorporated as is, if appropriate, or modified to meet any project-specific conditions.]

Label all samples collected in a clear and precise way for proper identification in the field and for tracking in the laboratory. A copy of the sample label is included in Annex __. The samples will have pre-assigned, identifiable, and unique numbers. At a minimum, sample labels will contain the following information: sample number (sample ID), date of collection, analytical parameter(s), and method of preservation, if any. Every sample, including those collected from a single location but destined for separate laboratories, will be assigned a unique sample number. If an electronic sample-tracking system is being used, it should generate most, if not all, of the information, e.g., bar codes.

9.3 Sample Chain-Of-Custody Forms and Custody Seals

In general, a sample is considered to be in custody if it is either in someone's physical possession, in someone's view, locked up, or kept in a secured area that is restricted to authorized personnel. Samples should be in custody at all times. Chain of custody (COC) forms keep track of who has custody and when. This template assumes that standard COC forms and container seals stocked by sampling contractors or EPA staff adequately document the necessary information.

[The following paragraphs provide a generic explanation and description of the use of COC forms and custody seals. The paragraphs can be incorporated as is, if appropriate, or modified to meet any project-specific conditions.]

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All samples shipped for analyses will be accompanied by a chain-of-custody (COC) record. Form(s) will be completed and sent with every shipment of samples. The COC form will identify the contents of each shipment and document the custodial integrity of the samples. Until the samples are shipped, the custody of samples will be the responsibility of _____ [name of agency or organization conducting sampling]. The sampling team leader or designee will sign the COC form in the “relinquished by” box and note date, time, and shipping (air bill) number. The sample numbers for all standard samples, reference samples, laboratory QC samples, and collocated samples will be documented on this form (see Section 10.0). A photocopy will be made for the _____’s [name of agency or organization conducting sampling] master files. A self-adhesive custody seal will be placed across the lid of each sample container or wrapped around the cap. Shipping containers in which samples are stored (usually a sturdy picnic cooler or ice chest) will be sealed with self-adhesive custody seals any time they are not in someone’s possession or view before shipping. All custody seals will be signed and dated.

9.4 Packaging and Shipment

[The following paragraphs provide a generic explanation and description of how to pack and ship samples. The information can be incorporated as is, if appropriate, or modified to meet any project-specific conditions.]

All sample containers will be placed in a strong, outside shipping container (steel-belted cooler). The following information outlines the packaging procedures to be followed for low-concentration samples.

1. When ice is used, pack it in zip-locked, double plastic bags. Seal the drain plug of the cooler with fiberglass tape to prevent melting ice from leaking out of the cooler.
2. Line the bottom of the cooler with bubble wrap to prevent breakage during shipment.
3. Check screw caps for tightness, and, if not full, mark the sample volume level of liquid samples on the outside of the sample bottles with indelible ink.
4. Secure bottle or container tops with clear tape, and custody seal all container tops.
5. Affix sample labels onto the containers with clear tape.
6. Wrap all glass sample containers in bubble wrap to prevent breakage.
7. Seal all sample containers in heavy-duty, plastic, zip-lock bags. Write the sample numbers on the outside of the plastic bags with indelible ink.
8. Place samples in a sturdy cooler(s) lined with a large plastic trash bag. Enclose the appropriate COC(s) in a zip-lock plastic bag affixed to the underside of the cooler lid.
9. Fill empty space in the cooler with bubble wrap or Styrofoam peanuts to prevent movement and breakage during shipment.
10. Double-seal ice used to cool samples in two zip-lock plastic bags, and place them on top and around the samples to chill them to the correct temperature.
11. Securely tape shut each ice chest with fiberglass strapping tape, and affix custody seals to the front, right, and back of each cooler.

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Records of the following information will be maintained by the [organization]'s sample custodian:

- Sampling contractor's name (if not the organization itself).
- Name and location of the site or sampling area.
- Case or Regional Analytical Program (RAP) number.
- Total number(s) by estimated concentration and matrix of samples shipped to each laboratory.
- Carrier, air bill number(s), and method of shipment (priority next-day).
- Shipment date and when it should be received by the laboratory.
- Irregularities or anticipated problems associated with the samples.
- Whether additional samples will be shipped or if this is the last shipment.

10.0 Quality Control

Specify the types and numbers of quality control samples that are being collected. Include field QC samples, confirmation samples, and laboratory QC samples. Wherever possible, the locations at which the samples will be collected should be identified and a rationale provided for the choice of location. Frequency of collection should be discussed. All samples, except laboratory QC samples, should be sent to the laboratory blind, wherever possible. Laboratory QC samples should be identified on the chain of custody and additional sample volume collected if necessary. If the laboratory selects which samples are to be used for its internal QC, then every field sample should have sufficient volume for that purpose.

Different phases of response to a CWA or TIC event in a major transportation facility require different levels of quality assurance. For example, the need for legally defensible data may be much greater for clearance sampling than for characterization sampling. Similarly, field methods may have adequate quality for much (though not all) characterization sampling, but are unlikely to meet data quality objectives of clearance sampling.

10.1 Field Quality Control Samples

Field quality control samples are intended to (1) determine whether field contamination is occurring, and (2) assess variability. The former looks for substances introduced in the field during sampling and is assessed using blanks of different types. The latter includes variability arising from sampling technique, instrument performance, and heterogeneity of the sample matrix. Such issues are assessed using collocated (duplicate) sample collection. The following sections cover field QC.

10.1.1 Assessment of Potential Field Contamination (Blanks)

Field contamination, i.e., contamination inadvertently introduced into sample media by means other than actual sample collection, is usually assessed through the collection of different types of blanks.

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Equipment blanks are obtained by passing solvent over or through sampling equipment after it has been decontaminated between uses. The solvent is collected and sent to the laboratory for analysis. Detection of the analyte of interest in an equipment blank indicates cross-contamination from one sample to the next.

Field blanks are sample containers filled in the field with clean matrix. They help assess contamination from ambient conditions, sample containers, transit, and the laboratory. A wipe or swab field blank consists of a wipe or swab that is handled in every way identically to a true sample, except that no surface is wiped or swabbed.

Trip blanks are prepared by the laboratory and shipped to and from the field. They help assess contamination from shipping and the laboratory.

This template recommends that field blanks be collected. Equipment blanks should be collected if using sampling methods that require cleaning and reuse of sampling equipment, as may be the case for bulk samples. Trip blanks can be used if there is concern about cross-contamination in the laboratory, but they otherwise have a low priority because of their limited utility in assessing cross-contamination.

10.1.1.1 Equipment Blanks

In general, equipment (rinsate) blanks should be collected when reusable, nondisposable sampling equipment (e.g., trowels, scoops, chisels, or scissors) is being used to collect bulk samples. A minimum of one equipment blank is prepared each day when equipment is decontaminated in the field. The blanks are submitted to the laboratory and packaged like other samples, each with its own unique identification number. Sending the samples “blind” is not possible because solvent is a different matrix than the field sample.

[Include this subsection if equipment blanks are to be collected; otherwise delete it.]

[If equipment blanks are to be collected, describe how they are to be collected and the analyses that will be performed. A maximum of one blank sample per matrix per day should be collected, but at a rate to not exceed one blank per 10 samples. The 1:10 ratio overrides the one per day requirement. Use the language below, or reference the appropriate sections in a Quality Control SOP, and state in which Annex the SOP is located.]

Equipment rinsate blanks will be collected to evaluate field sampling and decontamination procedures by pouring solvent over the decontaminated sampling equipment. One equipment rinsate blank will be collected each day that sampling equipment is decontaminated in the field. The rinsate blanks that are collected will be analyzed for _____ [the CWA or TIC of interest.]

[Always include this paragraph.]

Equipment rinsate blanks will be preserved, packaged, and sealed in the manner described for the environmental samples. A separate sample number will be assigned to each sample, and it will be submitted to the laboratory.

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10.1.1.2 *Field Blanks*

Field blanks are collected when sampling surfaces, because equipment decontamination is not necessary with surface sampling. A minimum of one field blank is prepared each time surface samples are collected. Such blanks are submitted “blind” to the laboratory, packaged like other samples, and each is assigned its own unique identification number.

[Include this subsection if field blanks will be collected; otherwise delete it.]

Field blanks will be collected to evaluate whether contaminants have been introduced into samples during sampling as a function of ambient conditions or from sample containers. Field blank samples will be obtained by following the wipe or swab sampling protocol, except that no surface is wiped or swabbed. The wipe or swab is transferred directly to the sample container. Field blanks will be analyzed for _____ [the CWA or TIC of interest.]

[Always include this paragraph.]

Field blanks will be preserved, packaged, and sealed in the manner described for the environmental samples. A separate sample identification number will be assigned to each sample, and it will be submitted blind to the laboratory.

10.1.1.3 *Trip Blanks*

Trip blanks are required only if no other type of blank will be collected. If trip blanks are required, one is submitted to the laboratory for analysis with every shipment of samples. Such blanks are submitted “blind” to the laboratory, packaged like other samples, each with its own unique identification number. Trip blanks will be used only for surface samples. (Trip blanks for bulk materials would require going to another different facility known to be uncontaminated, and collecting bulk samples of similar materials.)

[Include this subsection if trip blanks will be collected; otherwise delete it. Only one trip blank sample per matrix per day should be collected.]

Trip blanks will be prepared to evaluate if the shipping and handling procedures are introducing contaminants into samples, and if cross-contamination in the form of CWA or TIC migration has occurred between the collected samples. A minimum of one trip blank will be submitted to the laboratory for analysis with every shipment of samples for CWA or TIC analysis. Trip blanks are sample containers in which a wipe or swab has been placed while outside the contaminated zone, and then sealed in the same way as a field sample. Sealed trip blanks are not opened in the field and are shipped to the laboratory in the same cooler that contains field samples. Trip blanks will be preserved, packaged, and sealed in the manner described for the environmental samples. A separate sample identification number is assigned to each trip sample, and it is submitted blind to the laboratory.

10.1.1.4 *Temperature Blanks*

[Include this paragraph with all plans.]

For each cooler that is shipped or transported to an analytical laboratory, a 40-mL VOA vial will be included that is marked “temperature blank.” This blank will be used by the sample custodian to check the temperature of samples upon receipt.

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10.1.2 Assessment of Variability using Collocated Samples

Collocated samples are collected simultaneously with, and close to, a standard sample from the same source under identical conditions, into separate sample containers. In the IDTQF UFP-QAPP Manual such samples are called collocated field duplicate (or replicate) samples. Each sample must be assigned its own sample number so that it will be blind to the laboratory. Collocated samples are handled in exactly the same manner as standard samples.

At least 10% of samples collected per event should have an associated collocated sample. The standard samples with which a collocated sample will be associated should be selected at random.

[State how many collocated samples will be collected.]

Collocated samples will be at a rate of _____ [1 per 5 / 10 / 20 / other] standard samples.

[List sample locations next to which duplicate or collocated samples will be collected]

Collocated samples will be collected at sample locations _____.

[Always include this paragraph.]

Collocated samples will be collected, packaged, documented, and transported in the same manner as routine samples of the same matrix (wipe, swab, bulk), as described in Sections 5 through 9. A separate sample number will be assigned to each collocated sample, and it will be submitted blind to the laboratory.

10.2 Field Screening and Confirmation Samples

For projects where field-screening methods are used (typically defined as testing using field test kits or portable analytical equipment, but not usually defined as the use of a mobile laboratory that accepts standard field samples and generates data equivalent to a fixed laboratory), two aspects of the tests should be described. First is the QC that will be run in conjunction with the field screening method itself. Second is any fixed laboratory confirmation tests that will be conducted. QC acceptance criteria for the tests should be defined in Section 10.2, rather than in the DQO section.

10.2.1 Field Screening Samples

[For projects in which field screening methods are used, describe the QC samples that will be run in the field to ensure that the screening method is working properly. The samples usually consist of a combination of field duplicates and background (clean) samples). Specify acceptance criteria and corrective action to be taken if results are not within defined limits. Discuss confirmation tests below.]

10.2.2 Confirmation Samples

If the planned sampling event includes a combination of field screening and fixed laboratory confirmation, describe the frequency with which confirmation samples will be collected and the criteria that will be used to select confirmation locations. Frequency and criteria will depend on the use of data in decision-making. It is recommended that the selection process be at a minimum of 10% and that selection criteria include checks for both false positives (i.e., the field detections are invalid or the concentrations are not accurate) and false negatives (i.e., the analyte was not detected in the field). Because many field screening techniques are less sensitive than laboratory

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methods, false negative screening is especially important unless the field method is below the action level for any decision-making. It is recommended that some “hits” be chosen and that other locations be chosen randomly.

[Describe confirmation sampling. Discuss the frequency with which samples will be confirmed and how the location will be chosen. Define acceptance criteria for the confirmation results (e.g., $RPD \leq 25\%$) and corrective actions to be taken if samples are not confirmed.]

10.2.3 Field Split Samples (subsample field duplicates)

For the purpose of this template, field split samples are samples that are divided after collection and sent separately to one or more laboratories. In the IDTQF UFP-QAPP Manual, such samples are called subsample field duplicate samples.

After splitting, each portion must be assigned its own sample number so that it will be blind to the laboratory. After splitting, split samples are handled in exactly the same manner as standard samples. If split samples are used, the samples to be split should be selected at random. It is desirable that splits cover the entire range of concentrations.

[Describe the purpose of split sampling. Describe how results are to be compared, and define criteria by which agreement will be measured. Discuss the corrective action to be taken if results are found to not be in agreement.]

10.3 Laboratory Quality Control Samples

Laboratory quality control (QC) samples are analyzed as part of standard laboratory practice. The laboratory monitors the precision and accuracy of the results of its analytical procedures through analysis of QC samples. In part, laboratory QC samples consist of matrix spike and matrix spike duplicate samples for organic analyses, and matrix spike and duplicate samples for inorganic analyses. The term “matrix” refers to use of the actual media collected in the field (e.g., wipe, swab, or bulk samples).

Laboratory QC samples are an aliquot (subset) of the field sample. They are not a separate sample, but a special designation of an existing sample. Consult with the laboratory to determine the sample volume required to allow the laboratory to aliquot.

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The laboratory may request that the sampling team provide blank wipe or swab material for preparing blanks and matrix spikes. Such blanks are preferable to having the laboratory supply its own blank material, because their blank material may not be of the same material as used for field samples.

[Include the following language if laboratory QC samples are to be associated with surface samples. Otherwise delete it.]

For wipe samples, the analytical laboratory will be responsible for preparing its internal QC samples. Provide blank wipes to the laboratory.

[Include the following language if laboratory QC samples are to be associated with field bulk samples. Otherwise delete it.]

For bulk samples, a double volume of sample is supplied to the laboratory for its use for QC purposes. Two sample containers are filled, and all containers are labeled with a single sample number. The laboratory should be alerted as to which sample is to be used for QC analysis by a notation on the sample container label and the chain of custody record or packing list.

At a minimum, one laboratory QC sample is required per 14 days or one per 20 samples (including blanks and duplicates), whichever is greater. If the sampling lasts longer than 14 days or involves collection of more than 20 samples per matrix, additional QC samples will be designated.

For this sampling event, samples collected at the following locations will be the designated laboratory QC samples:

[If a matrix is not being sampled, delete the reference to that matrix.]

[List surface sample locations and numbers designated for Laboratory QA/QC.]

- For surface, samples _____

[List bulk sample locations and numbers designated for Laboratory QA/QC.]

- For bulk, samples _____

[Add a paragraph explaining why the sample locations were chosen for QA/QC samples. QA/QC samples should be samples expected to contain moderate levels of contamination.]

[Include the following if supplying blank sample media to the laboratory for its internal QA/QC.]

The following quantities of blank _____ [wipes and swabs] are being supplied to the laboratory for their internal QA/QC.

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11.0 Field Variances

[It is not uncommon to find that, on the actual sampling date, conditions are different from expectations such that changes must be made to the SAP once samplers are in the field. The following paragraph provides a means for documenting such deviations or variances. Adopt the paragraph as is, or modify it according to project-specific conditions.]

Because conditions in the field may vary, it may become necessary to implement minor modifications to sampling as presented in this plan. When appropriate, the Quality Assurance Coordinator will be notified and a verbal approval will be obtained before implementing the changes. Modifications to the approved plan will be documented in the sampling project report.

12.0 Field Health and Safety Procedures

[Describe any agency, program or project-specific health and safety procedures that must be followed in the field, including safety equipment and clothing that may be required, explanation of potential hazards that may be encountered, and location and route to the nearest hospital or medical treatment facility. A copy of the organization health and safety plan may be included in the Annex and referenced in this section.]

Attachments

[To the extent that they are needed, include the following attachments. Edit as appropriate.]

Attachment Table A-1 summarizes available analytical methods.

Attachment Table A-2 summarizes physical properties of selected CWAs and TICS.

Attachment A-3 provides an example wipe procedure.

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Table A-1. EPA sampling, preparation, determination, and storage methods for selected CWAs and TICs.

Analyte	Sample Mass (solid) or Area (wipe) ^a	Sample Preparation ^a	Determination ^a	Sample Storage ^a	Detection Limit ^e (approximate)
Cyanogen chloride (CK)	5 g	EPA 5035A	EPA 8260C	< -7°C for up to two weeks	
	(b)	(b)	(b)	(b)	
Cyclosarin (GF)	10 g	EPA 3541	EPA 8270D	4°C for up to two weeks	
	10 to 30 g	EPA 3545A	EPA 8270D	4°C for up to two weeks	
	wipe 2" × 12"	EPA 3570 (extraction)	EPA 8270D	4°C for up to two weeks	
Hydrogen cyanide (AC or HCN)	(c)	(c)	(c)	(c)	
Phosgene (CG)	(d)	(d)	(d)	(d)	
Sarin (GB)	2 to 3 g	EPA 3570	EPA 8270D	4°C for up to 2 weeks	
	5 g	EPA 3571	EPA 8270D	Add 1 mL glacial acetic acid to 1g sample; extract within 3 days; analyze within 14 days	
	wipe 2" × 12"	EPA 3570 (extraction)	EPA 8270D	4°C for up to 2 weeks	
Soman (GD)	10 to 30 g	EPA 3545A	EPA 8270D	4°C for up to 2 weeks	
	2" × 12"	EPA 3570 (extraction)	EPA 8270D	4°C for up to 2 weeks	
Sulfur mustard (H, HD)	5 g	EPA 3571	EPA 8270D	Add 1 mL glacial acetic acid/NaCl per 1 g sample; extract in 3 days; analyze within 14 days	
	wipe 2" × 12"	EPA 3570 (extraction)	EPA 8270D	4°C for up to two weeks	
Tabun (GA)	10 to 30 g	EPA 3545A	EPA 8270D	4°C for up to two weeks	
	wipe 2" × 12"	EPA 3570 (extraction)	EPA 8270D	4°C for up to two weeks	
VX (VX)	5 g	EPA 3571	EPA 8270D	Extract within 3 days Analyze within 14 days	
	wipe 2" × 12"	EPA 3570 (extraction)	EPA 8270D	4°C for up to two weeks	

See notes on the next page.

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Notes for Table A-1:

^a As specified in EPA (2011).

^b Cyanogen chloride (CK) is a gas at $T \geq 56.8^{\circ}\text{F}$ (13.8°C), so surface or solid contamination might not be of concern.

^c Hydrogen cyanide (AC) is a gas at $T \geq 78^{\circ}\text{F}$ (26°C), so surface or solid contamination might not be a concern.

^d Phosgene (CG) is a gas at $T \geq 47^{\circ}\text{F}$ (8.2°C), so surface or solid contamination might not be of concern.

^e Estimated method detection limits based on expected instrument detection limits and recommended preparation methods.

Check for updates in the most recent version of EPA *Standardized Analytical Methods for Environmental Restoration following Homeland Security Events* (Revision 6.0, as of June 2011).

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Table A-2. Chemical and Physical Properties.

Compounds (CAS #)	Physical State	Molecular Weight	Boiling Point	Freezing Point	Melting Point	Vapor Pressure	Vapor Density (air = 1)	Specific Gravity (water = 1)	Water Solubility	Solvent Solubility
Cyclosarin (GF) (329-99-7)	liquid	180.16	228°C	-30° to -50°C	-12 °C	0.0927 mmHg @ 25°C	6.2	1.128 @ 25°C	3.7g GF/100g @ 20°C; hydrolysis, t _{1/2} =42hr @ 20°C in DI water	organic solvents
Sarin (GB) (107-44-8)	liquid	140.11	297°F (147°C)	-71°F (-57°C)	-56 °C	2.9 mmHg @ 25°C	4.86	1.10 @ 20°C	miscible; hydrolysis under acidic conditions; t _{1/2} =80hr @ 20°C, pH 7	organic solvents
Soman (GD) (96-64-0)	liquid	182.19	333°F (167°C)	-94°F (-70°C)	-42 °C	0.401 mmHg @ 25°C	6.3	1.026	2.1g GD/100g @ 20°C; hydrolysis, t _{1/2} =45hr @ pH 6.65	organic solvents
Sulfur Mustard (H, HD) (505-60-2)	liquid	159.08	423°F (217°C)	57°F (14°C)	-14.5 °C	0.09 mmHg @ 30°C	5.5	1.2741	very slightly soluble; hydrolysis t _{1/2} =5min @ 25°C only for what dissolves	fats, oils, organic solvents
Tabun (GA) (77-81-6)	liquid	162.13	248°C	-51°F (-46°C)	-50 °C	0.07 mmHg @ 25°C	5.63	1.073 @ 25°C	7.1g GA/100g @ 20°C; hydrolyzes, t _{1/2} =8.5hr @ 20°C, pH 7	organic solvents
VX (50782-69-9)	liquid	267.36	568°F (298°C)	< -60°F (<-51°C)	-39 °C calculated	0.0007 mmHg @ 25°C	9.2	1.0083 @ 25°C	30g/L @ 25°C; miscible @ 9.4°C; hydrolysis, varies t _{1/2} = 17 - 42 days @ 25°C, pH 7	lipids; organic solvents

Adapted from Tables 3 and 4 in *A Literature Review of Wipe Sampling Methods for Chemical Warfare Agents and Toxic Industrial Chemicals*, EPA/600/R-07/004, January 2007 (mostly from MSDSs). Additional information from *Airport Remediation Guidance* document, Table F-1.

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Attachment A-3. Surface-Wipe Procedure

A 2007 literature review of wipe sampling procedures for CWAs and TICs did not identify a “best” procedure (*A Literature Review of Wipe Sampling Methods for Chemical Warfare Agents and Toxic Industrial Chemicals*, EPA/600/R-07/004, January 2007). Wipes were generally moistened with a solvent wetting agent. The wetting agents used included acetone, IPA, ethyl acetate, DCM, and methanol. Following is an example surface-wipe protocol.

Example Surface-Wipe Procedure

Samples should be taken using methanol-dampened wipes. Wipes can be filters, gauze pads, or swabs. (Recommended: 3-in. by 3-in. general-use gauze sponge, e.g., Kendall Versalon sterile, all-purpose sponge.)

The sampler should have clean hands and must wear gloves during each sampling event to avoid contaminating samples. The sampling area should be a relatively dry surface.

1. Sampler puts on a clean pair of gloves.
2. Sampler attaches template or measures with a ruler and marks by using tape a pre-designated sampling location or area. Sampler should avoid touching the area within tape or template to avoid disturbing the sampling area.
3. Sampler replaces gloves with a clean pair of gloves.
4. Either soak the sampling wipe (filter or gauze pad) with 2-mL methanol, or take the wipe out of a per-soaked container. Use dampened wipe within 5 seconds of applying methanol to ensure that the wipe is damp. *A dry wipe will not capture a representative sample.*
5. Horizontally wipe the surface within the marking/template side to side in an overlapping “Z” pattern. Wipe so that the entire selected surface area is covered. End with an upward, scooping motion. Avoid wiping the marking tape or template.
6. Open the wipe, and fold the sampled side in. With a clean quarter-section of the wipe exposed, vertically wipe the surface within the template side to side in overlapping “N” pattern. Wipe so that the entire selected surface area is covered. End with an upward, scooping motion. Avoid wiping the marking tape or template.
7. Fold the wipe so the sampled side is folded in.
8. Insert the wipe into the sample collection container.
9. Record the location, date, and time of the sample on the sample container, the chain of custody form, and sampling notebook.
10. Discard gloves and marking tape, and proceed to the next sampling location.

Adapted from Clandestine Drug Lab General Cleanup Guidance, Minnesota Department of Health, Minnesota Pollution Control Agency, January 1, 2006. Downloaded September 2009 from www.health.state.mn.us/divs/eh/meth/lab/guidance0106.pdf.

Essentially the same protocol is available in guidance from the State of Kentucky; available at <http://www.waste.ky.gov/NR/rdonlyres/6226B37B-5E46-4037-BC4F9C324D3AE942/0/KentuckyMethamphetamineLabDecontaminationGuidanceForInhabitableProperties.pdf>.

A 1991 EPA protocol for wipe sampling for PCBs (www.epa.gov/waste/hazard/tsd/pcbs/pubs/wipe-samp.pdf) is similar. EPA Method 8290 hints at a wipe procedure in its Annex A.

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The reference to wipes in EPA 8290 suggests wiping a 2-in. × 12-in. area. Other protocols generally suggest less area. To maximize detection capability, wipe as large an area as possible, provided the wipe remains wet throughout.

Annex H References

EPA (1996), U.S. Environmental Protection Agency, *SW-846 Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*, Rev. 3, Chapter 4.

EPA (2011), U.S. Environmental Protection Agency, *Standardized Analytical Methods for Environmental Restoration following Homeland Security Events*, Revision 6.0, available at: <http://www.epa.gov/nhsr/sam.html>, updated 5/13/2011; accessed 6/16/2011.

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Annex I**Annex I. Sampling Zone and Sampling Unit Information
Forms for Characterization and Clearance**

This Annex contains templates that are designed to help workers keep track of sampling zones and units, remind investigators of the kinds of information that should be collected, and help samplers record information about sampling zones and units. The entity responsible for leading the sampling and characterization efforts, or those designated by such entity, are responsible for filling out the templates on the following pages. If an airport decides to identify sampling zones and units as well as characterization zones as part of pre-planning, the airport owner or operator selects the entity that completes the templates.

Sampling zones and units are described in detail in Chapter 2, Section 2.2.5, and in Annex C, Section C.2.2. The concepts of sampling zones and sampling units are briefly reviewed here.

A sampling zone is a discrete portion of an airport within which sampling is conducted. Sampling zones should be identified as part of an airport's pre-planning and are based on the physical structure of an airport. Sampling zones should be chosen in a way that will help remediation planners and workers keep track of what sampling has been done, where it has been done, and what information has been acquired from sampling. Sampling zones should also be based on whether portions might be remediated as discrete units (e.g., remediated and cleared early or late in an overall remediation project). Consolidation of pre-defined sampling zones may be appropriate if decontamination will be conducted simultaneously in two or more sampling zones.

Characterization zones are made up of one or more sampling zones, and their selection depends on the details of a specific event. If fumigation is anticipated, a good basis for defining fumigation zones is to find rooms, areas, or sections of a facility that can be isolated (sealed off) from each other, each of which either will or will not be decontaminated in its entirety. The clearance decision can be made independently for each such zone because each one is isolated from every other. The basis for identifying characterization zones is primarily physical, that is, such areas are physically separated from each other by sealed barriers.

Sampling units are defined within sampling zones. A sampling unit is any structure, or set of one or more objects, that can be sampled and evaluated collectively as a unit. For example, in an airport concourse, the floor would be considered to be one sampling unit; walls (if sampled at all), air-returns, and ticket-counters would each be separate sampling units. Sampling units are selected on the basis of location within a sampling zone, orientation (e.g., vertical versus horizontal surfaces), materials, and other considerations.

Annex I**Sampling Zone Form—Characterization**

Complete one form for each sampling zone

Sampling zone code**Sampling zone name**

Choose a sampling zone code (a short abbreviation that can be used as part of sample names), and a short, descriptive, user-friendly name. For example, “second-floor offices”, or “area served by air handling unit 12 (AHU-12)”. Short codes that can be incorporated into sample IDs are recommended.

Area (sq ft):

HVAC unit(s):

Sampling zone description

Describe the zone (its size, shape, types of activities it is used for, and other relevant information). Show the location of the zone on a facility floor plan.

Incident-related information about this zone

Summarize information from the First Response Phase and other assessments described in Section 2.2 of the *Remediation Guidance*. This information should be specific to this zone.

Information applicable only to specific sampling units within the zone should be on the sampling unit information form.

Assessment of likelihood of contamination in this zone, and why

Is this zone contaminated? Choose one of the following categories, or write a description. Decide how much confidence can be placed in the assessment.

- Class 1:** Known or assumed to be contaminated above guideline levels (the release location and its immediate vicinity; direct air flow path connected to the release location).
- Class 2:** High likelihood of being contaminated above guideline levels (contamination seems likely due to proximity to release or known dispersion mechanisms, but definitive evidence of contamination does not [yet] exist; all areas served by the same AHU as the release location, including other floors of the building, and all AHU zones sharing a common return plenum with the release zone).
- Class 3:** Low likelihood of being contaminated above guideline levels (contamination is possible, but seems unlikely due to distance from release point, to building layout, or absence of known dispersion mechanisms; AHU zones adjacent to the release zone).
- Class 4:** Extremely low likelihood of being contaminated above guideline levels (all remaining areas not connected via a direct air flow path to the release zone).

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Note whether the zone may be a pathway to affect other zones, or if other zones could affect this zone.

This categorization is based on information available as characterization begins, and may be enhanced by additional ad hoc sampling. Formal characterization is used to decide whether or not decontamination is necessary from a comparison with guideline levels.

From the above assessment, identify hypotheses and type of characterization to be done

Decide whether to use the sampling strategies suggested in the Airport CWA Guidance document for the four classes:

Class 1: judgmental samples to support source reduction and decontamination planning

Class 2: judgmental samples to confirm the expected contamination as quickly as possible; follow with statistical sampling (likely a grid) if not found in initial judgment. Judgmental samples suggested to be of materials expected to retain agent (permeable or porous).

Class 3: judgmental samples to quickly find contamination if it is present, but since contamination is considered unlikely, also sample to begin to develop confidence the zone does not need decon.

Class 4: expected to be clean therefore sample to develop confidence it is clean (in essence, attempt to “clear” the zone now).

Otherwise, identify hypotheses to test, questions to answer, or decisions that need to be supported with sampling data. Write your own, or use the following.

Decide whether

- Sufficient information exists to design the decontamination without additional sampling, or
- Information from characterization sampling is needed to design the decontamination.

If the latter, choose one or more of the following characterization goals:

- Determine whether or not contamination is present (i.e., if presence is uncertain).
- Confirm the absence of contamination (i.e., if presence is believed unlikely).
- Compare with guideline levels to determine whether decontamination is necessary.
- If gas/vapor phase decontamination is expected, determine what level needs to be maintained (concentration × time) if presence is confirmed or assumed.
- Identify areas that should receive surface decontamination (washing) either as the only decontamination method or as extra decontamination prior to gas- or vapor-phase decontamination (if it is believed that such areas can be identified, and if the contamination levels are expected to be so high that surface decontamination is worthwhile).

Other potential purposes of characterization

- Search for hotspots.
- Develop a map of contamination.
- Sample locations having high levels for future comparison with clearance samples (for targeted sampling during clearance).

See Annex C, Section C.3.3, Figure C-3, and Section 2.4 of the *Remediation Guidance*.

Annex I**List sampling units within this zone**

For CWA contamination, sampling units may be best defined by material, e.g., carpet; vinyl tile; glass; polymeric materials that are part of vertical surfaces; permeable materials; porous materials, etc. be defined by material type

Prepare a sampling unit form for each potential sampling unit.

Assess each sampling unit. Decide whether or not sampling the unit will contribute to testing the hypotheses, answering questions, or supporting the decisions. Note relations between sampling units.

For each sampling unit selected for sampling, choose a sampling strategy: judgmental, random, or statistical (may use more than one).

Annex I**Sampling Unit Form—Characterization**

Complete one form for each sampling unit within each sampling zone

Sampling zone designation

State the name of the sampling zone containing this sampling unit.

Sampling unit code**Sampling unit name**

Choose a sampling unit code (an abbreviation that can be used as part of sample names) and a short, descriptive, user-friendly name.

Sampling unit description

Include any useful descriptive information (e.g., hard, porous, smooth, rough). If appropriate, provide a figure showing where the sampling unit is in its sampling zone (e.g., carpeted vs. noncarpeted floor). Refer to locations of the sampling unit by cross-referencing to facility documentation.

Incident-specific information

Provide any information specific to this sampling unit that pertains to this particular incident and that is not already described in the sampling zone form.

Annex I**Choose a sampling strategy**

Decide whether sampling this unit will help test the hypotheses; answer the questions; or support decisions, objectives, or purposes identified for the zone. If sampling is to be done, choose:

- A sampling strategy based on zone- and unit-specific information. Options include one or more of judgmental, random, and statistical sampling. See Annexes D and E.
- The sampling protocol to be used (e.g., swab, wipe, or vacuum). The method must be appropriate to the physical material (type of surface—smooth or not, porous or not) and type of material (wood, carpet, metal, or HVAC filter). Include details, such as the exact surface area to be wiped, if wipes are used.
- The sample-handling protocol to be used. Include details, such as how to package the sample, decontaminate the outside of the sample container, label, document, and so forth.
- The analytical method to be used.
- The types and number of quality-control samples to be collected.

If a different strategy is needed for other sampling units, repeat the above process for those units.

If a single decision (and thus sampling design) will be made for the combined sampling units within a zone, proceed to the next page.

Annex I**Sampling Zone Form—Clearance**

Complete one form for each sampling zone

Sampling zone code**Sampling zone name**

Same as characterization, unless sampling zones are changed for clearance.

Sampling zone description

Same as characterization, unless sampling zones are changed for clearance.

Characterization-phase information about this zone

Summarize any characterization phase information that is relevant to clearance planning. Refer to the characterization sampling zone forms.

Decontamination-phase information about this zone

Summarize information from the decontamination phase that is relevant to clearance planning. Include any process-monitoring measures, such as fumigant concentration, temperature, humidity, and bio-indicator strip results, as applicable. Explicitly state whether the decontamination process met its design criteria in this zone (otherwise, the next activity should be more decontamination, not clearance).

List sampling units within this zone

Same list as characterization phase, unless zone or sampling unit definitions have been modified.

1. For each sampling unit in the zone, decide whether or not to sample.
2. For each unit being sampled, choose a sampling strategy (targeted, biased, random, or statistical). See Annexes D and E.

Annex I**Sampling Unit Form—Clearance**

Complete one form for each sampling unit

Sampling zone designation

State the name of the sampling zone containing this sampling unit.

Sampling unit code**Sampling unit name**

Same as characterization, unless sampling units are changed for clearance.

Sampling unit description

Same as characterization, unless sampling units are changed for clearance.

Incident-related information

Describe any information acquired since characterization that is specific to this sampling unit.

Annex I**Choose a clearance sampling strategy**

Decide whether sampling this unit is necessary to support the clearance decision (see Section 4). If so, then

- Decide where to sample, what to sample, how many samples to collect. For surfaces, see Section 4.2.2 for current recommendations. Options include, but are not restricted to, one or more of the following:
 - Judgmental sampling
 - Random sampling
 - i. Demonstrate that nearly all of the sampling unit is below a guideline level (UTL, Section 4.2.2)
 - ii. Confirmation sampling
 - iii. Testing whether the average is below a guideline level
 - iv. Detection sampling
 - v. Hot spot search.
- Specify the sampling method to be used (e.g., swab, wipe, or vacuum; see Annex D). The method must be appropriate to the physical material (type of surface—smooth or not, porous or not) and type of material (wood, carpet, metal, or HVAC filter). Include details such as the exact surface area to be wiped, if wipes are used.
- If air sampling is used in this zone, include a sampling unit form to represent the air sampling.
- Specify the sample-handling protocol to be used. Include details, such as how to package the sample, decontaminate the outside of the sample container, label, document, and so forth.
- Specify the analytical method to be used.
- Identify types and number of quality-control samples to be collected.

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Date: October 16, 2009

Name/org: Ellen Raber/LLNL, Global Security

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Annex J

Annex J. Remediation Action Plan Template

This Annex is a template for a Remediation Action Plan (RAP) to be used in the event of a chemical warfare agent (CWA) or toxic industrial chemical (TIC) release at a major transportation facility. The template is designed to help organize the required information in a concise way, to streamline the process necessary for approvals and decisions, and thereby facilitate rapid remediation of a facility.

Some remediation actions should take place as soon as possible after the release occurs. These include source reduction, isolation of sensitive equipment and valuable items, and containment. Source reduction could include, for example in the case of a liquid release, the prompt removal of any carpet soaked with liquid agent. If this is not done, the soaked carpet could serve as a source of secondary contamination. Since it is important that such actions occur as quickly as possible, they would not be part of a formal written RAP. They would, of course, be documented in the RAP as having been done.

A Clearance Sampling and Analysis Plan (Clearance SAP) is required before the RAP is implemented.

If volumetric space decontamination is used, an Ambient Air Monitoring Plan (AAMP) is also required to ensure that the CWA, TIC, or treatment gas does not escape a facility in concentrations hazardous to the surrounding population. The RAP is implemented in a series of daily Incident Action Plans (IAPs), as defined in the National Incident Management System (NIMS).

Major sections of the RAP are:

1. **Facility Information.** Includes basic information on the facility's location, facility use, and land use in the surrounding area.
2. **Project Team.** Includes the member names of the Unified Command and Technical Working Group, as well as any other relevant contacts.
3. **Contamination.** Concisely summarizes the event, initial actions (e.g., first responders, early containment, and preliminary remediation), facility conditions, and meteorological details.
4. **Work to date.** Describes initial (early) decontamination-related actions such as source reduction, containment, and isolation. Summarizes the methods and results of characterization sampling and initial air monitoring. Reports on any review and update of pre-incident planning information (if any exists).
5. **Proposed Decontamination Action.** This is the most detailed and extensive portion of the RAP. Key decisions are documented and justified in this section. Examples include: what decontamination technologies will be used, justifications for using the decontamination technologies, what items will be removed or decontaminated in place, staging and storage areas for decontamination equipment and waste, how areas will be sealed off, how the effectiveness of decontamination will be monitored, and what monitoring will be conducted

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to detect inadvertent releases of decontaminant. It is anticipated that contractors will provide much of the information, write the plan, and perform the work.

6. **Waste Disposal.** Discusses the disposal procedures for waste generated from the decontamination process.
7. **Safety.** At a minimum, refers to the Health and Safety Plan (HASP).
8. **Clearance Sampling and Analysis.** At a minimum, refers to the clearance Sampling and Analysis Plan (SAP).
9. **Ambient Air Monitoring Plan.** If a gas or vapor phase decontamination option is used, determine whether an ambient air monitoring plan is required. This plan will define how outside air will be monitored in order to detect releases of the decontamination reagent from the facility while treatment is taking place.
10. **Schedule.** Describe the schedules planned for the remediation process.
11. **References.** Include if applicable.

Annex J**Remediation Action Plan****1. Facility Information****1.1 Facility Name and Owner, Location, and Address**

Facility name and owner:

Facility location with latitude and longitude (attach figures, if applicable, as Figures 1.1.1 through 1.1.x):

Facility address:

1.2 Facility Use and Physical Description

Facility use:

Auxiliary use or tenants:

Physical description of facility:

Access to facility:

Topography around facility:

Describe any special security issues:

Specialized equipment or items requiring special attention:

Describe the type and availability of facility information that can be used in developing the Remediation Action Plan (e.g., CAD drawings, floor plans, HVAC system descriptions, videos, or existing environmental monitoring):

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1.3 Land Use in the Vicinity

General description of land use and population within a specified distance (all directions):

Annex J**2. Project Team****2.1 Unified Command Structure**

List the name, title, and affiliation of each individual on the Unified Command:

2.2 Technical Working Group

List the name, title, and affiliation of each individual on the Technical Working Group:

2.3 Additional Support

List the name, title and affiliation for other key functions or contacts:

Annex J**3. Contamination Information****3.1 Event**

Time, date, and location of the event:

Describe discovery of the release:

Estimated number of people occupying the facility at the time of release:

3.2 First response phase actions

Describe HVAC system operational status and other airflow conditions at the time of the event, and changes and time of those changes:

List any measures to seal off areas (containment):

Discuss management and evacuation of workers and the public (how many and where moved, how tracked, any personnel decontamination procedures implemented):

List any preventive measures taken regarding equipment, materials, or items (e.g., fire-suppression system use).

Report any initial (first response) sampling and results (attach figures and tables, if applicable, as Figures 2.2.1 through 2.2.x and Tables 2.2.1 through 2.2.x, respectively):

3.3 Meteorological Information Outside the Facility

Wind direction and speed at the time of the event:

Temperature, humidity, cloud cover, and precipitation at the time of the event:

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Significant changes in meteorological parameters since the event:

Anticipated meteorological parameters at the time of decontamination, based on climatology:

Describe any relevant effects any of these may have or have had.

Annex J**4. Work to Date****4.1 Initial remediation-related actions**

Document any source removal actions (e.g., neutralization or removal of bulk agent, if present; prompt removal of contaminated items or materials) that has been done. Include both actions taken during first response, as well as ad hoc actions taken after first response but before the implementation of the RAP.

Document any isolation actions.

Document any containment actions.

Document any building preparations that began early on.

Establish hot lines.

4.2 Characterization Sampling and Results

Some of the following information can be obtained from the Characterization SAP template (Annex H).

Overall sampling strategy and rationale:

Dates of characterization sampling:

Sample locations, sample types (methods), and sample numbers by sampling unit and zone (attach maps, if applicable, as Figures 4.1.1 through 4.1.x):

Sample collection method(s):

Analytical method(s) and laboratory:

Sample results (attach additional tables, as applicable, or attach figures, such as contamination maps):

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Summarize results, interpretation, and description of areas (zones) that need remediation.

4.3 Initial Air Monitoring and Results

Sampling strategy and rationale:

Identify locations (attach maps, if applicable, as Figures 4.3.1 through 4.3.x):

Sample collection method(s):

Sample collection frequency:

Analytical method(s) and laboratory:

Sample results (attach additional tables as applicable):

Summarize results, and describe the areas that need remediation and/or further investigation:

4.4 Pre-incident planning information

Review and update pre-incident planning information (*Guidance Document* Table 3-5).

Document HVAC and AHU systems.

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5. Proposed Remediation Action

5.1 Select decontamination approaches

Decide which decontamination approach(es) will be utilized, and why. (Annex F.2.4)

- Natural Attenuation (Annex F 3.3.1)
- Removal and disposal
- Surface: Soap & water, bleach, caustics, decontamination foams/gels, sealants, or other (Annex F.2.3)
- Volumetric: flushing, hot air, hot humid air, mVHP[®], ClO₂, or other (Annex F.2.4)

Document agent-specific properties that need to be understood in order to make appropriate decontamination decisions.

Identify special considerations for:

- Sensitive equipment (Annex F-2.5, Table F-4)
- Personnel
- Delicate items (i.e., artwork)
- Susceptible to corrosion

Decide whether in-situ treatment based on contamination zones can be used, or whether the entire building can be treated uniformly (*Remediation Guidance* Section 2.2.5)

Document design and application of each method in appropriate sections below.

5.2 Pre-Decontamination Work

List items to be removed for disposal *without treatment*. Attach tables, if applicable, as Tables 5.4.1 through 5.4.x. (Offsite decontamination of removed items or waste is documented in Section 5.X.X of this RAP)

Describe any additional methods to seal off or contain contaminated areas (refer to Sections 2.2.6 and 3.4 of the *Remediation Guidance*):

Describe methods for additional partitioning of contaminated areas, if necessary (refer to Section 2.2.5 of the *Remediation Guidance*):

Describe methods to isolate important items (sensitive electronic equipment, valuable artwork, other) (Section 3.4.2.3 and Annex F-2.1 of the *Remediation Guidance*):

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Identify waste disposal facilities, if not previously done as part of pre-planning.

5.3 Natural Attenuation

If the proposed remediation activity involves any options not requiring rigorous decontamination, such as natural attenuation, describe those options here:

Describe methods to monitor the attenuation rate and confirm that attenuation is occurring.

5.4 Removal

List the characteristics and quantities of items to be removed for treatment offsite. Include any information about CWA or TIC levels in such items determined from characterization sampling. Attach tables, if applicable, as Tables 5.1.1 through 5.1.x; refer to Section 3.4.1 of the *Remediation Guidance*:

Describe the method for safely (in terms of human health and to prevent inadvertent spread of contamination) removing these items from the contaminated area:

Describe proposed offsite decontamination technologies (refer to Section 3.4.2 of the *Remediation Guidance*). For example, what technologies will be used to decontaminate sensitive electronic equipment and small, personal, or valuable items, such as baggage and artwork?

Discuss the rationale for using these technologies (refer to Section 3.4.2 of the *Remediation Guidance* and Annex F):

List contact information for the state solid-waste management regulators, disposal facilities (e.g., landfills, incinerators, autoclaves), and/or wastewater treatment facilities that will be accepting the waste:

Annex J**5.5 Surface Decontamination Technology**

Identify the locations of surfaces to be treated onsite (attach figures, if applicable, as Figures 5.2.1 through 5.2.x):

Describe the proposed surface decontamination technologies (refer to Section 3.4.2 of the *Remediation Guidance* and Annex F):

Discuss the rationale for using these technologies (refer to Section 3.4.2 of the *Remediation Guidance* and Annex F):

Describe methods to contain and collect any liquid wastes.

5.6 Gas or Vapor Decontamination Technology

Locations of spaces to be treated (attach figures, if applicable, as Figures 5.3.1 through 5.3.x):

Sizes (L × W × H) and volumes of the areas to be treated (refer to Data Supplement B, which is available from LAX):

Describe the proposed technologies (refer to Section 3.4.2 of the *Remediation Guidance* and Annex F):

Discuss the rationale for using these technologies (refer to Section 3.4.2 of the *Remediation Guidance* and Annex F):

Describe the conditions required to ensure effectiveness of the technology (e.g., temperature, relative humidity, reagent concentration, contact time, etc.):

Describe any safety precautions that need to be employed (include PELs and so forth):

Describe measures used to confirm that the areas and equipment are sealed off:

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Describe the generation system for the decontamination technology:

Describe electrical power and other general site requirements:

Describe the distribution system (attach figures, if applicable, as Figures 5.5.1 through 5.5.x):

Describe any required pre-tests for parts or all of the system (e.g., equipment calibration or low-level performance tests):

Describe methods to prevent release of reagent to the outside, if necessary (see also this template Section 9 Ambient Air Monitoring Plan)

Describe operational details of the process, and the scheduling/phasing of the work:

5.7 Monitoring Effectiveness of Decontamination

List and describe any sensors, monitors, chemical indicators, or samples used to monitor the effectiveness of the decontaminant:

Indicate locations of sensors, monitors, indicators, or samples used (attach figures, if applicable, as Figures 5.6.1 through 5.6.x):

Specify the acceptable range of values for sensors, monitors, indicators, or samples.

If using natural attenuation, describe methods to monitor the attenuation rate and confirm that attenuation is occurring.

Specify what actions will be taken if any results are outside the acceptable range.

List analytical laboratories to be used, laboratory requirements, and necessary quality assurance/quality control (QA/QC):

Annex J**6. Waste Disposal**

Attach a Waste Disposal Plan (refer to Annex L for a discussion of considerations).

Describe any information available about CWA or TIC levels determined from characterization sampling.

Generate estimates for quantities and characteristics of wastes. Include waste from building preparations (source removal etc.) and the decontamination itself (e.g., spent reagent):

Liquid waste
Solid waste
Waste generated from personnel entering hot zones (such as PPE and personnel rinsate).

Identify disposal facilities for the various types of waste

List contact information for important waste-disposal stakeholders (such as state solid waste official, local POTW representative, potential landfills, incinerators).

Discuss pre-treatment and disposal options for various types of wastes.

Discuss waste-storage and waste-holding temporary areas, isolation, and security for waste-storage areas.

Describe specific needs, such as monitoring.

Determine transportation paths

Ensure that waste will be adequately tracked (“cradle to grave”; see Annex L, Section L.1.2)

Acquire regulatory approvals

Annex J**7. Safety**

Attach applicable Health and Safety Plan (refer to Section 2.2.11 of the *Remediation Guidance*):

8. Clearance Sampling and Analysis

Attach applicable Clearance Sampling and Analysis Plan (refer to Section 4.2 of the *Remediation Guidance* and Annexes D, E, and H):

9. Ambient Air Monitoring Plan

Attach an Ambient Air Monitoring Plan if one is required. It includes:

List and describe any sensors or monitors used to detect and measure decontaminant releases, should they occur:

Indicate locations of sensors or monitors used (attach figures, if applicable, as Figures 5.7.1 through 5.7.x):

Describe equipment calibration:

Describe sampling frequency and data collection methods:

Describe analytical methods used, QA/QC, and detection levels, if applicable:

Describe the criteria (e.g., air monitoring results) that would trigger a response action. Describe the resulting response action:

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10. Schedule

Discuss proposed timeframe for the various stages of the decontamination process:

11. References (if applicable)

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Date: October 16, 2009

Name/org: Ellen Raber/LLNL, Global Security

Guidance (if applicable): CG-CB-2; Topics 5510, 5530, 5342, 5220, 4211, 4220, 4131, 3210, 3230, 2211, 1320, 1211, 1110, 1130, 3310, 7220, 7100

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Annex K

Annex K. Remediation Contact Lists

Airport decision makers should identify the resources shown in Table K-1 in advance of a chemical warfare agent (CWA) or toxic industrial chemical (TIC) incident so that such resources can be mobilized immediately. Fill in the contact information, and verify the contact names and phone numbers at least once a year.

Table K-1. Site characterization resources that should be identified in advance.

Resource	Contact	Phone
National Response Center	www.nrc.uscg.mil	800 424-8802
Members of Unified Command or organization in charge		
Members of Technical Working Group		
Sampling team(s) and contractor(s)		
Primary analytical laboratory		
Secondary analytical laboratory		
Specialists who maintain architectural drawings of airport facility		
Data management and documentation specialists		
Agent air monitoring team and contractor		
Personal protective equipment (PPE) rental		
Facility engineering and construction team(s)		
Air-transport modeling team and contractor		
Centers for Disease Control and Prevention (CDC)		
U.S. Environmental Protection Agency (EPA)		
Waste-disposal resource personnel		
U.S. Department of Defense (DOD)		
Wastewater management authorities		

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Airport decision makers should identify the decontamination agencies, teams, and technical contacts shown in Table K-2 in advance of a CWA or TIC incident so that such resources can be mobilized immediately. Verify the contact names and phone numbers at least once a year.

Table K-2. Site decontamination resources.

Resource	Contact	Phone
Facility engineering and construction team(s)		
Decontamination team (may include decontamination reagent suppliers and contractors)		
National Decontamination Team, On-Scene Coordinators, and National Homeland Security Research Center (EPA)		
Primary analytical laboratory		
Secondary analytical laboratory		
Sampling team(s) and contractor(s)		
Centers for Disease Control and Prevention (CDC)		
Personal protective equipment (PPE) rentals		
State solid-waste management division		
Local wastewater treatment facility		

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Annex L**Annex L. Waste Management Considerations Applicable to CWA and TIC Decontamination**

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This Annex provides background information regarding waste management decisions during remediation following a potential CWA or TIC attack at an airport facility. The principal topics are the environmental laws and regulations that apply to waste management, waste-related implications of the *National Response Framework* (NRF), the regulation of CWA and TIC waste streams under the Resource Conservation and Recovery Act (RCRA), and disposal issues under the Clean Water Act and Clean Air Act. Because many states in the U.S. have unique regulations layered over Federal regulations, Annex L concludes with two case studies, one for California and one for Utah.

The role of an On-Scene Coordinator (OSC) is an important one in waste management. Sections 300.120(a) and 300.135(a) of the National Contingency Plan (NCP) states that the OSC directs response efforts and coordinates all other efforts at the scene of a discharge or release. The OSC is pre-designated by the regional or district head of the lead agency within the affected jurisdiction (e.g., EPA, USCG, DOD, or DOE). Section 300.130(a) of the NCP 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 states that the OSC coordinates response efforts with other appropriate Federal, state, and private response organizations. The OSC promotes the use of a Unified Command (UC) that brings together Federal, state, and local governments with the owner and operator of the affected facility to achieve an efficient and effective response. As EPA OSC can bring to bear various Federal authorities and resources to support the local Incident Commander in issues related to waste management, including the mobilization of Special Forces under the NCP. Special Forces trained in counter-terrorism response include the EPA's Environmental Response Team, the U.S. Coast Guard's National Strike Force, and NOAA's Scientific Support Coordinator.

L.1. Structure of Environmental Waste Regulations

Environmental laws and regulations reflect the patchwork of statutes enacted to address targeted environmental problems. Although the Clean Air Act and the Clean Water Act are good examples of comprehensive statutes passed to address an entire medium (air and water), other statutes deal with particular problems, such as the following:

- The Comprehensive Environmental Response and Liability Act (CERCLA), enacted to address cleanup of accidental spills or sites with chronic environmental damage.

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- The Resource Conservation and Recovery Act (RCRA), enacted to address the handling, management, and final disposal of solid and hazardous waste.
- The Safe Drinking Water Act, enacted to address the purity of drinking water supplied to the public by public drinking water suppliers.
- The Hazardous Materials Transportation Act and the Department of Transportation's (DOT's) Hazardous Materials Regulation provisions (49 CFR 100–185), which govern the placarding, packaging, and safe transportation of hazardous materials, including most hazardous wastes, destined for disposal at hazardous waste treatment, storage, or disposal facilities.

The Federal Government's cleanup contractors, especially the EPA's Emergency Rapid Response Services (ERRS) contractors, have specialized Transportation and Disposal Coordinators who are trained in applying complex Federal regulations to shipments of hazardous waste materials from CERCLA sites.

Even today, some areas such as cleanup levels for soil and groundwater are not addressed in Federal environmental law. Applicable Federal environmental statutes are listed in Table L-1. For the purposes of airport remediation following a CWA or TIC attack, it is important to have a basic understanding of CERCLA, RCRA, and the Clean Water Act.

Table L-1. Key environmental statutes.

Statute	Citation	Summary
Comprehensive Environmental Response and Liability Act	42 USCA §9601 et seq	Provides for the cleanup of contaminated sites including releases of hazardous substances.
Resource Conservation and Recovery Act	42 USCA §6901 et seq	Directs the management and disposal of solid and hazardous wastes.
Clean Water Act	33 USCA §1251 et seq	Addresses pollution to U.S. waters, including discharges to surface water bodies and wastewater treatment facilities.
Clean Air Act	42 USCA §7401 et seq	Addresses and controls pollution to ambient air through national air standards and control of air pollution sources.
Safe Drinking Water Act	42 USCA §300f et seq	Protects public health by establishing standards for the nation's public drinking water supply.
National Environmental Policy Act	42 USCA §4331 et seq	Requires Federal agencies to evaluate and consider effects on the environment in decision-making.
Toxic Substance Control Act	15 USCA §2601 et seq	Addresses the use and disposal of PCBs as well as tracking of industrial chemicals currently produced by or imported into the U.S.
Endangered Species Act	16 USCA §1531	Provides for the conservation of threatened and

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Statute	Citation	Summary
	et seq	endangered plants and animals and the habitats in which they are found.
Oil Pollution Act	33 USCA §2702 et seq	Provides for the prevention and response to catastrophic oil spills.
Federal Insecticide, Fungicide and Rodenticide Act	7 USCA §136 et seq	Provides for the Federal control of pesticide distribution, sale, and use.
Federal Emergency Planning and Community Right To Know Act	42 USCA §11001 et seq	Provides tracking and notification of chemical hazards to local communities to protect public health, safety, and the environment.

L.1.1. CERCLA

Congress passed CERCLA (also known as the Superfund) in response to a growing national concern about the release of hazardous substances from abandoned waste sites. CERCLA requires parties responsible for contamination to conduct or pay for cleanup and authorizes the Federal government to take court action to recover cleanup costs. If EPA efforts to hold a responsible party accountable are unsuccessful or no responsible party can be found, the Federal government can clean up a site using the Superfund.

Response actions are guided by CERCLA's implementing regulations, known as the National Contingency Plan (NCP) (40 CFR 300). The NCP describes the steps that responsible parties must follow when hazardous substances are released into the environment. The NCP establishes the criteria, methods, and procedures the EPA uses to determine which releases have priority for cleanup, evaluation of contaminated sites, and selection of remedial response. CERCLA responses are categorized as removal actions or remedial actions. Airport remediation to address a release of CWAs or TICs would be conducted under a removal action. Removal actions are short-term actions taken to:

- Clean up or remove released hazardous substances, pollutants, or chemicals of concern.
- Mitigate a threat of release of hazardous substances.
- Monitor and evaluate release conditions.
- Dispose of removed material.
- Mitigate or prevent damage to public health, welfare, or the environment.

In contrast to removal actions, remedial actions include the discovery, selection, study, design, and construction of longer-term actions aimed at a permanent remedy.

L.1.2. Resource Conservation and Recovery Act

The RCRA, enacted by Congress in 1976, establishes a system for managing nonhazardous and hazardous solid wastes in an environmentally sound manner. Specifically, it provides for the management of hazardous wastes from the point of origin to the point of final disposal ("cradle

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to grave”). Under RCRA, no material can be a hazardous waste unless it is a solid waste. RCRA defines a solid waste as:

...any garbage, refuse, sludge from a waste treatment plant, water supply treatment plant, or air pollution control facility and other discarded material, including solid, liquid, semisolid, or contained gaseous material resulting from industrial, commercial or mining and agricultural operations, and from community activities... [excluding]... solid or dissolved materials in domestic sewage, or solid or dissolved materials in irrigation return flows, or industrial discharges which are point sources subject to permits under Section 402 of the Federal Water Pollution Control Act..., or source, special nuclear, or byproduct material as defined by the Atomic Energy Act [AEA] of 1954.... [42 U.S.C.A. §6903 (27)]

Wastes from an airport remediation effort in response to a CWA or TIC attack would be considered solid wastes because the furniture, computer equipment, carpet, and other materials would be considered a solid discarded material. Any furniture or building components that are decontaminated and reused would not be considered solid wastes because the items are not being discarded.

Once a solid waste is generated, waste generators must determine if those solid wastes are also hazardous wastes (40 CFR 262.11). The determination of whether solid wastes are also hazardous wastes can be made in two ways. The first method is by testing the waste using precise testing methods the EPA has prescribed for determining whether any of the hazardous waste characteristics are present [40 CFR 262.11(c)(1)]. The second method applies if a person has knowledge of the hazard characteristic(s) of the waste from experience with that type of waste. Such an individual can “declare” the waste to be hazardous or not [40 CFR 262.11(c)(2)].

L.1.2.1. Listed and Characteristic Waste

The EPA uses two approaches for defining RCRA hazardous waste. For the first approach, the EPA has identified specific chemicals or process residuals that are known to pose a threat to human health and the environment if improperly disposed. Hundreds of the process residuals and toxic chemicals are identified on four separate lists. The four lists of wastes are: F wastes, K wastes, P wastes, or U wastes. The F wastes are wastes from common manufacturing and industrial processes, including spent solvents, heavy metal and cyanide wastes, dioxin wastes, wood-preserving wastes, petroleum refining sludge, and leachate from multiple sources. Because any one of these wastes can be produced in a wide variety of industrial operations, the F-listed wastes are known as wastes from nonspecific sources. The K-listed wastes are produced from a specific industrial process and are identified in the lists by the industry that generates them. The last two lists are for commercial chemical products that are being discarded or have been spilled in essentially pure form. The P-listed wastes are for acutely toxic wastes and are regulated when they are generated at a rate of at least 1 kg/month. The U-listed wastes are mainly toxic wastes but also include ignitable, reactive, and corrosive wastes and are regulated when they are generated at a rate of 100 kg/month. Wastes that appear on any of the lists are called “listed”

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wastes. The only way to have a listed waste relieved from hazardous waste management requirements is to petition the EPA, or a state authorized to implement RCRA in lieu of the EPA, to de-list the waste (40 CFR 260.22). The TICs are listed on the P-list of hazardous wastes.

The second approach that the EPA uses to define hazardous wastes is the particular characteristics of the waste. The EPA evaluates four characteristics of hazardous waste: ignitability, reactivity, corrosivity, and toxicity (see Table F-1). The characteristic of ignitability includes solid waste with any of the following properties:

1. A liquid, other than an aqueous solution containing less than 24 percent alcohol by volume, with a flash point less than 60°C (140°F) as determined by a test method specified in ASTM Standard D-3278-78 (closed cup), or as determined by an equivalent test method approved by the EPA Administrator.
2. Not a liquid that is capable under standard temperature and pressure of causing fire through friction, absorption of moisture, or spontaneous chemical changes and that, when ignited, burns so vigorously and persistently that it creates a hazard.
3. An ignitable compressed gas as defined in 40 CFR 261.21(a)(3).
4. An oxidizer as defined in 40 CFR 261.21(a)(4).

The characteristic of reactivity includes several criteria (40 CFR 261.23). Most of the reactive characteristics are fairly obvious in that they include those wastes generally that explode or react violently either alone or when mixed with water. For the purposes of solid wastes that would be generated as a result of a remediation effort at an airport following a CWA or TIC attack, only the following reactivity criteria could 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, which 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.

The characteristic of corrosivity includes corrosive aqueous wastes and those liquid wastes that are corrosive to steel (40 CFR 261.22). Specifically it includes solid wastes that are either:

- Aqueous and have a pH less than or equal to 2, or greater than or equal to 12.5 (EPA 2004), or
- Liquid and corrode steel at a rate greater than 6.35 mm (0.250 inch) per year at a test temperature of 55°C (130°F) (EPA 2004).

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The characteristic of toxicity includes a defined list of toxic chemicals (heavy metals, pesticides, and chlorinated solvents) derived from concentration-based standards. Characteristic wastes are solid wastes that, when the Toxicity Characteristic Leaching Procedure (TCLP) (Method 1311, EPA 2004) is performed on a representative sample of waste, the extract of the waste contains one of the 40 contaminants listed in Table 1 of 40 CFR 261.24

(<http://www.epa.gov/epaoswer/osw/hazwaste.htm>) above the regulatory level listed for the contaminant in that table. The intent of the toxicity characteristic and TCLP protocol is to simulate the leaching of contaminants out of a municipal waste landfill to groundwater. When concentrations of the chemicals listed in the regulations exceed a level that would not protect human health if leached from a landfill, they are considered hazardous waste. Chemicals included in the toxicity listing are a subset of regulated chemicals commonly found in industrial and commercial hazardous wastes. None of the CWAs or TICs considered by this *Remediation Guidance* appears in the toxicity listing of 40 CFR 261.24. Therefore, although decontamination wastes resulting from a CWA or TIC restoration effort prior to waste treatment could be toxic from a scientific and technical perspective, they would not be classified from a regulatory perspective as hazardous waste on the basis of the characteristic of toxicity under Federal RCRA regulations. Such decontamination wastes could still be considered hazardous waste on the basis of another characteristic of hazardous waste, such as corrosivity, or the waste itself (aside from the CWA or TIC involved in an attack) being listed as a hazardous waste. If a waste is not classified as hazardous waste, it is by default a solid waste.

With minor exceptions, when hazardous waste is treated, treatment residuals are classified as follows:

- When the waste treated is “characteristic,” the treatment residuals are only hazardous waste 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)].

L.1.2.2. Hazardous Debris Rule

With respect to characterizing and treating wastes, the EPA determined that when certain solid materials (referred to as debris) are contaminated with a hazardous waste, the treatment methodology applicable to the underlying hazardous waste may not be appropriate to the contaminated solid material. Therefore, the EPA promulgated what has come to be known as the hazardous debris rule. The rule establishes separate treatment standards for debris the EPA defines as solid material greater than 2.5 inches in size (the size of a tennis ball) that is intended for disposal and that is a manufactured object, plant or animal material, or a natural geologic material [40 CFR 268.2(g)]. As part of the rule, the EPA codified the “contained-in” policy with respect to debris that alters the classification of hazardous debris after treatment with specified treatment technologies. Debris is considered to be hazardous debris (and regulated as RCRA hazardous waste) when the debris 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

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debris rule, 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 to be a hazardous waste. In addition, the corollary to the contained-in policy also allows the EPA to make a case-by-case determination that debris treated by other methods no longer contains a listed hazardous waste and thus exits RCRA regulation [40 CFR 261.3(f)(2)]. Therefore, debris that was contaminated with a listed hazardous waste that has been treated with one of the specified technologies in the debris rule or such that the debris no longer contains the listed waste (i.e., the listed waste has been neutralized) would no longer be considered hazardous. For characteristic waste, if the treated waste no longer exhibits the hazardous waste characteristic, it exits hazardous waste regulation.

L.1.2.3. Hazardous Waste Identification and Management

Proper identification and management of hazardous wastes are critical to the success of the cradle-to-grave program. If wastes are hazardous, the generator must notify the EPA, or an authorized state if appropriate, of the hazardous waste management activities and obtain an EPA identification (ID) number (40 CFR 262.12). Under current regulations, the generator would most likely be either the airport or the EPA OSC. An airport facility could be considered the waste generator under RCRA because it is in the best position to ensure compliance. The airport should have been assigned an EPA RCRA Generator Identification Number for normal hazardous waste management activities that occur at the airport. The number would be listed in the generator section of the Uniform Manifest for shipment of hazardous wastes generated from chemical remediation activities at the airport. Alternatively, the EPA OSC could be designated on manifests as the waste generator for an airport remediation if the EPA were using its cleanup contractors to perform the decontamination. Under RCRA, the waste generator bears certain responsibilities for the costs and obligations of disposal. The OSC may assume the designation as generator when conducting a Federal-lead response—as opposed to an airport conducting the response under oversight of the EPA—because under such conditions the EPA would be in the best position to identify materials subject to the response; to ensure compliance with applicable packing, transport, and disposal regulations; and to provide information regarding the cradle-to-grave management of waste materials.

For wastes characterized as hazardous waste, subsequent management of the waste streams must be in accordance with RCRA hazardous waste regulations. After identifying a waste as RCRA hazardous waste, it must be stored and further managed in accordance with RCRA hazardous waste regulations. For wastes identified as hazardous wastes, any treatment must follow RCRA requirements for treatment, or a waiver of the requirement under the NCP must be obtained. RCRA requires all treatment to be conducted in a treatment facility, such as a tank or containment building (which could be constructed within an airport facility). Before being land disposed, waste must meet land disposal restrictions (LDRs), expressed as concentrations limits or required treatment methods in 40 CFR 268.40, depending on the particular waste code. Dilution cannot be used as a substitute for adequate treatment to meet the treatment standards in 40 CFR 268.3.

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If wastes are considered characteristic or listed RCRA hazardous waste, temporary storage may be necessary before transfer for treatment or disposal. Such wastes may be stored onsite for 90 days or less without a permit, provided the waste is stored in compliance with 40 CFR 262.34. Under an NRF response, waste may be stored longer than 90 days without obtaining a permit because of exemptions provided by the NCP.

During airport decontamination, the most likely method of storage for any hazardous waste generated will be a container (e.g., 55-gallon drum, roll-off container, shipping container, or railroad car). If large volumes of liquid are generated, tanks may be the best way to store the waste stream. The RCRA container storage requirements of 40 CFR 265.171–174 and additional requirements in 40 CFR 262.34, as shown in Table L-2, are applicable to any storage of waste as a result of remediation activities.

After removal from the accumulation area, waste could be treated onsite and transported offsite for disposal, or transported to a treatment and disposal facility located offsite. Regulations governing the transportation of hazardous waste are in 40 CFR 263. In developing its regulations, the EPA adopted by reference most of the DOT's hazardous materials transportation regulations implementing the Hazardous Materials Transportation Act (HMTA) for the safe transportation of hazardous wastes (49 CFR 171–179). Before shipping waste offsite, the generator of hazardous waste must comply with the generator pre-transport requirements shown in Table L-3.

Primary responsibility for implementing the RCRA hazardous waste program has been largely delegated to the states in lieu of the EPA. The EPA delegates this responsibility through a rulemaking process called authorization; hence, states with such responsibility are termed “authorized states.” As of May 2009, all states except Iowa and Alaska have been authorized for the base RCRA program. An authorized state promulgates its own hazardous waste regulations that apply in lieu of Federal regulations. Under RCRA, state RCRA programs and regulations must be at least as stringent as the Federal requirements, but states can adopt more stringent requirements (RCRA Section 3009, 42 U.S.C. §6929).

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Table L-2. RCRA container storage requirements for 90 days or less in an accumulation area.

Requirement	Description	Regulation
Container	Container must be compatible with the waste to be stored	40 CFR 265.172
	Container must always be closed during storage, except as necessary to add or remove waste	40 CFR 265.173
	Container must be clearly marked with the date upon which accumulation began	40 CFR 262.34
	Container must be clearly labeled as “Hazardous Waste” with the EPA hazardous waste number	40 CFR 262.34
	Containers must be managed to prevent rupture or leakage	40 CFR 265.173
	Container areas must be inspected at least every seven days for leaks, deterioration of containers, corrosion, and other items	40 CFR 265.174
	If any container starts to leak or is no longer in good condition, all waste must be transferred to containers in good condition	40 CFR 265.171
General facility	Facility must be designed, constructed, maintained, and operated to minimize fire, explosion, or release of hazardous waste or constituents into the environment	40 CFR 265.32
	Facility must be equipped with specified equipment, maintained in an operable condition (e.g., internal communication or alarm system, an immediately accessible telephone, fire-control equipment, decontamination equipment, and adequate water supply)	40 CFR 265.32
	Adequate aisle space must be maintained for movement of personnel, fire equipment, and related activities	40 CFR 265.35
	A Contingency Plan for the facility must be prepared and maintained	40 CFR 265, Subpart D

Table L-3. RCRA pre-transport requirements.

Package the waste in accordance with the pertinent U.S. DOT regulations on packaging set forth in 49 CFR Parts 173, 178, and 179	40 CFR 262.30
Label each package in accordance with the pertinent DOT regulations on hazardous materials set forth in 49 CFR Part 172	40 CFR 262.31
Mark each package of hazardous waste pursuant to DOT regulations on hazardous materials set forth in 49 CFR Part 172	40 CFR 262.32
Placard or offer the initial transporter the appropriate placards pursuant to DOT regulations in 49 CFR Part 172, Subpart F, prior to transporting hazardous waste or offering hazardous waste for transportation off site	40 CFR 262.33

Annex L**L.1.3. The Clean Water Act**

The Clean Water Act consists of two major parts. The first part involves provisions that authorize Federal financial assistance for construction of municipal sewage treatment plants. The second part is the regulatory requirements that apply to industrial and municipal dischargers.

Before 1987, programs were primarily directed at point source pollution (wastes discharged from discrete sources, such as pipes and outfalls). Amendments in 1987 authorized measures to address nonpoint source pollution (storm water runoff from farm lands, forests, construction sites, and urban areas).

Under this Act, Federal jurisdiction is broad, particularly regarding establishment of national standards or effluent limitations. Certain responsibilities are delegated to the states for day-to-day activities of implementation and enforcement. To achieve its objectives, the Clean Water Act embodies the concept that all discharges of pollutants into the nation's waters are unlawful, unless specifically authorized by a permit, which is the Act's principal enforcement tool. The law has civil, criminal, and administrative enforcement provisions.

The Clean Water Act requires the EPA to establish effluent limitations for the amounts of specific pollutants that may be discharged by municipal sewage plants and industrial facilities. The two-step approach to setting the standards includes: (1) establishing a nationwide, base-level treatment through an assessment of what is technologically and economically achievable for a particular industry, and (2) requiring more stringent levels of treatment for specific plants if necessary to achieve water-quality objectives for the particular body of water into which that plant discharges. For example, the EPA sets limits based on water quality to control pollution in waters designated by the states for drinking, swimming, or fishing.

The primary method by which the act imposes limitations on pollutant discharges is the nationwide permit program established under Section 402 of the Clean Water Act and referred to as the National Pollutant Discharge Elimination System (NPDES) (33 U.S.C.A. §1342). Under the NPDES program, any person responsible for the discharge of a pollutant or pollutants into any waters of the U.S. from any point source must apply for and obtain a permit.

All facilities that discharge wastewaters to either a surface water body or a POTW must comply with the Clean Water Act. Facilities that directly discharge wastewaters must obtain an NPDES permit [33 U.S.C.A. §1342(a)]. This permit specifies the discharge standards and monitoring and reporting requirements that the facility must achieve for each point source or outfall.

Facilities that discharge to a municipal or publicly owned wastewater system do not have to obtain an NPDES permit, but they must follow the pretreatment regulations (33 U.S.C.A. §1317). Pretreatment regulations require that industrial dischargers remove or treat all pollutants that could pass through the municipal system untreated or could adversely affect the performance of the municipal system. Toxic pollutants are the primary concern of these regulations. Facilities must also follow regulations established by the municipal or publicly owned wastewater system

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operators, which may include obtaining a permit to discharge to the system, discharge parameters, or other requirements.

L.2. Waste-Related Implications of the *National Response Framework*

The overall response to a CWA or TIC attack, including the regulatory structure, will be affected by the *National Response Framework* (NRF). Airport facility personnel will have direct input from and support of Federal, state, and local officials through a temporary field office located at, or proximal to, the airport facility. Federal, state, and local officials can bring to bear vast amounts of resources, personnel, and equipment to assist facility personnel in the response effort.

The NRF is the Federal Government's comprehensive plan for managing domestic incidents, such as terrorist attacks. In part, it establishes a framework for Federal agencies to coordinate their response and explains how Federal agencies will coordinate with state and local governments and the private sector. The NRF distinguishes between incidents that can be responded to by state and local officials, with the Federal government serving in a support role, and those that involve a Governor's request for Federal assistance, with the Secretary of Homeland Security managing the Federal response as the principal Federal official.

Response to a release of oil or hazardous materials under the NRF is addressed by the NRF's Emergency Support Function (ESF) #10—Oil and Hazardous Materials Response Annex. In general, for releases at an airport facility, the EPA will be the primary Federal agency for ESF #10 actions. Hazardous materials addressed under ESF #10 include chemical weapons of mass destruction, whether accidentally or intentionally released. ESF #10 directs that responses to the release of hazardous materials be conducted under the National Contingency Plan (NCP) process. Emergency repair of damaged infrastructure and critical facilities, including removal of contaminated and uncontaminated debris from roads, demolished buildings, or damaged structures, is addressed by the NRF's Emergency Support Function (ESF) #3—Public Works and Engineering Annex. The DOD/USACE is the primary agency assigned to response activities under ESF #3. The management of contaminated debris is coordinated with ESF #10. In general, the NCP contemplates wastes generated as a result of hazardous waste response actions to be handled under ESF #10. However, depending on site-specific circumstances and coordination between the EPA and DOD/USACE, either agency may take the lead on removing contaminated debris.

The NCP process has been promulgated pursuant to CERCLA and the Clean Water Act and established a process to address releases of hazardous materials. Under the NCP, coordination is carried out through the National Response System provided in the NCP, including the National Response Team (national planning and response coordination), the Regional Response Team (deploys regional resources and provides assistance and advice), and the On-Scene Coordinator (OSC). The NRF in ESF #10 indicates these NCP teams coordinate and operate in the NRF structure.

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As described in Section L.1.1, the NCP process provides for two types of responses to releases of hazardous materials: removal or remedial actions. Under the NCP, the most likely form of response to a CWA or TIC attack at an airport would be removal actions, which are used for early responses. Removal actions respond to an immediate release or threat of a release of hazardous substances. They are distinct from remedial actions in that removal actions mitigate or stabilize an immediate threat at a site. Removal actions are categorized as emergency (immediate), time-critical (action to be taken in less than 6 months), or non-time-critical (action to be taken in greater than 6 months) on the basis of the urgency and threat of the release. Most removal actions related to a release of chemical agents at an airport would likely be classified as emergency removal actions. Emergency removal actions are streamlined to quickly address the immediate nature of the threat. Documentation of emergency removal actions under the NCP occurs after the action has taken place. In accordance with Section 300.415(I) of the NCP, onsite removal actions conducted under CERCLA must meet applicable or relevant and appropriate requirements (ARARs) under federal or state environmental statutes or regulations to the extent practicable and considering the exigencies of the situation. The NCP identifies two factors that should be considered in determining whether identifying and complying with ARARs is practicable: (1) urgency of the situation, and (2) scope of the removal action. The NCP provides waivers of ARARs under certain circumstances.

The NCP provides that actions performed onsite are not required to obtain permits. The term “onsite” is defined as “the areal extent of contamination and all suitable areas in very close proximity to the contamination necessary for implementation of the response action” [40 CFR 300.400(e)]. The NCP requires actions conducted onsite to comply with the substantive state and Federal requirements. These provisions reflect CERCLA provisions that exempt onsite response action from state and Federal permits [42 U.S.C.A. §9621(e)]. CERCLA and the NCP offer such relief to respond quickly to emergencies. Releases at an airport facility that are responded to through the NCP process would not require Federal, state, or local permits (such as a RCRA permit for treatment and decontamination procedures).

L.3. Assumptions for Regulatory Determinations Regarding Waste

Regulatory determinations regarding waste characterization, and further waste management and disposal requirements, are case-by case-determinations. In an actual event, such determinations will be made by response personnel along with Federal and state regulatory agencies. To provide a context in which to make regulatory determinations regarding waste and for purposes of illustration in this guidance document, the following assumptions apply concerning the nature of remediation activities at an airport:

1. Decontamination wastes will include materials such as spent decontamination fluids, PPE, cleaning materials used in the decontamination process (e.g., rags and mops), and items found in an airport that will be disposed and not reused. Potential waste items could include decontaminated airport furniture, passenger luggage, computers, upholstery, carpet, drywall, and the like. This Annex does not analyze the disposal of facility

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components that would be considered hazardous waste in and of itself, such as items that contain PCBs, asbestos, or building components that, when disposed, would be considered hazardous waste absent contamination by a CWA or TIC.

2. Wastes will not include any pure CWAs or TICs. Any pure agent or undispersed CWA or TIC from a failed device will be addressed and removed as part of initial emergency response.
3. All airport items that are to be disposed will be decontaminated prior to offsite disposal to eliminate any potential for cross-contamination of agent to previously unexposed areas, eliminate potential for secondary source production, reduce agent exposure to decontamination workers, and facilitate waste handling and transportation.
4. Decontamination will be performed until all CWAs or TICs have been reacted to completion; however, in an actual event, it may not be practical, necessary, or cost-effective to sample some waste items to a level that ensures that no residual agent remains in an item.
5. Potentially toxic CWA or TIC degradation products will be neutralized or reacted to nontoxic degradates by decontamination procedures.
6. All decontamination waste streams will be contained until treatment and monitoring can ascertain that the waste streams are not toxic to personnel or the environment from the presence of unreacted agent, excess bleach, or the like.
7. Likely decontamination methods will include, but not be limited to, chlorine bleach solutions, chemical decontamination foam, modified vaporized hydrogen peroxide, and natural attenuation/hot air/steam.
8. A CWA or TIC terrorist attack on a major airport facility would invoke provisions of the NRF and all appropriate provisions of the NCP. All disposal activities will take place within existing environmental regulatory frameworks at state and Federal levels.

The regulatory analysis in this Annex corresponds only to a remediation effort that reflects the above assumptions. The assumptions were 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, considering the possibility of more stringent state regulations and with coordination of Federal, state, and local officials through the local JFO.

L.4. Regulation of CWA and TIC Waste Streams under RCRA

The following discussion addresses the regulation of waste streams from an airport decontamination activity under Federal regulations. Almost all states have adopted their own RCRA program and have obtained authorization from the EPA to operate the RCRA program in lieu of the EPA. Although the regulations of most states follow Federal regulations closely, some states have promulgated and implemented regulations that are more stringent than the Federal

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program. As part of pre-incident planning for a decontamination effort, the owner or operator of an airport facility must consult state-specific regulations and appropriate state agencies regarding pertinent waste-related requirements.

L.4.1. Origin of the Waste Stream (Disposal versus Reuse)

During an airport remediation, some materials and structural components are likely to be decontaminated for reuse in the facility, whereas other materials may be removed from the facility for decontamination and subsequent disposal. In general, materials that will be decontaminated and reused in the facility will not qualify as solid waste or hazardous waste.

Spent decontamination fluids or materials, carpet, furniture, computers, telephone sets, and other facility components that are discarded and not reused would need to be managed and disposed of as waste. Residuals of decontamination solutions that remain on airport surfaces or materials would not be considered 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 those items that qualify as solid waste, the generator requirements under RCRA would be triggered, requiring a determination to be made as to whether or not the solid waste also qualifies as hazardous waste (40 CFR 264.11).

L.4.2. Characterizing Waste Streams from the Decontamination Technologies

One of the primary waste streams from decontamination efforts will be the spent decontamination solution or material used to implement the decontamination activity. If the spent solution is in liquid form and treated and disposed of by discharge to a POTW or to a waterway, the discharges will be regulated by the Clean Water Act (see the Clean Water Act, below).

Four decontamination methods are recommended for use in decontaminating an airport facility, as outlined in Annex F. They are:

- Bleach solutions in water.
- Sandia Decontamination Foam Technology (DF-200).
- Modified vaporous hydrogen peroxide (mVHP®).
- Natural attenuation/hot air/steam.

Spent decontamination solution, PPE, carpet, furniture, computers, telephones, and other facility components disposed of by transfer to a landfill or other non-Clean Water Act treatment facility are regulated, depending on the classification as a hazardous or nonhazardous waste, on the bases of characterization determined by monitoring. If waste does not meet the classifications of a hazardous waste, it is considered a nonhazardous waste or solid waste. Thus, the first step in classifying waste is to determine if it is RCRA hazardous waste (either listed or characteristic waste).

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L.4.2.1. Listed Waste

The first determination in characterizing a waste stream is whether or not the waste is a listed waste. None of the decontamination materials or CWAs considered in this guidance document are listed wastes at the Federal level. However, some of the TICs considered by this analysis are P-listed wastes. Hydrogen cyanide, cyanogen chloride, and phosgene are all listed as RCRA hazardous wastes and carry the waste codes P063, P033, and P095, respectively. Regardless of the fact that decontamination technologies will have neutralized the chemical, spent decontamination waste streams from remediation of these three TICs would potentially be listed hazardous wastes. P-listed wastes apply to commercial chemical products that are discarded or spilled in essentially pure form. However, in the event of a TIC release as a result of a terrorist attack, it is unlikely that a TIC 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, contaminant, or waste is not a listed hazardous waste. In the context of an airport remediation where information is inconclusive or unavailable to make a listed waste determination, the EPA allows the facility owner/operator to assume that the source, contaminant, or waste is not a listed waste. This approach was first articulated in the proposed and final NCP rulemaking and most recently in EPA guidance (see, 53 FR 51444, December 21, 1988 for proposed NCP preamble discussion; 55 FR 8758, March 13, 1990 for final NCP preamble discussion; and EPA Guidance *Management of Remediation Wastes under RCRA*, EPA Office of Solid Waste and Emergency Response, EPA530-F-98-026, October 1998). Therefore, when information needed to make a listed waste determination is unavailable, waste streams from airport remediation of the three TICs would not be classified as listed hazardous waste.

L.4.2.2. Characteristic Waste

L.4.2.2.1. Spent Decontamination Solution or Material

Bleach solution in water could be considered a RCRA hazardous waste by exhibiting one of the hazardous waste characteristics. As discussed above, all CWAs and TICs involved in an attack are assumed to be completely reacted by the decontamination process, and the level of reaction will be monitored. However, bleach solution itself would be considered to exhibit the characteristic of corrosivity if the spent bleach solution pH is less than 2 or greater than 12.5. However, once the solution is treated to adjust the pH (to >2 but <12.5), the characteristic will have been removed, and the waste would no longer be 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 expected the Sandia Decontamination Foam residues would not exhibit any characteristics of hazardous waste after completely neutralizing a CWA or TIC.

The hydrogen peroxide part of the modified vapor hydrogen peroxide (mVHP®) technology decomposes to water and oxygen. Therefore, any recovered residues would not exhibit a hazardous waste characteristic. However, the modified process that is recommended also uses

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ammonia. It is not expected that the ammonia component of the modified process would result in decontamination residuals exhibiting a hazardous waste characteristic; however, standard waste-stream monitoring should be used 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 that would be recovered is condensate or runoff from steam. Assuming that the CWA or TIC has been fully reacted, the recovered steam would not exhibit any hazardous waste characteristic. Natural attenuation or hot air itself would not produce any waste stream from the decontamination technology; however, the exhausted air would likely be filtered during decontamination. Spent filters are not expected to exhibit a hazardous waste characteristic, but as a precaution, used filters should be either monitored or decontaminated before disposal. For all residual liquid waste streams, monitoring is recommended to ensure any recovered decontamination waste stream does not exhibit any characteristics of RCRA hazardous waste.

L.4.2.2.2. PPE, Carpet, Furniture, Computers, Telephones, and Other Facility Components

Following decontamination, facility components would only be considered hazardous waste 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. As discussed above, none of the CWAs is considered a hazardous listed waste at the Federal level, and any TIC-related waste is likely to be assumed as not meeting the hazardous waste listing. After decontamination, facility components previously contaminated with CWAs or TICs will also not exhibit any hazardous waste characteristic. Of the decontamination technologies considered in this *Remediation Guidance*, only bleach solution has a hazardous characteristic (corrosivity). However, after decontamination, any bleach solution remaining on an item would not be likely to retain a pH sufficient to be considered corrosive. For a summary of preliminary decontamination waste classifications see Table 3-3 of this *Remediation Guidance*.

L.4.3. Disposal as Nonhazardous Waste

Regulation of nonhazardous solid wastes is primarily the responsibility of the individual states. Federal regulation has been limited to establishing minimum criteria for solid waste disposal facilities. Criteria for classifying solid waste disposal facilities and practices are established in 40 CFR 257, Subtitle D. Direct implementation of the minimum nationwide standards outlined in Subtitle D remains a state and local function.

With respect to wastes from airport decontamination, the decision to accept solid waste that has been declared nonhazardous by the proper decision-making authorities is ultimately up to the individual Subtitle D landfill. Landfills have a considerable invested interest in the wastes they accept. Because of the unique nature of wastes potentially derived after a CWA attack, discussions with likely disposal facilities during the pre-planning stages are crucial to efficiently remediate an airport facility after a chemical attack. TICs do not generally cause the same types

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of concerns because public and private sectors have had considerable experience in dealing with TIC-contaminated materials.

For solid wastes disposed of as a result of an airport decontamination event, the wastes would need to be transferred to an approved solid waste landfill or other solid waste disposal facility. The type of facility appropriate for decontamination wastes and waste-handling procedures are controlled by state regulations governing solid wastes. A few states have promulgated regulations that differentiate solid wastes on the basis of the level of threat a solid waste poses after disposal in a municipal waste landfill.

L.5. Disposal Under the Clean Water Act

Disposal of recovered decontamination solutions and materials (e.g., bleach solution or Sandia Decontamination Foam) or rinse waters may take place either to a sewer (a POTW, see Table L-4) or to a surface water body if prerequisites for such discharges can be met. Clean Water Act discharges to a POTW or surface water body under an NPDES permit are exempted as hazardous wastes under RCRA [40 CFR 261.4(a)(1); 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. On the basis of such prohibitions, the bleach in water solution would potentially require adjustment of pH before being discharged to a sewer.

Decontamination solution that is to be discharged to a surface water body will be regulated by the NPDES discharge program. As for RCRA, most states have adopted regulations and have been authorized by the EPA to operate the NPDES program in lieu of the EPA. The NPDES program requires all dischargers to obtain a permit and meet effluent limitations prior to discharge with the objective of maintaining surface water criteria. Requirements for such discharges are based on the specific classification and criteria of the particular receiving body and on the characteristic of the discharge determined on a case-by-case basis. A permit would be required for a discharge to a surface water body under the NPDES discharge program because the discharge from a remediation effort would be considered an offsite action.

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Table L-4. Pretreatment requirements prior to discharge to a POTW.

Requirements	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 in 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 <5.0) pollutants	40 CFR 403.5(b)
	Discharges that obstruct flow, or discharges at a flow rate or concentration that result in interference	40 CFR 403.5(b)
	Increase of the temperature of wastewater entering the treatment plant, which result in interference, but in no case raise 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 in a quantity that may cause acute worker safety problems	40 CFR 403.5(b)

L.6. Issues under the Clean Air Act

An airport facility will take measures during response and remediation to contain any released CWA or TIC and reduce its spread. After remediation is complete, the CWA or TIC will be neutralized such that any releases following remediation will be minimal. Any vapor releases outside a facility during the event will likely be at an insignificant level and would not be directly regulated under the Clean Air Act.

L.7. State-Specific Regulatory Schemes

California and Utah were selected as examples of the impact of state regulations on chemical remediation efforts. California is included as an example state because of the location of LAX. The largest U.S. domestic CWA munitions stockpile is located outside Salt Lake City, Utah, and regulatory precedents exist there. All CWAs are represented in this repository and have been addressed by state regulators in policy and statute. Both California and Utah are good examples of how wastes are regulated for disposal. The regulatory schemes of these two states highlight considerations that must be accounted for in monitoring to ensure that waste acceptance criteria at various facilities are met.

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L.7.1. California

For those California environmental regulations that would be applicable to remediation following a chemical attack at an airport facility, California environmental regulations in general reflect the Federal regulations discussed above. However, California RCRA regulations contain several additional categories of characteristic hazardous waste. California hazardous waste regulations also contain a separate list of chemicals that are presumed to be hazardous waste (22 CCR, Annex X). Table L-5 shows the additional provisions applicable to decontamination treatment residues and discarded components from an airport facility.

Solid waste regulations in California are more stringent than comparable Federal minimum standards for solid waste landfills. In California, solid waste facilities fall into several classes; some are more robust in design based on the types of wastes a facility can accept. Testing would need to occur on a waste in question to determine if it is considered to be a designated waste (with potential to leach constituents above the applicable water quality standard) and if the waste could meet a particular disposal facility's waste acceptance criteria. Table L-6 identifies the types of solid waste in California and the types of facilities that can accept those wastes. As part of any pre-planning effort, solid waste facilities that could accept potential CWA decontamination solid wastes should be identified. A facility's waste acceptance criteria should be evaluated, and related issues resolved, in advance.

A major distinction in California is the regulation of surface water and groundwater. In California, water quality for both groundwater and surface water is regulated by the State Water Resources Control Board (SWRCB) and nine Regional Water Quality Control Boards (RWQCBs), each regulating a separate geographical region of the state. The SWRCB develops and issues statewide requirements for water quality. SWRCB requirements for water quality are published in resolutions that are promulgated in the same manner as a regulation and carry the same enforceability as a legal requirement in state regulations. Each RWQCB regulates through the promulgation of Water Quality Control Plans (also known as Basin Plans) and adoption of resolutions for their specific region. The Basin Plans establish water quality standards for groundwater and surface water specific for each region. The nine individual regions reflect the state as separated by the major drainage divides. The nine regions are shown in Figure L-1. For any planned discharges to California surface water, the appropriate regional board and appropriate regional Basin Plan should be consulted for applicable requirements.

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Table L-5. California's additional hazardous waste classifications.

Additional California Hazardous Waste Characteristics	Implications
Corrosivity: it is not aqueous and, when mixed with an equivalent weight of water, produces a solution having a pH ≤ 2 or $\geq 12.5^a$ [22 CCR § 66261.22(a)(3)]	For the six CWAs and three TICs considered in this <i>Remediation Guidance</i> , and from the assumptions listed in Section L.3, none of the spent decontamination materials or PPE and building waste arising from remediation should meet the parameters of the additional California characteristic wastes. However, determination should be made on a case-by-case basis through sampling and analysis of wastes streams. If the CWA waste stream is not decontaminated, it could exhibit the hazardous waste characteristic of toxicity under California definitions.
Corrosivity: it is not a liquid and, when mixed with an equivalent weight of water, produces a liquid that corrodes steel (SAE 1020 ^b) at a rate greater than 6.35 mm (0.250 in.) per year at a test temperature of 55°C (130°F) ^c [22 CCR § 66261.22(a)(4)]	
Toxicity: it contains the inorganic or organic substances listed in the regulations at a concentration that equals or exceeds the listed TTLC or STLC values for such substance ^d [22 CCR § 66261.24(a)(2)]	
Toxicity: has an acute oral LD ₅₀ <2500 mg/kg [22 CCR § 66261.24(a)(3)]	
Toxicity: has an acute dermal LD ₅₀ <4300 mg/kg [22 CCR § 66261.24(a)(4)]	
Toxicity: has an acute Inhalation LC ₅₀ <10,000 ppm as gas or vapor [22 CCR § 66261.24(a)(5)]	
Toxicity: has an acute aquatic 96-hr LC ₅₀ <500 mg/L ^e [22 CCR § 66261.24(a)(6)]	
Toxicity: contains any of the organic substances listed ^f in the regulations at a single or combined concentration $\geq 0.001\%$ by wt. [22 CCR § 66261.24(a)(7)]	
Toxicity: it has been shown through experience or testing to pose a hazard to human health or environment because of its carcinogenicity, acute toxicity, chronic toxicity, bioaccumulative properties, or persistence in the environment [22 CCR § 66261.24(a)(8)]	

^a Determined by a pH meter using either Method 9040 in "Test Methods for Evaluating Solid Waste, Physical/Chemical Methods," SW-846, 3rd edition and updates, or an equivalent test method approved by the California EPA, Department of Toxic Substances Control, pursuant to 22 CCR §66260.21.

^b SAE 1020 is Society of Automotive Engineers grade-1020 steel. Metallurgists (metal experts) recognize that this code means a simple alloy of iron and carbon that contains 0.20 percent by weight of carbon.

^c As determined by the test method specified in NACE Standard TM-01-69 as standardized in "Test Methods for Evaluating Solid Waste, Physical/Chemical Methods," SW-846, 3rd edition and updates or an equivalent test method approved by the California EPA, Department of Toxic Substances Control pursuant to 22 CCR §66260.21.

^d 22 CCR §66261.24(a)(2) lists 20 inorganic and 18 organic substances (considered persistent and bioaccumulative toxic substances) along with their associated Soluble Threshold Limit Concentrations (STLC) and Total Threshold Limit Concentrations (TTLC). If the waste extract (in mg/L) using the Waste Extraction Test (WET) as described in Annex II of the regulation equals or exceeds the listed STLC, the waste is considered to exhibit the characteristic of toxicity and thus a hazardous waste. If a representative sample of the waste (in mg/kg) equals or exceeds the listed TTLC, the waste would also be considered to exhibit the characteristic of toxicity and thus a hazardous waste.

^e When measured in soft water (total hardness 40 to 48 mg/L of calcium carbonate) with fathead minnows, rainbow trout, or golden shiners according to procedures described in Part 800 of the "Standard Methods for the Examination of Water and Wastewater (16th edition)," American Public Health Association, 1985, and "Static Acute Bioassay Procedures for Hazardous Waste Samples," California Department of Fish and Game, Water Pollution Control Laboratory, revised November 1988, or by other test methods or test fish approved by the California EPA, Department of Toxic Substances Control, using test samples prepared or meeting the conditions for testing as prescribed in subdivisions (c) and (d) of Annex II of the regulations, and solubilized, suspended, dispersed, or emulsified by the cited procedures or by other methods approved by the Department.

^f Listed organic substances are: 2-acetylaminofluorene (2-AAF); acrylonitrile; 4-aminodiphenyl; benzidine and its salts; bis (chloromethyl) ether (BCME); methyl chloromethyl ether; 1, 2-dibromo-3-chloropropane (DBCP); 3, 3'-dichloro-benzidine and its salts (DCB); 4-dimethylaminoazobenzene (DAB); ethyleneimine (EL); alpha-naphthylamine (1-NA); beta-

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naphthylamine (2-NA); 4-nitrobiphenyl (4-NBP); N-nitrosodimethylamine (DMN); beta-propiolactone (BPL); and vinyl chloride (VCM).

Table L-6. Prescribed facilities for California solid wastes.

Designated wastes ^a	Class I or Class II
Nonhazardous wastes that do not qualify as designated waste	Class I, Class II, or Class III facility.
Inert wastes ^b	No particular designated facility

^a Wastes that are nonhazardous but contain pollutants, which when placed in a waste management unit could leach pollutants in concentrations that exceed applicable water-quality objectives or uses, are considered designated waste and must be sent to a Class I or II facility (27 CCR §20210).

^b Wastes that do not contain hazardous waste, designated waste, or significant quantities of decomposable wastes may qualify as inert waste that is not required to be sent to a Class I, II, or III facility (27 CCR § 20230).

North Coast Region (Region 1)
 San Francisco Bay Region (Region 2)
 Central Coast Region (Region 3)
 Los Angeles Region (Region 4)
 Central Valley Region (Region 5)
 Lahontan Region (Region 6)
 Colorado River Basin Region (Region 7)
 Santa Ana Region (Region 8)
 San Diego Region (Region 9)

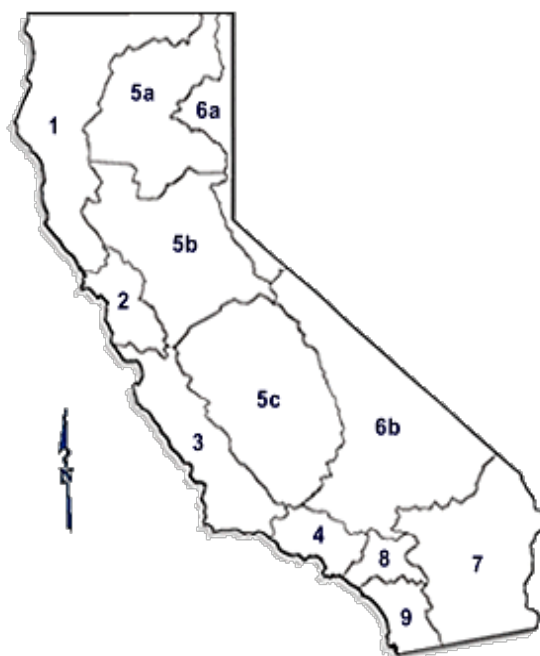


Figure L-1. The nine RWQCBs, each regulating a separate geographical region of California.

L.7.2. Utah

Environmental regulations in Utah that would affect remediation efforts following a chemical event at an airport facility primarily involve Utah's RCRA hazardous waste regulations. Like all other states, Utah has its own solid waste regulations. Utah is one of a few states that has added listed classifications in the RCRA regulations for discarded CWAs and residues from treatment

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of CWAs. Like most other states that do have such classifications, the listings have been added by Utah as a result of Department of Defense CWA treatment and disposal facilities located in the state (specifically, the Tooele Chemical Agent Disposal Facility located in Tooele, UT). Utah adds two listed hazardous waste classifications, as shown in Table L-7. The classifications alter the RCRA hazardous waste characterization results that would occur under Federal regulations.

Table L-7. Utah-specific listed hazardous waste (more stringent than Federal requirements).^a

	Tabun (GA) Sarin (GB) Soman (GD) Cyclosarin (GF) VX Sulfur mustard (HD)	
Added Utah Listed Wastes	Decontam- ination Materials	PPE and Building Waste
F-coded hazardous waste from nonspecific source [Utah Rule R315-2-10(e)(1); R315-50-9] ^b F999 Residues from demilitarization, treatment, and testing of nerve, military, and chemical agents CX, GA, GB, GD, H, HD, HL, HN-1, HN-2, HN-3, HT, L, T, and VX. (R,T,C,H)	Listed Hazardous Waste F999	Listed Hazardous Debris F999
P-coded discarded commercial chemical products [R315-2-11(e)(1)] P999 nerve, military, and chemical agents (CX, GA, GB, GD, H, HD, HL, HN-1, HN-2, HN-3, HT, L, T, and V)	Listed Hazardous Waste P999	Listed Hazardous Debris P999

^a Utah waste classifications are not reflected in Federal regulations. Under Federal regulations, these decontamination wastes would not be considered “listed” wastes. See Table 3-3 for a summary of waste classifications under Federal requirements.

^b The Utah Department of Environmental Quality (DEQ), Division of Solid and Hazardous Waste, Chemical Demilitarization Section representative indicates that the F-listing and P-Listing do not depend on the source of the chemical agent. Identified chemical agents from nonDOD sources are also covered by the listing. According to Utah DEQ representative, waste generated from decontamination activities would be considered waste from treatment activities, and the F999 waste code would apply.

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Many of the agents considered nonhazardous under Federal regulations are listed hazardous waste under Utah regulations. However, as discussed in Section L.1.2.2, for those wastes meeting the definition of hazardous debris, the hazardous wastes may exit hazardous waste regulation after treatment.

Utah regulates the disposal of solid waste in several classes of disposal facilities. The classes are not primarily distinguished by the type of waste or threat posed by the waste. Multiple classes of facilities in Utah could potentially accept CWA decontamination solid wastes. It is likely that a facility would be selected on the basis of its location and the ability of a particular waste stream to meet that facility's waste acceptance criteria. Determinations would need to be made on a case-by-case basis. Table L-8 summarizes the classes of solid waste facilities in Utah.

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Table L-8. Utah solid-waste facility classifications.

Class of Landfill	Description	Waste Type
Class I	Noncommercial or solely under contract with a local government taking municipal solid waste	Municipal solid waste Any other nonhazardous waste RCRA conditionally exempt waste from a small-quantity generator of hazardous waste that is in conjunction with municipal solid waste or other nonhazardous waste
Class II	Noncommercial or solely under contract with a local government taking municipal solid waste that receives 20 tons or less of solid waste per day	Municipal solid waste Any other nonhazardous waste RCRA conditionally exempt waste from a small-quantity generator of hazardous waste that is in conjunction with municipal solid waste or other nonhazardous waste
Class IIIa	Industrial solid waste landfill not open to the public	Any nonhazardous industrial waste Waste that is exempt from the RCRA hazardous waste regulations RCRA conditionally exempt waste from a small-quantity generator of hazardous waste
Class IIIb	Industrial solid waste landfill not open to the public	Any nonhazardous industrial waste except (1) certain specified wastes that are exempt from hazardous waste regulations and (2) RCRA conditionally exempt waste from a small-quantity generator of hazardous waste
Class IV	Noncommercial landfill	Construction and demolition waste Yard waste Inert waste Dead animals Wastes tires Petroleum-contaminated soils
Class V	Commercial nonhazardous solid waste disposal facility	Municipal solid waste Any other nonhazardous waste RCRA conditionally exempt waste from a small-quantity generator of hazardous waste that is in conjunction with municipal solid waste or other nonhazardous waste
Class VI	Commercial nonhazardous solid waste disposal facility	Construction and demolition waste Yard waste Inert waste Dead animals Wastes tires Petroleum-contaminated soils Cannot receive: Hazardous waste Construction and demolition waste containing PCBs Garbage Municipal solid waste Industrial solid waste As further limited by permit

Annex L**L.8. Annex L References**

EPA (2004), U.S. Environmental Protection Agency, *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*, EPA Publication SW-846, EPA Office of Solid Waste and Emergency Response; available at: <http://www.epa.gov/epaoswer/hazwaste/test/main.htm>

DHS (2008), Department of Homeland Security, *National Response Framework*; documents available at <<http://www.fema.gov/emergency/nrf/>>.