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Remediation Guidance for Major Airports After a Chemical Attack

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California Department of Public Health

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List of Acronyms

A2LA	American Association for Laboratory Accreditation
AAMP	Ambient Air Monitoring Plan
AC	hydrogen cyanide (also referred to as HCN)
ACAMS	Automatic Continuous Air Monitoring System
ACGIH	American Conference of Governmental Industrial Hygienists
ACH	air changes per hour
AEGL	Acute Exposure Guideline Level
AEL	airborne exposure limit
AFJM	Air Force Joint Manual
AHU	air handling unit
AIHA	American Industrial Hygiene Association
ARAR	Applicable or relevant and appropriate
ATP	adenosine triphosphate
ATSDR	Agency for Toxic Substances and Disease Registry
BAL	bronchoalveolar lavage
B. anthracis	*Bacillus anthracis*
BIT	binary ionization technology
BROOM	Building Restoration Operations Optimization Model (software)
BWA	biological warfare agent
CAA	Clean Air Act
CAM	chemical agent monitor
CARC	chemical agent resistant coating
CAS	Chemical Abstracts Service
CASCAD	Canadian Aqueous System for Chemical–Biological Agent Decontamination (a foam)
CDC	Centers for Disease Control and Prevention
CEEL	community emergency exposure level
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980.
CF	Canadian Forces
CFR	Code of Federal Regulations
CG	phosgene
CK	cyanogen chloride
COC	chain of custody
CONOPS	concept of operations
CPR	cardiopulmonary resuscitation
CSEPP	Chemical Stockpile Emergency Preparedness Program
CSM	conceptual site model
CST	(National Guard) Civil Support Team
CT	concentration × time value

List of Acronyms

CTEH	Center for Toxicity and Environmental Health
CTX	baggage-screening equipment
CUP	Central Utilities Plant (at LAX)
CWA	chemical warfare agent
DA	U.S. Department of the Army
DAAMS	Depot Area Air Monitoring System
DF-200	Sandia National Laboratories decontamination foam
DHHS	Department of Health and Human Services
DHS	Department of Homeland Security
d.l.	detection limit
DOD	Department of Defense
DOE	Department of Energy
DOT	Department of Transportation
DQO	data quality objectives
DRDC	Defense Research and Development Canada
ECBC	Edgewood Chemical and Biological Center (U.S. Department of the Army)
EOC	Emergency Operations Center
EPA	U.S. Environmental Protection Agency
EPA ETV	Environmental Protection Agency's Environmental Technology Verification Program
ERDEC	Edgewood Research Development and Engineering Center
ERLN	Environmental Response Laboratory Network (EPA)
ERPG	Emergency Response Planning Guideline
ERRS	Emergency Rapid Response Services
ESF	Emergency support function
ESI	electrospray ionization
EU	Environmental Unit (a unit of the Planning Section of a Unified Command)
FAA	Federal Aviation Administration
FBI	Federal Bureau of Investigation
FEMA	Federal Emergency Management Agency
FAA/CASFO	Federal Aviation Administration/Civil Aviation Security Field Office
FID	flame ionization detector
FOSC	Federal On-Scene Coordinator (EPA)
FPD	flame photometric detector
FS	Feasibility Study
GA	chemical warfare nerve agent tabun
G agents	chemical warfare nerve agents tabun, sarin, soman, and cyclosarin
GB	chemical warfare nerve agent sarin
GC	gas chromatography
GC/FPD	gas chromatograph/flame photometric detector
GC/MS	gas chromatograph/mass spectrometric detector

List of Acronyms

GD	chemical warfare nerve agent soman
GF	chemical warfare nerve agent cyclosarin
GPL	general population limit
HASP	Health and Safety Plan
HazMat	hazardous materials
HBESL	health-based environmental screening level
HCN	hydrogen cyanide
H	sulfur mustard formulation containing impurities
HD	distilled (purified) sulfur mustard
HTH	high-test hypochlorite (calcium hypochlorite)
HMTA	Hazardous Materials Transportation Act
HSOC	Homeland Security Operations Center
HVAC	heating, ventilation, and air conditioning
IAP	Incident Action Plan
IATA	International Air Transport Association
ICAO	International Civil Air Organization
IC	Incident Command
ICP	Incident Command Post
ICS	Incident Command System
IDL	instrument detection limit
IDLH	immediately dangerous to life or health
IITRI	Illinois Institute of Technology Research Institute
IMAAC	Interagency Modeling and Atmospheric Assessment Center
IMDC	International Maritime Dangerous Goods
IMS	ion mobility spectrometer (or spectrometry)
IMT	Incident Management Team
INS	Incident of National Significance
IO	Information Officer
IR/FTIR	infrared/Fourier transform infrared spectroscopy
IRIS	Integrated Risk Information System (EPA)
JFO	Joint Field Office
JIC	Joint Information Center
JOC	Joint Operations Center
JRIC	Joint Regional Intelligence Center
JSOR	Joint Service Operational Requirement
JSSED	Joint Service Sensitive Equipment Decontamination
JTTF	Joint Terrorism Task Force
LAFD	Los Angeles Fire Department
LAPD	Los Angeles Police Department
LAWA	Los Angeles World Airports

List of Acronyms

LAWA PD	Los Angeles World Airports Police Department
LAX	Los Angeles International Airport
LC	liquid chromatography
LDR	Land disposal restriction
L-Gel	Lawrence Livermore National Laboratory decontamination gel
LLNL	Lawrence Livermore National Laboratory
LOAEL	lowest adverse effect level
LOD	limit of detection
MACT	Maximum achievable control technology
MCL	maximum contaminant level
MDL	method detection limit
MINICAMS®	MINIature Chemical Agent Monitoring System
MPDS	multi-purpose decontamination systems
MS	mass spectrometer
MSDS	Material Safety Data Sheet
mVHP®	modified vaporous hydrogen peroxide
NAA	Nonattainment area
NAAQS	National Ambient Air Quality Standard
NAC	National Advisory Committee (for Acute Exposure Guideline Levels for Hazardous Substances)
NAM	negative air machine
NAU	negative air unit, also known as negative air machine, or NAM
NCP	National Contingency Plan
NCTC	National Counterterrorism Center
NECD	Newport Chemical Depot
NESHAPs	National Emissions Standards for Hazardous Air Pollutants
NHSRC	National Homeland Security Research Center
NIOSH	National Institute for Occupational Safety and Health
NIMS	National Incident Management System
NIST	National Institute of Standards and Technology
NOAA	National Oceanographic and Atmospheric Administration
NOAEL	No observable adverse effect level
NOC	National Operations Center
NPDES	National Pollutant Discharge Elimination Program
NRC	National Research Council
NRF	*National Response Framework*
NRT	National Response Team
NSPS	New source performance standard
NTA	nontraditional agent
NWS	National Weather Service

List of Acronyms

OASA	Office of the Assistant Secretary of the Army
OES	Office of Emergency Services
OHS	Office of Homeland Security (California)
OPCW	Organisation for the Prohibition of Chemical Weapons
ORNL	Oak Ridge National Laboratory
OSC	On-Scene Coordinator (EPA)
OSHA	Occupational Safety and Health Administration
OTSG	Office of the Surgeon General (Army)
PA	Preliminary Assessment
PAL	Provisional Advisory Level
PEL	permissible exposure limit
PFO	Principal Federal Official
PID	photoionization detector
POTW	Publicly Owned Treatment Works
ppbv	part per billion volume
PPE	personal protective equipment
ppmv	part per million volume
PPRTV	provisional peer reviewed toxicity value
PRG	Preliminary Remediation Goal (model)
PUF	polyurethane foam
PVC	polyvinyl chloride
QAPP	Quality Assurance Project Plan
QASP	Quality Assurance Sampling Plan
QATT	Qualified Anti-Terrorism Technology
QA/QC	quality assurance and quality control
RAP	Remediation Action Plan
RBS	Risk-Based Concentration (model)
RCRA	Resource Conservation and Recovery Act
RfC	reference concentration
RfD	reference dose
RfD_{est}	estimated reference dose
RI	Remedial Investigation
ROD	Record of Decision
RRCC	Regional Response Coordination Center
RSL	regional screening level
RTAP	Real-Time Analytical Platform
RWQCB	Regional Water Quality Control Board
SAFETY (Act)	Support Anti-Terrorism by Fostering Effective Technologies Act
SAP	Sampling and Analysis Plan
SCDHEC	South Carolina Department of Health and Environmental Control

List of Acronyms

SDF™	Surface Decontamination Foam
SDME	single-drop microextraction
SI	site inspection
SIOC	Strategic Information and Operations Center (FBI)
SME	subject matter expert
SNL	Sandia National Laboratories
SPME	solid phase microextraction
SRCL	Surface removal contaminant level (guideline)
SSC	Scientific Support Coordinator
START	Superfund Technical Assistance and Response Team
STB	supertropical bleach
STE	Strategic Technologies Enterprises, Inc.
STEL	Short-term exposure limit
STTAC	State Terrorism Threat Assessment Center
SWRCB	State Water Resources Control Board
TBIT	Tom Bradley International Terminal (at LAX)
TCLP	Toxicity Characteristic Leaching Procedure
TEW	Terrorist Early Warning
TOCDF	Tooele Chemical Agent Disposal Facility
TOF	time of flight (refers to mass spectrometer)
TIC	toxic industrial chemical
TSA	Transportation Security Administration
TSWG	Technical Support Working Group (DOD)
TWA	time-weighted average
TWG	Technical Working Group
UC	Unified Command
USCA	United States Code Annotated
VPHP	vapor-phase hydrogen peroxide
VOC	volatile organic compound
VSP	Visual Sample Plan (software)
VX	chemical warfare nerve agent VX
WPL	worker population limit

Glossary

Refer to the Glossary references at the end of this section for the source of definitions identified as being derived from other publications, agencies, or authorities. All other terms in the list are defined according to their specific use in this *Remediation Guidance* document.

Acute Exposure Guideline Level (AEGL). AEGLs represent federally endorsed guidance criteria for the assessment and management of single-exposure emergency events, such as accidents or intentional terrorist attacks. AEGLs, published by the National Research Council Committee on Toxicology, are threshold airborne concentrations of a chemical in the air above which different health effects could begin to occur among members of the general public. Three levels, called AEGL-1, AEGL-2 and AEGL-3, for each of five exposure periods (10 min, 30 min, 1 hr, 4 hr, and 8 hr) are distinguished by varying degrees of severity of toxic effects, with level 3 being the more severe.

Agent. A chemical, physical, mineralogical, or biological entity that may cause deleterious effects in an organism after exposure to it (EPA 2002).

Agent GA. The chemical ethyl N,N-dimethylphosphoramidocyanidate, Chemical Abstracts Service (CAS) registry number 77-81-6, synonym = tabun. A nerve agent with chemical formula $C_5H_{11}N_2O_2P$.

Agent GB. The chemical isopropyl methylphosphonofluoridate, Chemical Abstracts Service (CAS) registry number 107-44-8, synonym = sarin. A nerve agent with chemical formula $C_4H_{10}FO_2P$.

Agent GD. The chemical pinacolyl methylphosphonofluoridate, Chemical Abstracts Service (CAS) registry number 96-64-0, synonym = soman. A nerve agent with chemical formula $C_7H_{16}FO_2P$.

Agent GF. The chemical O-cyclohexyl methylfluorophosphonate, Chemical Abstract Service (CAS) registry number 329-99-7, synonym = cyclosarin. A nerve agent with chemical formula $C_7H_{14}FO_2P$.

Agent H. Commonly known as sulfur mustard and less frequently referred to as Levinstein mustard. Chemical Abstracts Service (CAS) registry number 505-60-2. Agent H is a blister agent with a chemical formula of $C_4H_8Cl_2P$.

Agent HD. Distilled sulfur mustard, Chemical Abstracts Service (CAS) registry number 505-60-2. Agent HD is a blister agent with the chemical formula $C_4H_8Cl_2P$.

Agent VX. The chemical O-ethyl S-(diisopropylaminoethyl) methylphosphonthiolate, Chemical Abstracts Service (CAS) registry number 50782-69-9. Agent VX is a nerve agent with the chemical formula $C_{11}H_{26}NO_2PS$.

Glossary

Airborne Exposure Limit (AEL). A general term used by the Centers for Disease Control and Prevention (CDC) and the U.S. Army to refer to a set of exposure standards (concentrations expressed in mg/m^3 for various exposure frequencies and durations) that have been specifically developed for chemical warfare agents (nerve and blister agents). AELs include occupational and general-population standards used to monitor, assess, and prevent unacceptable exposures associated with operations at U.S. Army chemical warfare agent stockpile sites and laboratories. Such standards are similar to other Federal industrial occupational and general-population criteria. For workplaces in which agents are regularly processed or are routinely proximity to workers, the standards include Immediately Dangerous to Life and Health (IDLH), the Short-Term Exposure Limit (STEL), and the chronic-exposure, time-weighted-average (TWA) Worker Population Limit (WPL). The general population limit (GPL) is an atmospheric concentration level (mg/m^3) at which no adverse effects would occur in the general population, including sensitive subpopulations, assuming a continuous, daily (24/7). chronic (lifetime) exposure (Mioduszewski et al. 1998; DHHS 1988, 2002, 2003). The CDC points out the AELs are not precise thresholds of potential human toxicity.

Air sampling. Collecting a chemical from the air for the purpose of submitting it for chemical analysis. If the expected concentration of a chemical in air is high, air sampling can be performed by directly transferring air into a container, such as a Tedlar bag or canister. If the expected concentration of a chemical in air is low, the chemical can be collected as a large volume of air passed through a medium, such as XAD resin or Tenax, to which the chemical sorbs, but through which air passes without retention, thus allowing the chemical to be concentrated so that it can be detected when the medium is later extracted and analyzed in the laboratory.

Ambient Air. In this document, the air outside a contaminated facility.

Ambient Air Monitoring Plan (AAMP). A written plan for monitoring ambient air, designed to detect any escape of a gas (such as a fumigant and any agent of concern) from a facility in concentrations that may be a hazard to the surrounding population.

Area Command (Unified Area Command). An organization established (1) to oversee the management of multiple incidents that are each being handled by an Incident Command System (ICS) organization or (2) to oversee the management of large or multiple incidents to which several Incident Management Teams have been assigned. Area Command becomes Unified Area Command when incidents are multi-jurisdictional. Area Command may be established at an Emergency Operations Center (see EOC) facility or at some location other than an Incident Command Post (see ICP). (DHS 2008.)

Biased sampling. Sampling during clearance at locations close to areas found during characterization to be contaminated, or at locations expected to have considerable contact by people. A special case of judgmental sampling.

Glossary

Bulk sampling. Environmental sampling done by collecting a volume (or mass) of material such as soil, water, rubber, acoustic tile, or concrete, etc. In the context of this document, the mass is expected to be small, on the order of a few grams in most cases.

Characterization. In the context of this document, the process of obtaining information about a CWA or TIC attack for the purpose of determining further action. Characterization includes two relatively distinct activities: (1) assessing the physical nature of the chemical of concern (e.g., its identity, formulation, toxicological properties, persistence, and other physical properties) and (2) assessing the degree of contamination of a facility. Such information is used to estimate the potential for exposure to the chemical of concern and to decide where to decontaminate, what to decontaminate, and how to decontaminate. Facility characterization generally occurs after the First-Response Phase and before the Decontamination Phase (see Figure 1-1). Characterization of the agent of concern occurs as early as possible during the overall response.

Characterization sampling. Environmental sampling intended to assess the identity and extent (location and quantity) of contamination of an area or items, and to provide information needed to decide whether and where to decontaminate, what to decontaminate, and how to decontaminate. Occurs after the First-Response Phase and before the Decontamination Phase (see Figure 1-1).

Characterization zone. A discrete section or segment of a contaminated site, for example, the first floor of a particular terminal, that is a manageable piece for gathering data related to characterization.

Chemical warfare agent (CWA). A chemical intended for military use (or used by terrorists in the context of this document) with lethal or incapacitating effects on personnel. The classes of chemical warfare agents are (1) nerve agents, (2) blister agents, (3) choking agents, (4) blood agents, and (5) vomiting agents, all of which produce incapacitation, serious injury, or death. (Modified from the Center for Nonproliferation Studies at the Monterey Institute of International Studies, *Glossary, Biological Weapons Terrorism Tutorial*, 2004.)

Chemicals of Concern. This *Remediation Guidance* focuses on the nerve agents tabun, sarin, soman, cyclosarin, and VX; the blister agent sulfur mustard; the choking agent phosgene; and the blood agents hydrogen cyanide and cyanogen chloride. Collectively, the nine chemicals are referred to as chemicals of concern.

Clearance. The process of determining that a clearance goal has been met for a specific chemical of concern in or on a specific site or item. Generally occurs after cleanup and before reoccupancy.

Clearance criteria or clearance decision criteria. Conditions that must be met as part of a defined process for determining whether clearance goals have been met. The process should include ensuring that exposure guidelines are met with a level of confidence that is acceptable to stakeholders.

Glossary

Clearance/cleanup goal. An amount of contamination for a specific chemical of concern in or on an area or item that provides acceptable protection to human health and the environment. A clearance (cleanup) goal specifies criteria for determining the success of decontamination that are measurable and for permitting unprotected reentry. (DHS and EPA 2009.)

Clearance sampling. Environmental sampling, conducted after decontamination, that is intended to provide a basis for determining whether a clearance goal is met for a specific chemical of concern in an area or on items.

Clearance Sampling and Analysis Plan (Clearance SAP). A formal, written plan that describes how clearance sampling will be done, including the rationale for the clearance sampling design. It specifies the clearance decision criteria, including how the clearance sampling results will be used to determine whether clearance goals have been met. The Clearance SAP is a companion to the Remediation Action Plan (RAP), and is required before the RAP is executed.

Clearance zone. A discrete section or subsection of a contaminated site for which a clearance decision is made.

Cold zone. See staging area. Also called the clean zone, per Hazardous Waste Operations and Emergency Response (HAZWOPER).

Community emergency exposure level (CEEL). In November 1995, the National Advisory Committee for Acute Exposure Guideline Levels for Hazardous Substances (NAC1) was established to identify, review, and interpret relevant toxicologic and other scientific data and to develop acute exposure guideline levels (AEGLs) for high-priority, acutely toxic chemicals. The NRC's previous name for acute exposure levels, namely community emergency exposure levels (CEELs), was replaced by the term AEGLs to reflect the broad application of these values to planning, response, and prevention in the community, workplace, transportation, the military, and remediation of Superfund sites. See AEGL. (Commission on Life Sciences 2001).

Concept of Operations (CONOPS). A formal plan that describes the roles, responsibilities, and relations of organizations involved in a response to a contaminated area or items. A CONOPS in this guidance document addresses Federal, state, and local agencies, as well as facility owners, and how they should interact when responding to a potential or actual terrorist threat or incident.

Consequence Management. A management function that includes measures to protect public health and safety; restore essential government services; and provide emergency relief to governments, businesses, and individuals affected by the consequences of terrorism. Can include measures to identify the cause, location, and extent of contamination (characterization); clean up the contamination (decontamination); ensure that all health and environmental issues are addressed (clearance); and permit recovery (reoccupancy). The requirements of consequence management and crisis management are combined in the *National Response Framework* (DHS 2008). See also Crisis Management.

Glossary

Containment. In the context of this document, includes actions or measures taken to prevent the spread of a chemical of concern (in this document, a chemical warfare agent or toxic industrial chemical) from a particular zone or to prevent the movement of a chemical of concern within a zone. Compare with Isolation. This term is defined differently by different agencies.

Contamination reduction zone. The transition area between the exclusion and support zones where responders enter and exit the exclusion zone and where decontamination activities of responders take place. Also called the Warm Zone. (EPA 2004.)

Covert release. In the context of this document, refers to the intentional release of a chemical warfare agent or toxic industrial chemical that is not observed at the time the release occurs.

Crisis Management. Predominantly a first-responder and law-enforcement function that includes measures to identify, acquire, and plan the use of resources needed to anticipate, prevent, and/or resolve a threat or act of terrorism. In the context of this document, includes measures that are predominantly first-responder and law-enforcement functions to resolve the immediate threat or act of terrorism. The requirements of consequence management and crisis management are combined in the *National Response Framework* (DHS 2008). See Consequence Management.

Decision maker. A person within the Incident Command System having the authority to determine or direct appropriate actions in response to a chemical attack at a particular site.

Decontamination. The process of inactivating, reducing, or removing a chemical of concern in or on buildings, humans, animals, plants, food, water, soil, air, areas, or other items through physical, chemical, or other methods including monitored natural attenuation, to meet a clearance goal. For the purposes of this document, decontamination focuses on buildings and their contents and includes waste disposal. The term is also used to refer to decontamination of personnel and equipment in the contamination reduction zone. This term is defined differently by Federal agencies and other entities.

Decontamination reagent. A substance that reacts chemically with a chemical warfare agent or toxic industrial chemical to degrade it to a less-toxic substance. An effective decontamination reagent reduces the concentration of CWA or TIC on humans, animals, plants, inanimate surfaces, or in other media. An example is 5% sodium hypochlorite (household bleach).

Decontamination zone or area. A discrete section or subsection of a contaminated site that can be subjected to isolation with respect to other areas and then decontaminated as a unit.

de minimus. In context of risk, risk de minimus refers to a risk that is negligible and too small to be of societal concern (usually assumed to be a probability of less than 10^{-5} or 10^{-6}); also means "virtually safe." (U.S. National Library of Medicine, National Institutes of Health; accessed July 3, 2008). In the U.S., the legal term, de minimus, is used to mean negligible risk to the individual.

Glossary

Designated Agency Official. The representative from an agency or organization, that has jurisdictional authority or functional responsibility to respond to an incident, who is authorized to make decisions on the behalf of their agency or organization and can commit agency or organization resources in support of the incident response. The representatives would reside in the UC at the incident command post.

Disposal. The transfer or placement of any solid or hazardous waste on or in the land or water.

Emergency Operations Center (EOC). The physical location at which the coordination of information, communication, and resource allocation and tracking to support domestic incident management activities normally takes place. An EOC may be a temporary facility or may be located in a more central or permanently established facility, perhaps at a higher level of organization within a jurisdiction. EOCs may be organized by major functional disciplines (e.g., fire, law enforcement, and medical services), by jurisdiction (e.g., Federal, state, regional, county, city, or tribal), or by some combination thereof. (DHS 2008.)

Environmental sampling. Sampling for a chemical of concern that is conducted on inanimate surfaces or in air, water, or soil. After a chemical warfare agent or toxic industrial chemical release, indoor sampling may include bulk sampling of porous materials or elastomeric (rubber-like) compounds and sealants, such as silicone caulk. In the context of this document, includes characterization sampling, clearance sampling, and sampling to support public health or medical-treatment decisions.

Environmental Unit (EU). A unit in the Incident Command System, Planning Section, responsible for tasks such as recommending response priorities, developing sampling plans, characterizing the extent and effects of site contamination, and developing cleanup plans. The Environmental Unit prepares environmental data for the Situation Unit and coordinates with other units and sections within the ICS structure to enable effective decision support to the IC or UC. (NIMS 2008)

EPA/IRIS. Integrated Risk Information System (IRIS) is a compilation of electronic reports on specific substances found in the environment and their potential to cause human health effects. IRIS was initially developed for EPA staff in response to a growing demand for consistent information on substances for use in risk assessments, decision-making, and regulatory activities. The information in IRIS is intended for those without extensive training in toxicology, but with some knowledge of health sciences. See <http://cfpub.epa.gov/ncea/iris/index.cfm>.

Exclusion zone. Per Hazardous Waste Operations and Emergency Response (HAZWOPER), an area in which contamination is known to be present. That is, an area in which the potential exists for exposure to a chemical of concern and into which entry is permitted only for persons wearing appropriate personal protective equipment (PPE). Equivalent to hot zone, red zone, or restricted zone.

Glossary

Exposure guideline. Exposure is defined by the EPA as contact made between a chemical, physical, or biological agent and the outer boundary of an organism. Exposure is quantified as the amount of an agent available at the exchange boundaries of the organism (e.g., skin, lungs, gut) (EPA/IRIS 2005). An exposure guideline in this *Remediation Guidance* is an amount (e.g., mg/m^3) of a particular chemical of concern (e.g., sarin) that provides protection against an undesired health effect for a particular exposure pathway (inhalation, ocular, dermal, or ingestion) in a specified population (e.g., transit passengers) over a specified interval (e.g., 8 hr). An example is the acute exposure guideline level (see AEGL; see also Risk Assessment).

First responders. Primarily local police, fire, and emergency personnel who, during the early stages of an incident, are responsible for protecting and preserving life, property, evidence, and the environment, including emergency response providers as defined in Section 2 of the Homeland Security Act of 2002 (6 U.S.C. 101), as well as emergency management, public health, clinical care, public works, and other skilled personnel who provide immediate support services.

First response. Actions taken immediately following notification of an incident or release involving an agent of concern. In addition to search and rescue, scene control, and law-enforcement activities, first response includes initial site containment, initial environmental sampling and analysis, and personnel decontamination. The First Response Phase follows the Notification Phase of a response (see Figure 1-1).

Federal On-Scene Coordinator (FOSC or OSC). The Federal official predesignated by the U.S. Environmental Protection Agency or the U.S. Coast Guard to coordinate responses under subpart D of the National Contingency Plan (NCP); or the government official designated to coordinate and direct removal actions under subpart E of the NCP. (DHS 2008.)

G agents. A class of chemical warfare nerve agents. See agent GA (tabun), agent GB (sarin), GD (soman), and cyclosarin (GF), defined above.

Gas- or vapor-phase decontamination reagent. In the context of this *Remediation Guidance*, a gas- or vapor-phase decontamination reagent is a gaseous or vaporized decontamination reagent, such as modified vaporous hydrogen peroxide (mVHP®), which is known to be effective in reducing concentrations of chemicals of concern.

Gas/vapor-phase decontamination zone. A discrete section or subsection of a building or facility that is isolated with respect to other areas of the building or facility for the purposes of gas/vapor phase decontamination. See Isolation.

General population limit (GPL). The airborne exposure limit (see AEL) for chronic, long-term, general population exposures (e.g., 24/7 for years) expressed as an atmospheric concentration in mg/m^3. (DHHS 1998 and 2002; Mioduszewski et al. 1998). GPLs have been established by the U.S. Army and the Centers for Disease Control and Prevention for assessing, monitoring, and

controlling potential emissions from demilitarization operations (e.g. incinerators) at chemical agent stockpiles in the U.S.

Hazardous material. A substance or material that has been determined by the Secretary of Transportation to be capable of posing an unreasonable risk to health, safety, and property when transported in commerce, and which has been so designated (49 CFR 171.8).

Health-based environmental screening level (HBESL). Environmental screening levels (referred to by different names by different EPA regions) are concentrations of individual chemicals in environmental media that, if not exceeded, are unlikely to present a human health hazard for two common exposure scenarios involving only a single chemical of concern. The residential HBESL is a highly protective soil and solid matrix exposure criterion (expressed in mg/kg) for 24-hr per day, lifetime exposure of the general population including more susceptible individuals. The HBESL may be used alone or in conjunction with vapor exposure criteria (GPL or AEGL-1) to assess the possible existence of residual chemicals in semi-porous or porous media and demonstrate the unlikelihood of a chemical being present in or on an item or material at levels of public health concern, provided that the assumptions made in the HBESL scenarios are at least as conservative as site-specific values. Screening levels should not be construed as remediation levels. Adapted from USACHPPM (1999).

Health and Safety Plan (HASP). A written plan required under the Occupational Health and Safety Administration's (OSHA's) Hazardous Waste Operations and Emergency Response (HAZWOPER) standard (29 CFR 1910.120). This standard requires a written HASP, which identifies site hazards and appropriate controls to protect employee health and safety. (National Response Team, NRT 2005.) The HASP describes known physical, chemical, and biological hazards at a site; the establishment of hot (contaminated), cold (uncontaminated), and warm (intermediate, or contamination reduction) zones; personal protective equipment (PPE); personal decontamination procedures; and emergency procedures to be used by sampling and decontamination personnel.

Hot zone. See Exclusion zone.

Immediately dangerous to life and health (IDLH). Concentration representing the maximum level of a chemical from which an individual could escape within 30 minutes without escape-impairing symptoms or irreversible health effects (EPA 2002).

Incident. An occurrence or event, natural or human-caused, that requires an emergency response to protect life or property. Incidents can include major disasters, emergencies, terrorist attacks, terrorist threats, wild land and urban fires, floods, hazardous materials spills, nuclear accidents, aircraft accidents, earthquakes, hurricanes, tornadoes, tropical storms, war-related disasters, public health and medical emergencies, and other occurrences requiring an emergency response. (DHS 2008.)

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Incident Action Plan (IAP). An oral or written plan containing general objectives reflecting the overall strategy for managing an incident. The plan may include the identification of operational resources and assignments. It may also include attachments that provide direction and important information for managing the incident during one or more operational periods. In the context of this document, the Remediation Action Plan (RAP) and the Sampling and Analysis Plan (SAP) are implemented through a series of IAPs.

Incident Commander (IC). The individual responsible for all incident activities, including the development of strategies and tactics and the ordering and the release of resources. The IC has overall authority and responsibility for conducting incident operations and is responsible for the management of all incident operations at the incident site. (NIMS 2008; DHS 2008.)

Incident Command Post (ICP). As defined in the NIMS and NRF, the ICP is the field location at which the primary, tactical-level, on-scene incident command functions and management organizations are located. The ICP may be collocated with the incident base or other incident facilities and is normally identified by a green rotating or flashing light.

Incident Command System (ICS). A standardized, on-scene, emergency management construct specifically designated to provide for the adoption of an integrated organizational structure that reflects the complexity and demands of single or multiple incidents, without being hindered by jurisdictional boundaries. ICS is the combination of facilities, equipment, personnel, procedures, and communications operating with a common organizational structure, designed to aid in managing resources during incidents.

Incident Management Team (IMT). A team of agency officials trained in ICS key leadership positions, including the Incident Commander, command staff (Safety Officer, Liaison Officer, and Information Officer) and general staff (Operations Section Chief, Planning Section Chief, Logistics Section Chief, and Finance Section Chief).

Instrument detection limit (IDL). The IDL is the analyte concentration that is required to produce a signal (statistically) distinguishable from noise, where noise refers to the variation in the signal produced when a blank (matrix without analyte) is analyzed.

Initial environmental sampling. Environmental samples during the initial response to an incident involving release of a chemical of concern.

IRIS. See EPA/IRIS.

Isolation. For the purposes of this document, action taken to seal a site, or portions of a site, to permit gas/vapor phase decontamination and prevent release of gas/vapor phase decontamination reagent. Also, an action taken, such as enclosing a baggage scanner with a tent, to exclude a chemical of concern from critical equipment. Compare with containment. This term has been used differently by various agencies. Also used to refer to enclosing or encapsulating objects

such as sensitive equipment or valuable property in a protective material to protect it from a gas/vapor phase reagent during decontamination.

Judgmental sampling. Environmental sampling in which the locations are determined by professional judgment. Generally based on incident-specific information, such as a known release location, visible evidence of contamination, or facility-specific information including airflow patterns.

LCt_{50}. Median lethal dose of a vapor or aerosol.

Life-safety zones. The interior zones or regions of a building that are used for smoke control in the event of a fire. Life-safety zones are defined by the dedicated air-handling units (AHUs) of the building's heating, ventilation, and air conditioning (HVAC) system. They may constitute logical zones for characterization and decontamination.

Liquid reagent. A liquid or other material, such as a foam or gel, that when applied to a surface will conform to the surface contours.

Lowest observed adverse effect level (LOAEL). The lowest dose of a chemical in a study or group of studies that produces statistically or biologically significant increases in frequency or severity of adverse effects between an exposed population and its appropriate control (EPA 2002).

Maximum contaminant level (MCL). The highest level of a contaminant or naturally occurring mineral, such as fluoride, that is allowed in U.S. domestic drinking water from distributed systems. MCLs are enforceable EPA standards for water-treatment utilities. See <http://www.epa.gov/safewater/mcl.html>.

Method detection limit (MDL). The minimum concentration of a substance that can be measured and reported with 99% confidence that the analyte concentration is greater than zero (defined by the EPA in Appendix B of 40 CFR 136). Practically speaking, the MDL represents a value at which a signal emerges from “noise” arising from the analytic process. Sometimes called the “limit of detection” or “detection limit.”

Modified vaporous hydrogen peroxide (mVHP®). A decontamination technology that involves flash vaporization of an aqueous peroxide mixture and added low levels of ammonia gas.

Monitored natural attenuation. A decrease in concentration of a hazardous substance, including chemical warfare agents and toxic industrial chemicals, into less hazardous concentrations via natural, environmental mechanisms such as heat, light, or volatilization, together with verification through a defined monitoring process. Such mechanisms can reduce or possibly eliminate a chemical hazard and should be considered as a possible decontamination option. Note that the associated term “degradation,” as used in this document, refers to a

transformation caused by chemical reactions with environmental species, such as water or hydroxyl radicals in the atmosphere.

National Incident Management System (NIMS). A nationwide template enabling Federal, state, local, and tribal governments and private-sector and nongovernmental organizations to work together effectively and efficiently to prevent, prepare for, respond to, and recover from domestic incidents regardless of cause, size, or complexity. The NIMS provides a core set of doctrine, concepts, terminology, and organizational processes to enable collaborative incident management at all levels.

National Response Framework (NRF). An all-discipline, all-hazards document that establishes a single, comprehensive framework for managing domestic incidents. The NRF provides the structure and mechanisms for coordinating Federal support to, and exercising direct Federal authorities and responsibilities for, such incidents.

Negative air unit (NAU). A system that subjects an area to a slightly negative pressure relative to surrounding areas to ensure that a chemical of concern (and decontamination reagent) remains in the contamination zone. NAUs often consist of an AHU HEPA filter, chemical scrubber, demister, carbon bed, fan, and stack. Air within a contamination zone is exhausted through the unit at a rate sufficient to create a slightly negative pressure in the contaminated zone.

Nerve agent. One of several organic esters of phosphoric acid used as a chemical warfare nerve agent because of extreme toxicity (see agents GA, GB, GD, and VX). All are potent inhibitors of the enzyme acetylcholinesterase, which is responsible for the degradation of acetylcholine in neuronal synapses or myoneural junctions.

No observed adverse effect level (NOAEL). That dose of chemical at which there are no statistically or biologically significant increases in frequency or severity of adverse effects seen between the exposed population and its appropriate control. Effects may be produced at this dose, but they are not considered to be adverse. (EPA 2002).

Notification. The process of communicating the occurrence or potential occurrence of an incident to and through designated authorities who will initiate first-response actions. Notification is generally one of the first steps in activating an emergency response (Figure 1-1).

Operational Period (OP). The time scheduled to execute a given set of operational actions specified in the Incident Action Plan. The IC or UC specifies operational periods (such as 12-hr shifts, sunrise to sunset, or 24-hr shifts). For the next OP, an Incident Action Plan with a new (or carryover) set of operational actions is developed. The process in repeated until operations are complete.

Operational Period Planning Cycle. For longer-term and complex responses, the Planning Section Chief adopts the Operational Period Planning Cycle (EPA 2007). Certain meetings, briefings, and information gathering during the cycle lead to an Incident Action Plan (IAP) that

guides operations of the next operational period. The diagram for the Operational Period Planning Cycle, known as the Planning "P," provides a visual representation of the IAP development process.

Operations Section. The Incident Command System section responsible for all tactical incident operations.

Overt release. In the context of this document, the intentional release of a chemical warfare agent or toxic industrial chemical that is correctly reported or openly acknowledged by terrorists, observed by surveillance systems or witnesses at the scene of the release, or made known at the time of release by other means.

Percutaneous exposure. The absorption of a chemical of concern through unbroken skin.

Permissible exposure limit (PEL, expressed as time-weighted average). A term used by the Occupational Safety and Health Administration (OSHA), the National Institute for Occupational Safety and Health (NIOSH), and in regulatory and compliance standards in occupational settings. The PEL is a concentration of a substance to which most workers can be exposed without adverse effects averaged over a normal 8-hr workday or a 40-hr workweek, as defined in the Federal Register, Vol. 57, No. 114, June 12 1992, pp. 26539, 26556, 26572, 26573 and 26590. The PEL for a chemical agent is comparable to the Worker Population Limit (see WPL).

Planning Section. The Incident Command System section responsible for collecting, evaluating, and disseminating operational information related to an incident and for preparing the Incident Action Plan. The Planning Section maintains information on the current and forecasted situation and on the status of resources assigned to the incident.

Preliminary Remediation Goal (PRG). Human health-risk-based concentration designed to be used as a guideline in screening-level evaluations of contaminated sites. PRGs are developed with explicit consideration of sensitive subpopulations and are considered protective for human health for exposures that may occur over a lifetime (EPA 2005).

Principal Federal Official (PFO). The Secretary of Homeland Security is the Principal Federal official for domestic incident management under the National Response Framework (DHS 2008). By Presidential directive and statutory authority, the Secretary is responsible for coordination of Federal resources utilized in the prevention of, preparation for, response to, or near-term recovery from terrorist attacks, major disasters, or other emergencies.

Process monitoring. Measuring and recording the key attributes or design parameters of a decontamination process as they occur. For example, during gas- or vapor-phase decontamination, decontamination reagent concentration, contact time, temperature, and relative humidity. or others as appropriate, are measured and documented over time.

Provisional Advisory Level (PAL). PALs are advisory exposure levels for chemical agents (including chemical warfare agents, pesticides, and toxic industrial chemicals) to assist in

emergency planning and response decision-making, and to aid in making informed risk management decisions for evacuation, temporary re-entry into affected areas, and resumed use of infrastructure. These risk management decision may be made at the federal, state, and local levels. Three exposure levels (PAL 1, PAL 2, and PAL 3), distinguished by severity of toxic effects, are developed for 24-hour, 30-day, 90-day, and 2-year durations for potential exposure to drinking water and ambient air by the general public. Source: Adeshina et. al. 2009. See also <http://www.epa.gov/nhsrc/news/news042210.html> (accessed June 2010).

Provisional peer-reviewed toxicity value (PPRTV). The EPA Office of Research and Development, National Center for Environmental Assessment, Superfund Health Risk Technical Support Center (STSC) develops PPRTVs on a chemical-specific basis when requested by the EPA Superfund program. PPRTVs are derived when (1) the STSC conducts a batch review of toxicity values and any new toxicity values developed are placed in the PPRTV database, or (2) when Regional Superfund Offices request a PPRTV for contaminants lacking a relevant IRIS value. The same methodologies are used to derive PPRTVs for both purposes. (Cook 2003).

Quality Assurance. An integrated system of activities involving planning, quality control, quality assessment, reporting, and quality improvement to ensure that a product or service meets defined standards of quality with a stated level of confidence. (EPA 2002.) For the purposes of this guidance document, this term refers to the quality of data.

Quality Assurance Project Plan (QAPP). A formal document describing in comprehensive detail the necessary quality assurance (QA), quality control (QC), and other technical activities that must be implemented to ensure that the results of the work performed satisfy the stated performance criteria. The QAPP documents how quality assurance and quality control are applied to an environmental data-collection operation to ensure that the results obtained satisfy the stated performance criteria. (EPA 2005a)

Quality Control. The overall system of technical activities the purpose of which is to measure and control the quality of a product or service so that it meets the needs of its users. The aim is to provide quality that is satisfactory, adequate, dependable, and economical. (EPA 2002.) For the purposes of this guidance document, this term refers to the quality of data.

Random sampling. Environmental sampling in which sampling locations are chosen with some degree of randomness. Such sampling is based on the idea that choosing locations at random ensures both representative and reproducible results.

RCRA Storage Area. One or more locations designated for storing hazardous wastes generated during source reduction, decontamination, and other removal or cleanup activities. The location is generally a secured and fenced area that complies with Resource Conservation and Recovery Act (RCRA) hazardous waste storage requirements.

Recommissioning. The process of testing and verifying that equipment and systems are fully functional and may be returned to normal use. Recommissioning can include buildings and mechanical equipment.

Recovery. The development, coordination, and execution of service- and site-restoration plans for impacted communities and the reconstitution of government operations and services through individual, private sector, nongovernmental, and public assistance programs (DHS 2008).

Reference concentration (RfC). An inhalation exposure guideline. An estimate of a continuous inhalation exposure for a given duration to the human population (including susceptible subgroups) that is likely to be without an appreciable risk of adverse health effects over a lifetime. It is derived from relevant toxicity data, and often has uncertainty and variability factors applied to reflect limitations of the data used. (EPA/IRIS 2005.)

Reference dose (RfD). An estimate, with an uncertainty spanning perhaps an order of magnitude or greater, of a daily exposure level for the human population, including sensitive subpopulations, that is likely to be without an appreciable risk of deleterious effects for chronic exposures during a lifetime. (EPA 1989, 2002.)

Remediation. The process of characterizing, decontaminating, and clearing a contaminated site or items, including disposal of wastes. Generally occurs after the First-Response Phase and before the Restoration Phase (see Figure 1-1). A synonym for cleanup.

Remediation Action Plan (RAP). A formal plan that describes actions to remove, reduce, or eliminate chemical of concerns at a site. In the context of this *Remediation Guidance* document, the RAP is a written, incident-specific plan that includes details on (1) what facilities and areas need to be decontaminated; (2) what materials and structural components are to be decontaminated in situ, or removed for treatment and either reused or disposed; (3) to what extent removed items will be decontaminated prior to disposal, and how and where such items will be decontaminated and disposed; (4) the decontamination technologies to be used; (5) the personnel and teams responsible for decontamination tasks; and (6) the types of wastes that will be produced and how they will be treated or disposed

Renovation. The process of reconstructing or refurbishing a facility prior to allowing the occupants to return. See Restoration.

Reoccupancy. The process of renovating a facility, monitoring restoration personnel, and deciding when to permit reoccupation. Generally occurs after a facility has been cleared but before occupants are allowed to return.

Residual contamination. Any amount of contamination remaining in an area or on an item after decontamination or monitored natural attenuation.

Response. Activities that address the short-term, direct effects of an incident, such as immediate actions to save lives, protect property, and meet basic human needs. Includes emergency

operations and incident mitigation activities designed to limit loss of life, personal injury, property damage, and other unfavorable outcomes (DHS 2008).

Restoration. The process of renovating or refurbishing a facility, bringing it back to an unimpaired or improved condition, and making a decision to allow occupants to return. Generally occurs after a facility has been cleared but before occupants are allowed to return (see Figure 1-1).

Risk. In the context of human health, the probability of adverse effects resulting from exposure to an environmental agent or mixture of agents (EPA/IRIS 2005).

Risk communication. The process of providing information about the expected type and magnitude of an outcome, particularly in the context of environmental health. Risk communication is often a discussion about an adverse outcome and the probability of that outcome occurring (Reynolds 2002).

Risk assessment. In the context of human health, the evaluation of scientific information on the hazardous properties of environmental agents (hazard characterization), the dose–response relation (dose–response assessment), and extent of human exposure to those agents (exposure assessment). The product of risk assessment is a statement regarding the probability that populations or individuals so exposed will be harmed and to what degree (risk characterization). (EPA/IRIS 2005.)

Safe Refuge Area (SRA). A safe area within the Contamination Reduction Zone for the assembly of individuals onsite at the time of a release. Separation of any potentially contaminated or exposed persons from nonexposed persons should be accomplished in the SRA.

Sampling and Analysis Plan (SAP). A plan that describes the methods, strategies, and analyses for environmental sampling. A Characterization SAP is a plan for characterization sampling; a Clearance SAP is a plan for clearance sampling, and so forth.

Sampling unit. A subsection of a sampling zone (for example, walls, floors, or furniture surfaces) that can be sampled and evaluated collectively. Sampling units can be used as a basis for developing stratified statistical sampling plans.

Sampling zone. A discrete section of a contaminated site in which environmental sampling is conducted.

Scientific Support Coordinator (SSC). A technical specialist, defined in the National Contingency Plan (NCP 300.145) as the principal advisor to the IC for scientific issues. The SSC is charged with gaining consensus on scientific issues affecting the response and ensuring that differing opinions within the scientific community are communicated to the IC (EPA 2007). Additional descriptions of SSC responsibilities are included in EPA (2007).

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Screening analysis. The process of analyzing environmental samples by nonlaboratory personnel, equipment, or facilities with the goal of providing immediate information about a sample. Typically performed at the site rather than in a laboratory. Screening analysis can be as simple as using color-indicating paper to determine the presence of a nerve agent. More sophisticated screening analyses use chemical instruments, such as ion mobility spectrometers.

Screening sampling. Sampling for the purpose of screening analysis. May sometimes be used to refer to initial environmental sampling, but in that case initial environmental sampling is the preferred term.

Short-term exposure limit (STEL). The concentration to which workers can be exposed continuously for a short time without suffering from irritation; chronic or irreversible tissue damage; or narcosis of sufficient degree to increase the likelihood of accidental injury, impair self-rescue, or materially reduce work efficiency. (ACGIH 2007.) STELs are often developed by the ACGIH; however, STELs for chemical warfare agents in particular were established by the Centers for Disease Control and Prevention.

Source reduction. In the context of this *Remediation Guidance*, activities designed to decrease the quantity of chemical warfare agent or toxic industrial chemical within a contaminated facility prior to the main decontamination activities. Source reduction can include the removal of contaminated material and items from a contaminated building to make decontamination easier, or the removal of items that are less costly to replace than to decontaminate.

Staging area. Under the ICS, a location where incident personnel and equipment are staged awaiting tactical assignment. The Operations Section Chief manages the staging area, which is located in the support zone (see below).

Subject-matter expert (SME). An individual who is a technical expert in a specific area of study or in performing a specialized job, task, or skill.

Support zone. An area of a site that is free from contamination and that may be safely used as a planning and staging area. (EPA 2004.) See also Staging area.

Swab sampling. A method of collecting environmental samples by rubbing a small surface area with a dry or wet absorptive material attached to the end of a wood or plastic stick.

Targeted sampling. Sampling during clearance at specific locations that were found to be contaminated during the Characterization Phase. A special case of judgmental sampling. The term has been used differently in different reports.

Technical Specialists. Personnel with special skills or expertise useful to the incident response. Specialists may serve anywhere within the organization, including the Command Staff. No specific incident qualifications are prescribed or required, as technical specialists normally perform the same duties during an incident that they perform in their everyday jobs, and they are typically certified in their fields or professions (NIMS 2008). Example specialties include

environmental sampling, air modeling, cleanup and decontamination technologies, risk assessment and toxicology, quality assurance, analytical laboratory services, transportation, and disposal.

Technical Working Group (TWG). In some incidents, a group of technical experts is established to review technical documents developed by the Planning Section's Environmental Unit. The TWG often consists of subject matter experts drawn from the EPA, other Federal agencies, and the private sector who review remediation plans and help to ensure conformance with current standard operating procedures and guidance.

Toxic industrial chemical (TIC). The International Task Force 25, Hazards from Toxic Industrial Chemicals, April 1998 (ITF-25) defines a TIC as a material that is produced in quantities of greater than 30 tons in a single factory and has a toxicity (LCt_{50} inhalation) of less than 100,000 mg per min/m^3 and an appreciable (undefined) vapor pressure at 20°C. See for example: www.wood.army.mil/cmdoc/WFS/TIMs/TICS%20%20TIMS.ppt

Time-weighted average (TWA). An exposure concentration averaged over a designated time. For example, a PEL is an exposure concentration standard for an averaged exposure over a normal 8-hr workday or a 40-hr workweek (EPA 2002; see also <www.OSHA.gov>).

Vapor-phase hydrogen peroxide (VPHP). A decontamination reagent that involves flash vaporization of an aqueous peroxide mixture. Low levels of ammonia gas may be added in proprietary preparations.

Unified Command. An application of the Incident Command System used when there is more than one agency with incident jurisdiction or when incidents cross political jurisdictions. Designated Agency Officials (who make up the Unified Command) with jurisdictional authority work together to establish a common set of objectives, strategies, and guidance. The UC, for example, approves the Incident Action Plans. (NIMS 2008; DHS 2008.)

Verification sampling. Sampling associated with a decontamination process for the purpose of establishing that the process is being conducted properly. See process monitoring. Verification sampling, which takes place during decontamination, might use chemical indicators to determine that a particular decontamination reagent has been in contact with specified surfaces. Compare this term with clearance sampling, which takes place after decision-makers are satisfied that the decontamination was conducted properly.

Volumetric space. The volume of a room or other indoor area.

Warm zone. Transition area between the exclusion and support zones, where responders enter and exit the exclusion zone, and where decontamination of personnel takes place. (EPA 2004.) Also called the contamination reduction zone per HAZWOPER.

Weapon of mass destruction (WMD). As defined in Title 18, U.S.C. § 2332a: (1) any explosive, incendiary, or poison gas, bomb, grenade, rocket having a propellant charge of more

than 4 ounces, or missile having an explosive or incendiary charge of more the one-quarter ounce, or mine or similar device; (2) any weapon that is designed or intended to cause death or serious bodily injury through the release, dissemination, or impact of toxic or poisonous chemicals or the precursors; (3) any weapon involving a disease organism; or (4) any weapon that is designed to release radiation or radioactivity at a level dangerous to human life.

Wipe sampling. Collecting environmental samples by rubbing a small area on surfaces with a thin, flat piece of dry or wet absorptive material. Sometimes referred to a swipe sampling.

Worker population limit (WPL). The concentration at which an unprotected worker can operate safely 8 hr/day, 5 days/week, for a working lifetime, without adverse health effects.

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Overview

This document provides remediation guidance for major airports following an attack involving the indoor release of any of five nerve agents (tabun, sarin, soman, cyclosarin, and agent VX), the blister agent sulfur mustard, or three toxic industrial chemicals (hydrogen cyanide, cyanogen chloride, and phosgene), collectively referred to as the "chemicals of concern." The Tom Bradley International Terminal at the Los Angeles International Airport was selected as an example facility to illustrate specific details associated with remediation. Actions taken during the Notification and First-Response Phases are briefly discussed in Annexes A and B, respectively. For example, during the initial stages following an attack the affected area will likely be considered a crime scene. During a forensic investigation and initial evidence gathering, first responders must coordinate their activities with police and FBI personnel. However, the focus of this guidance document is on cleanup and disposal activities associated with the Characterization, Decontamination, and Clearance Phases, as defined herein, that are necessary to support overall remediation of an airport. In addition to the main text of this *Remediation Guidance* and associated annexes, data supplements were developed specifically for Los Angeles International Airport. Requests for data supplements must be made directly to the Emergency Planning Operations Division of Los Angeles International Airport. A separate and much more succinct summary document entitled, *Draft Guidance: Response, Remediation, and Recovery Checklist for Chemically Contaminated Facilities*, is intended primarily as a component of the concept of operations to be used in an Emergency Operations Center as a decision tool for the Unified Command. The checklist document is available from Lawrence Livermore National Laboratory (refer to Raber et al. 2008).

This document does not describe outdoor cleanup or detailed public health responses (i.e., medical treatment) following release of a chemical of concern. If laboratory analytical results or other indicators confirm the presence of such a chemical, the responsible public health agency involved in the response will commence appropriate public health actions, such as medical examinations and the treatment and decontamination of potentially contaminated individuals. See the Centers for Disease Control and Prevention website for more information on emergency public health response, available at <http://www.bt.cdc.gov/>. Although effective communication with the media and the public is an essential component of a response, the topic is beyond the scope of this document (many helpful resources are identified in Section 1.1).

The response structure described in this document for remediation following an indoor release of a chemical of concern at a major airport conforms to the *National Response Framework* (NRF) (DHS 2008) and implementation of the *National Incident Management System* (NIMS 2008). This document anticipates that a Unified Command would be formed to direct the cleanup process jointly and to take ultimate responsibility for all cleanup decisions. The Unified Command would likely include the Airport Manager or Airport Emergency Operations Manager; representatives from state and local public health, environmental, and emergency management agencies; and Federal agencies, such as the U.S. Environmental Protection Agency. The Unified

Overview

Command and all of the Incident Command Staff should be co-located in an Incident Command Post in an uncontaminated area at or near the airport. The Secretary of Homeland Security is the Principal Federal Official for domestic incident management under the NRF. Federal assistance for incidents that do not require DHS coordination may be led by other Federal departments and agencies consistent with their authorities. Local response plans (such as emergency response plans, procedures, or protocols) are likely to govern notification and first response. Facility personnel, responders, and emergency management coordinators should be aware of all applicable plans and procedures and how to implement them. Under NIMS the remediation response is implemented through a series of separate, standardized, shorter-term Incident Action Plans (IAPs). Each IAP, requiring Unified Command approval, describes specific activities that are to commence during the next operational period (often 12 or 24 hours).

Remediation activities generally take place after the area designated as a crime scene has been released by authorities. The three major remediation activities are characterization, decontamination, and clearance (see Figure 1-1). They do not necessarily occur sequentially. For example, some decontamination activities, such as source reduction (see next paragraph) would take place at the same time as characterization. Remediation activities are likely to occur at different rates in different parts of a facility, depending on proximity to the release location and degree (amount or extent) of contamination.

Remediation activities commence with site containment, isolation of critical or sensitive equipment, and the expeditious removal of visible liquid contamination, if any, at the first opportunity, even while the site is a crime scene. Any such visible liquid contamination is destroyed or removed to eliminate vapor sources and to minimize the depth of penetration into materials of a chemical of concern. Areas suspected of being contaminated are contained to prevent further movement of a chemical of concern to uncontaminated areas or the environment, and to reduce the potential for future exposure. Sensitive and essential equipment should be isolated, for instance with tents, if conditions suggest that they need protection. Any containment measures that were used during the First-Response Phase should be reviewed and a decision reached as to whether additional containment is necessary. Potential containment barrier locations include fire doors and connector halls between major terminal areas. Such locations might be used later to form decontamination zones. Agent air monitoring in areas adjacent to the contained contamination zones is done to protect remediation personnel, the public, and the environment by detecting and monitoring any release from the contained zones.

The principal goals of characterization are to define the extent of contamination and gather information needed to design the decontamination approach, assuming that the chemical of concern has been identified. If the chemical of concern is not yet known, it must be identified now. Initial sampling data collected by first responders are assessed to approximate the location(s) of contamination and the types of materials contaminated. Confirmation of the identity and purity of a chemical warfare agent (including its concentration and identification of any additives or co-solvents) can only be obtained by a laboratory approved to work with authentic standards of chemical warfare agents because the use of reference standards is the only

method that can unambiguously determine the identity and concentration of these compounds. Confirmation for toxic industrial chemicals has different requirements, but because access to these materials is less restricted than is access to chemical warfare agents, more laboratories, including many commercial environmental laboratories, are equipped to analyze such chemicals.

The scheme for determining where to sample and how many samples are needed must be carefully planned to ensure confidence in such decisions. Annex H contains templates for time-critical sampling, for use in rapid early assessments and especially to support prompt source reduction, and for a more thorough and comprehensive characterization of an entire facility. Annexes C and E discuss options for sampling design. Various surface-sampling approaches are discussed in this document. For example, wipe samples are widely used for surface sampling. Swab samples can be used to sample nooks, crannies, joints, and seams. Water samples might be needed from open water sources such as fountains. Air samples can be taken to monitor any volatilized chemical in the air. Upon completion of the comprehensive characterization plan, an internal review is initiated, and the plan is attached to an Incident Action Plan for the next operational period. Upon approval by the Unified Command, characterization commences.

The Occupational Safety and Health Administration requires each involved agency or company employer to prepare a Health and Safety Plan for its employees. It is important that the Site Safety Officer develop a unified Health and Safety Plan when multiple agencies are involved in remediation to ensure that unified and coordinated health and safety measures are in place for all responding personnel. Such a plan describes physical, chemical, and biological hazards at the site, and levels of personal protective equipment, personal decontamination procedures, and emergency procedures to be used by sampling and remediation personnel.

An important part of planning that should begin as soon as possible is to set clearance goals. The overall purpose of remediation is to ensure negligible residual exposure potential, which is done by decontaminating sufficiently to meet clearance goals. Site- and incident- specific information should always be used to determine the most appropriate clearance goals. Section 2.3 describes the process of developing risk-based clearance goals, and Annex G provides additional information from the Environmental Protection Agency summarizing existing exposure guidelines. Clearance goals are also needed as soon as possible because the selection of sampling and analytical methods depends on the clearance goals. The methods must be able to detect the presence of contamination if it is present at levels greater than the clearance goals.

An incident-specific Remediation Action Plan is developed, which describes the decontamination methods to be used and other details, including waste disposal. The template in Annex J can facilitate preparation of a Remediation Action Plan. A Clearance Sampling and Analysis Plan must be prepared; and if gas/vapor-phase decontamination is used, then an Ambient Air Monitoring Plan—which can be a component of the Remediation Action Plan—is also required along with isolation measures to ensure the decontamination reagent(s), including gases and vapors, are not released into uncontaminated areas. A Contingency Plan is also recommended to specify procedures in the event of inclement weather, fire, explosion, unplanned releases, or other unanticipated events.

Overview

This *Remediation Guidance* document is written to address situations in which site decontamination is necessary. For some nonpersistent chemicals of concern, monitored natural attenuation may be an adequate decontamination option. Such an option would be less resource-intensive than technology-driven decontamination methods. If contamination is not extensive or a chemical of concern does not persist within materials, application of surface decontaminants may meet clearance goals. For extensive contamination by persistent chemicals, unproven gas- or vapor-phase decontamination methods might be an option, in which case source reduction, such as removing carpets that absorbed chemicals or pre-cleaning surfaces to reduce the contaminant load, would be especially important. To expedite remediation and prevent costs from escalating, a cost–benefit analysis should be incorporated in the decision process related to retention versus disposal of items. The cost–benefit analysis should consider political issues and community concerns. Certain materials and structures can be decontaminated for reuse, but other material may be decontaminated and removed for disposal as waste. This guidance document assumes that almost all waste items will be decontaminated before disposal, excluding certain airport items that might be disposed without decontamination if they meet disposal criteria. Decontamination of items before removal from an airport facility, although not required from a regulatory perspective, would eliminate any potential for cross-contamination of previously unexposed areas, eliminate the potential for secondary source production, reduce exposure of decontamination workers, and facilitate waste handling and transportation. In general, all wastes from a remediation activity must be analyzed to determine if they are hazardous wastes.

Disposal of wastes associated with remediation is a major time and cost issue. Developing an effective and comprehensive waste-management strategy is an essential part of remediation planning. Airport facilities should predetermine their waste-disposal options for potentially contaminated materials before an attack occurs. Identifying onsite structures for holding contaminated materials removed from operating areas prior to disposal may speed remediation. It is important to work with a highly trained and experienced transportation and disposal specialist who understands complex waste-handling, packaging, and shipping regulations.

Site preparation for decontamination includes sealing openings to prevent leaks, source reduction, isolating sensitive and critical airport equipment, such as luggage scanners, and setting up decontamination and monitoring equipment. Decontamination reagents and delivery systems are selected and all systems are pre-tested before carrying out treatment(s). The choice of decontamination technologies depends on the chemical of concern released, nature and extent of contamination, materials contaminated, and other site parameters identified during characterization. A pilot test can be done to evaluate the effectiveness of a selected technology. Decontamination-related decisions can have a major impact on waste-disposal costs, and it is necessary to develop a disposal plan identifying a means of disposal, required approvals, transportation, and other details.

The effectiveness of decontamination is assessed while it is being implemented by monitoring key process variables specific to the decontamination strategy and by sampling afterwards. Process parameters include ambient temperature, relative humidity, airflow, decontamination

reagent contact time, and gas-phase concentration of the chemical of concern. Concurrently, real-time or near-real-time methods (e.g., colorimetric strips, electrochemical sensors, and ion mobility spectroscopy) should be used to verify decontamination reagent concentration. Once specified criteria for the key process variables have been met, clearance begins.

A clearance strategy confirms a successful decontamination by demonstrating that health effects from exposure to residual contamination, if any, will be negligible. A clearance strategy should also be able to detect an unsuccessful or partially successful decontamination. A clearance sampling plan is developed, which describes how and where to collect samples after decontamination is complete. Such samples are used to help make the clearance decision. Clearance sampling includes both surface and air samples. Annex H includes a sampling plan template for clearance identifying the types of required information. The Environmental Unit evaluates clearance information, along with information from previous phases, and recommends whether clearance should be granted or whether further decontamination is necessary. The Environmental Unit can also consider whether post-clearance environmental monitoring should be done. The UC makes the final clearance decision.

Following clearance, the Restoration/Reoccupancy Phase can begin. This phase includes mitigation of any hazards that may have arisen during decontamination, any necessary rebuilding or renovation, the implementation of any post-clearance environmental monitoring, and finally a decision to reopen a facility.

A theme that is emphasized throughout this document is the importance of pre-planning. Many activities can greatly reduce the time required to re-establish airport operations if the activities are conducted prior to a release of a chemical of concern. A summary of resources (such as Federal, state, and local agency contacts; contractors; prospective Incident Management Team members; subject-matter experts; laboratory facilities; waste-disposal facilities; and other entities) that should be identified in advance by airport officials is provided in each pertinent section of this document, and summary contact lists of such resources are provided in Annex K. A summary of overall pre-planning actions that should be completed by airport officials is presented at the end of this document.

Overview References

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

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

Raber, E., S. Mancieri, T. Carlson, C. Fish, J. Hirabayashi-Dethier, A. Intrepido, D. MacQueen, R. Michalik, and J. Richards (2008), *Draft Guidance: Response, Remediation, and Recovery Checklist for Chemically Contaminated Facilities*, Lawrence Livermore National Laboratory, Livermore, CA, LLNL-TR-404441.

1 Introduction

In the event of a terrorist attack involving the indoor release of a chemical warfare agent (CWA) or toxic industrial chemical (TIC) at a major airport (the specific chemicals of concern in this document are identified in Section 1.2), decision makers will need to make important choices about how to respond. This *Remediation Guidance* identifies key activities and issues that must be considered by a major airport following an incident involving an indoor release of a CWA or TIC. Annexes provide more detailed information on specific topics as well as templates that can be used to facilitate remediation operations.

1.1 Description of Phases

Actions following a terrorist incident involving a CWA or TIC can be categorized into six principal phases, beginning with identification of an incident and ending with verification that all clearance goals have been met (Raber et al. 2002), followed by reoccupancy of a site. The six phases shown in Figure 1-1 are:

- **Notification Phase**. An Emergency Communications Center (such as a police or fire dispatch center) is informed of, or has knowledge about, a threat or an incident. Information gathering and dissemination are the main tasks.

- **First-Response Phase**. This phase begins with ad hoc response of local police and fire personnel, activation of an Incident Command and law enforcement and emergency operations personnel [e.g., security, medical, and hazardous materials (HazMat) teams, as needed], and the establishment of a Unified Command structure, and it continues as long as emergency personnel are present. Central activities are rescuing and evacuating people; decontaminating and treating people; mitigating any conditions that pose an immediate threat to human health, such as fire or explosion; documenting and limiting the spread of contamination, especially visible liquid contamination; controlling the crime scene; and sampling associated with the crime scene. First responders search for additional release devices. Initial sampling by first responders begins the process of identifying the chemical(s) of concern. Passengers and employees are evacuated according to a facility evacuation plan, or they may self-evacuate. The phase ends when conditions immediately dangerous to human health are controlled and when law enforcement turns control of the crime scene back to airport authorities and remediation personnel.

- **Characterization Phase**. The focus is on gathering information needed for subsequent activities, including obtaining positive confirmation of the chemical(s) of concern using a reliable laboratory (if not done during first response) and performing characterization environmental sampling to determine the extent of contamination and what areas and materials may need decontamination. The site is stabilized by containment, source reduction, or both, especially with respect to visible liquids before they spread further or penetrate more deeply into materials. Environmental characteristics of the chemical of concern (such as its volatility and persistence) as well as potential health consequences to

humans and harm to the environment are evaluated to determine what type and degree of decontamination are needed and what public health measures are needed for persons who were potentially exposed. Clearance goals should be set during this phase. The overall goal for facilities contaminated with a chemical of concern is to ensure negligible residual exposure potential, demonstrated by meeting appropriate health-based guidelines for the chemical of concern.

- **Decontamination Phase**. The focus is on preparing and implementing detailed plans for decontamination of contaminated areas to achieve clearance goals. A Remediation Action Plan and a Clearance Sampling and Analysis Plan are prepared before the main decontamination treatment begins. Preparation of the plans begins early in the Characterization Phase, immediately after the site is stabilized, and preparation continues until shortly after that phase is completed. Even before the Characterization Phase or the Remediation Action Plan is completed, decontamination actions may commence if such early actions can improve the characterization of surfaces and materials to be decontaminated in place. Options for decontamination in place include monitored natural attenuation (Section 3.2), application of surface decontaminants such as bleach, and gas- or vapor-phase decontamination with hot air or a mixture of vapor-phase hydrogen peroxide and ammonia. Decontamination ends when the treatment chemicals are removed or neutralized and all decontamination activities, including waste disposal, are complete. However, the next phase, clearance, may begin before waste disposal, provided that all such wastes are outside a building or facility.

- **Clearance Phase**. After decontamination is completed, the focus is on determining the risk associated with reoccupying the facility and re-establishing airport operations. Appropriate experts review and evaluate key data, such as characterization and clearance sampling results, decontamination process parameters, and quality assurance/quality control (QA/QC) and other relevant information. Goals of the remediation activities are examined, and specific criteria are applied to judge the effectiveness of the decontamination process and to determine whether unacceptable risks remain in reoccupying the facility. Final decisions on clearance are made by local, state, or Federal public health officials, government agencies, or some combination, depending on site-specific jurisdictional authorities.

- **Restoration/Reoccupancy Phase**. The focus is on preparing an airport for reoccupancy. Activities include renovating areas that have been affected by an attack, and addressing the potential need for long-term monitoring to protect human health and the environment.

The focus of this document is on activities associated with the Characterization, Decontamination, and Clearance Phases. Annex A describes considerations for the Notification Phase and identifies key Federal agency contacts. Annex B describes considerations for the First-Responder Phase. These two initial phases occur to a large extent before detailed characterization and decontamination activities commence. It is however probable that some of the initial activities will take place concurrently with certain cleanup activities. Mobilization and onsite preparations for cleanup should not be delayed until completing first-response activities, but should begin early during a response. Furthermore, other actions associated with the six principal

phases do not necessarily occur in strictly sequential order and may be concurrent. For example, preparation for the Characterization Phase should begin as soon as practical after confirmation of an incident and not be delayed until the First-Response Phase ends. Similarly, different portions of a facility may be in different phases at the same time. All key responders should be notified and mobilized early during response regardless of the phase of activity during which responders have primary responsibility.

Response and Recovery					
Notification	**First Response**	**Remediation/Cleanup**			**Restoration/ Reoccupancy**
		Characterization	**Decontamination**	**Clearance**	
Receive information on chemical incident Identification of suspect release sites Notification of appropriate agencies	Initial threat assessment HazMat and emergency actions Forensic investigation Public health actions Initial environmental sampling Determine agent type and concentration Risk communication	Detailed characterization of CWA or TIC Characterization of affected site Site containment Prompt source reduction Continue risk communication Characterization environmental sampling and analysis Initial risk assessment Clearance goals	Decontamination strategy Remediation Action Plan Worker health and safety Site preparation Continued source reduction Waste disposal Decontamination of sites, items, or both Verification of decontamination parameters	Clearance environmental sampling and analysis Clearance decision	Renovation Reoccupation decision Potential long-term environmental and public health monitoring

Figure 1-1. Response and recovery phases following chemical contamination. The focus of the *Remediation Guidance for Major Airports after a Chemical Attack* is on characterization, decontamination, and clearance activities (areas shaded blue).

This document does not describe in detail public health responses to release of a CWA or TIC. If laboratory analytical results confirm the presence of a chemical of concern, the responsible public health agency involved in the response will commence appropriate public health actions, such as treatment and decontamination of potentially contaminated individuals, and medical examinations. See the Centers for Disease Control and Prevention (CDC) website for more information on public health response: <http://www.bt.cdc.gov/>. Effective communication with

the media and public is an essential component of response and recovery. Although the topic is beyond the scope of this document, many helpful resources are available. See, for example:

<http://www.epa.gov/NHSRC/pubs/reportWHOhandbook120706.pdf>.
<http://www.epa.gov/superfund/community/pdfs/Toolkit/3comstrats.pdf>.
<http://www.bt.cdc.gov/firsthours/>.

Many other references and websites contain useful information for local, state, and Federal responders in the event of an incident involving a CWA or TIC release. See the reference list at the end of Section 1 for sources of information.

1.2 Scenarios

This *Remediation Guidance* considers the nerve agents tabun, sarin, soman, cyclosarin, and VX; the blister agent sulfur mustard; the choking agent phosgene; and the blood agents hydrogen cyanide and cyanogen chloride. Of these nine chemicals, the first six listed above are referred to collectively in the *Remediation Guidance* as CWAs, and the last three are referred to collectively as TICs. All nine chemicals are referred to collectively as "chemicals of concern." See Section 2.3.3 for a review of characteristics of the chemicals of concern.

Following the release of a CWA or TIC, immediate actions must be taken because of their acute toxicity. Passengers and airport personnel are immediately at risk and, depending on the chemical of concern, may begin to show symptoms within seconds of exposure. Some CWAs, including sulfur mustard, result in a delayed onset of symptoms.

Pre-incident remediation guidance must be flexible enough to apply to a wide variety of potential contamination scenarios. Figure 1-2 shows that potential indoor-release scenarios range from a single location in which a release is overt and symptoms are immediate, to multiple locations in which releases are covert and only discovered as former passengers begin to show symptoms later (a delayed-onset CWA). A few transit systems currently use real-time, early-warning chemical-detection and emergency management systems. For example, the GID-3, Centurion, or ChemSentry 150C are available, however their operation in an airport civilian setting still requires validation and appropriate verification of detection limits. Annex D Annex describes early-warning detection technologies in more detail.

Because CWA and TIC properties vary widely—from reactive and volatile compounds, such as phosgene, to persistent compounds, such as VX—this *Remediation Guidance* describes numerous decontamination technologies. Depending on its identity, the quantity of chemical released, and the type of materials contaminated, different decontamination measures might be required. Procedures for selecting decontamination technologies appropriate for specific CWA and TIC properties as well as contaminated materials are discussed in detail in Annex F.

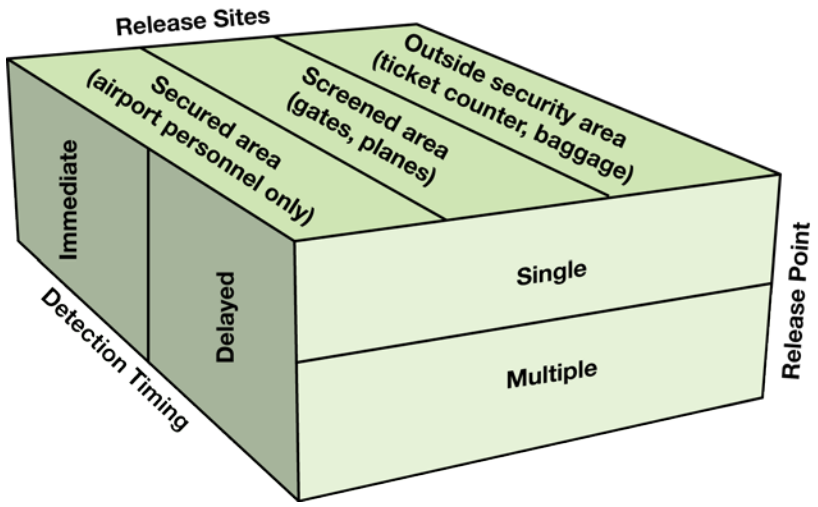


Figure 1-2. Range of potential indoor-release scenarios for contaminating a major airport following the release of a CWA or TIC.

A sound incident- and site-specific remediation response must develop information needed to rapidly characterize the chemical of concern, the site, and determine decontamination actions for an entire airport (in the case of multiple releases throughout an airport) as well as for isolating and decontaminating a portion of an airport (in the case of a small-scale, overt release).

1.3 Example Airport and Scenario

This *Remediation Guidance* is general in nature and applies to any major airport. However, an example terminal was selected because specific structures can provide concrete examples of concepts. The Tom Bradley International Terminal (TBIT) at the Los Angeles International Airport (LAX) was selected as the example terminal. LAX is owned and operated by Los Angeles World Airports (LAWA; see <http://www.lawa.org/lax/>); their participation and support is greatly appreciated.

Figure 1-3 is a schematic of LAX. The airport consists of eight terminals (Terminals 1–8) and the TBIT. Terminals 2, 4, 5, 6, and 7 provide international service in addition to domestic. All eight terminals are located on the outside of a U-shaped roadway, and all have upper and lower levels. Terminals 1, 2, and 3 comprise the north side of the U-shaped roadway; Terminals 4, 5, 6, 7, and 8 comprise the south side of the roadway; the TBIT is at the west end.

The terminal building and boarding areas at the TBIT are similar to those at many large airports. In addition to ticket counters, boarding gates, and baggage handling areas, numerous merchants, restaurants, and other vendors are present. The TBIT has numerous, state-of-the-art baggage screening machines (e.g., CTX equipment).

Figure 1-3. Plan view of LAX terminals and boarding areas.

In addition to this *Remediation Guidance* and annexes, which are designed to be applicable to major airports, data supplements were developed specifically for the TBIT. The data supplements include a detailed description of the airport, including sizes of areas, volumes of areas, materials present, and the HVAC system. To obtain any data supplement referenced in this document, a request must be made directly to the LAWA Emergency Planning Operations Division.

Sarin was selected for inclusion in the example scenario because this nerve agent is one of the most toxic and rapidly acting of known chemical terrorism agents. Pure sarin is a viscous, faintly odoriferous, colorless, and volatile liquid at room temperature. Sarin would evaporate and easily spread by the airflow of air-conditioned indoor environments. The volatility of sarin is ~22,000 mg/m^3 at 25°C. Vapor levels would depend on numerous conditions, such as the mass of material released, temperature, dissemination method, room size, and air exchange rate. Such

variables can cause vapor levels to range over many orders of magnitude. Sarin is heavier than air and, if introduced from overhead vents it could sink to the breathing zone and floor, increasing the exposure hazard for people. Pure sarin evaporates completely—although more slowly than water—from hard, impervious surfaces. It can be absorbed into many elastomeric (rubber-like) compounds and sealants, such as silicone caulking, and it can persist for months in such materials. Some clothing items in contact with sarin vapor can absorb and continue to release the vapor over time.

In the example scenario used in this *Remediation Guidance*, an indeterminate quantity of sarin is released over a relatively short time in a publicly accessible area of the ticketing level of the TBIT. The quantity is indeterminate because of the hypothesized characteristics of the container and release mechanism. It is assumed that all TBIT mechanical ventilation systems are operating at the time of release, as designed. In the example scenario, assumed operating conditions are 20% outside air and 80% recirculated air.

1.4 Remediation Response Structure

Figure 1-4 shows the remediation Incident Command (IC) structure for addressing a CWA or TIC release at a major airport. The relations shown among organizations involved in remediation activities conform to the *National Response Framework* (NRF) (DHS 2008), the National Incident Management System (NIMS 2008), and the Environmental Protection Agency Incident Management Handbook (EPA 2007). Table 1-1 identifies representatives from various agencies and organizations that make up the command structure during remediation activities (because agencies have different names in different states, generic labels are used for some types of agencies). Data Supplement A provides a specific consequence-management-phase command structure for LAX.

A Unified Command (UC) is formed when more than one agency has incident jurisdiction or when incidents cross different political jurisdictions. A designated agency official on the UC from the government, for example, is an individual who has jurisdictional authority and functional responsibility under statute or ordinance to manage a specific aspect of an emergency. The designated agency official's position and command authority are stipulated by law, ensuring that the UC consists of individuals who can make high-level decisions in a crises situation on behalf of an agency or organization without relying on approval from superiors when such approval might delay critical actions. Representatives must be able to commit resources to support the incident response, if needed. They must work cooperatively with other agencies and organizations to establish objectives and strategies, identify priorities, and develop Incident Actions Plans (IAPs), as defined in the NIMS. An incident of this type is likely to use the Operational Period Planning Cycle process (EPA 2007) to manage the development of IAPs.

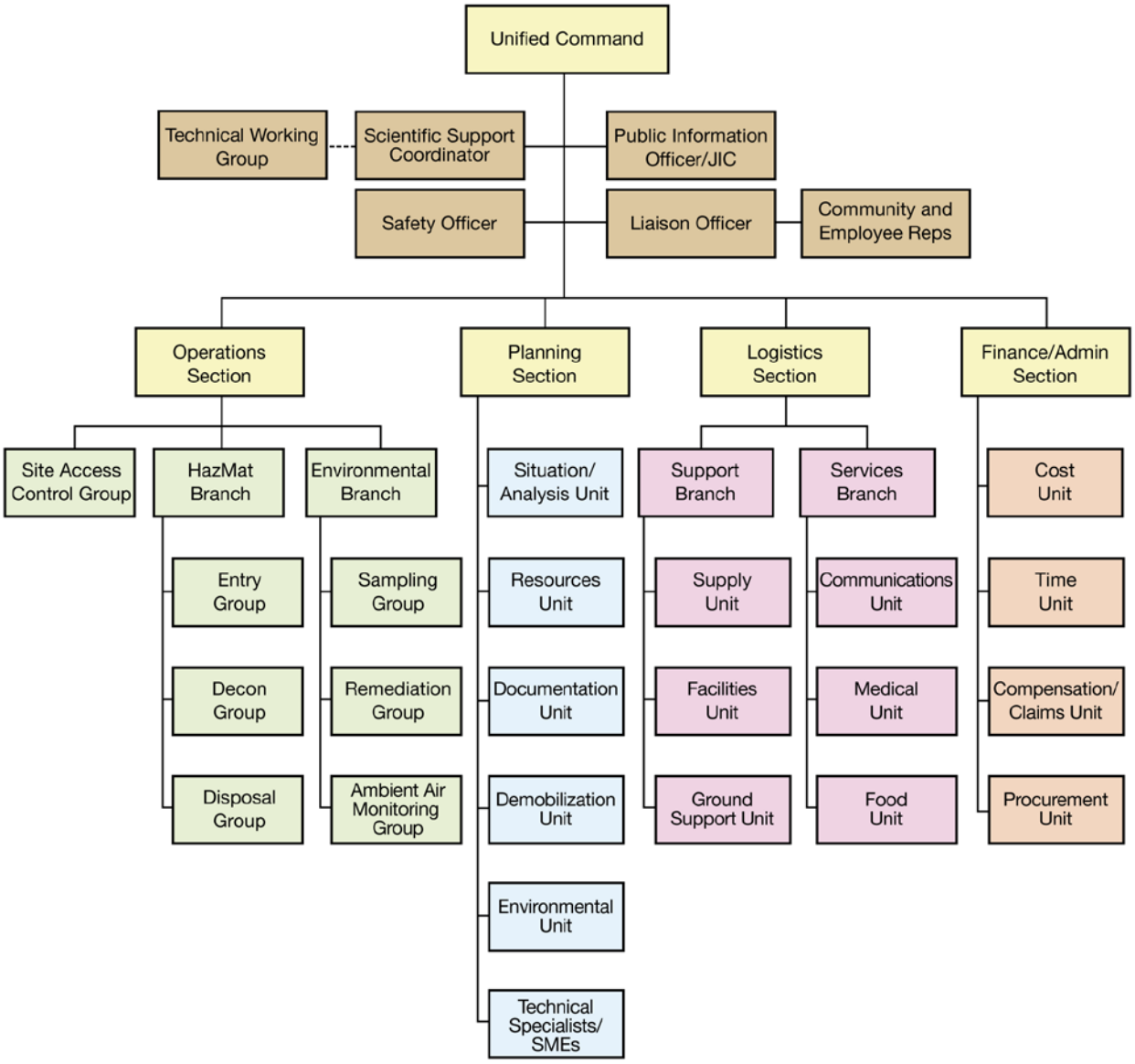


Figure 1-4. Remediation Incident Command Structure for a CWA or TIC release at a major airport. See Table 1-1 for more details.

Table 1-1. Agency representatives within the remediation incident command structure.[a]

Position in the UC	Agency Representatives
Unified Command	US Environmental Protection Agency (EPA) On-Scene Coordinator (OSC) State emergency management agency (State EM) On-Scene Coordinators State agency responsible for environmental protection (State EP) Airport Environmental Management Airport Police Department Airport Operations County Public Health Officer
Safety Officer	County Public Health- Safety Officer
Public Information Officer	Airport Public Relations
Operations Section	Section Leader: EPA
HazMat Branch	EPA, State EM
Entry Group	County Fire Department HazMat Team; contractors; State National Guard Civil Support Team; U.S. Coast Guard PST
Decon Group	EPA Decontamination Team; contractors; County Fire Department
Disposal Group	EPA, EPA ERT, EPA Decontamination Team, State EP, airport, contractors
Environmental Branch	EPA, agency responsible for environmental protection
Sampling Group	EPA, State EP, State National Guard Civil Support Team, contractors, U.S. Coast Guard PST, City Fire Department
Remediation Group	EPA, EPA Decontamination Team, State EP, contractors
Ambient Air Monitoring Group	Air Quality Management District; EPA; EPA ERT
Site Access Control Group	Airport Police Department, City Police Department
Planning Section	Section Leader: EPA
Situation/Analysis Unit	EPA, State EP, County Public Health, Airport C&M, Airport Operations, Airport Terminal Ops, Airport Engineering, City Fire Dept., Airport Environmental, contractors
Resources Unit	FEMA, EPA, State EP
Document Unit	EPA, contractor
Demobilization Unit	EPA, State EP, contractor
Environmental Unit	Airport Environmental, EPA, State EP, Local air quality management district, State Dept. Public Health, ATSDR, State water quality agency, County Public Health
Technical Working Group	Government Agencies: State Dept. Public Health, State EP, CDC, County Dept. of Public Health, County Fire Dept. Health HazMat. Div., DHS, DOE National Laboratories, EPA Region, EPA National Decontamination Team, EPA Environmental Response Team, OSHA Health Response Team, TSA, City Fire Dept., Private Industry, Academia
Logistic Section	
Supply Unit	FEMA, EPA, State EM, State EP, contractor
Facilities Unit	Airport Airfield Operations
Ground Support Unit	Airport Airfield Operations, Airport Police Dept. Traffic, City Fire Dept., Airport C&M, contractors
Communications Unit	State National Guard Civil Support Team, City Fire Dept., City Police Dept.
Medical Unit	County Public Health, County Health Services
Food Unit	FEMA, State EM, City Police Dept., City Fire Dept., All agency representatives
Finance and Admin Section	Section Leader: FEMA, State EM
Cost Unit	All response agencies
Time Unit	All response agencies
Compensation/Claims	All response agencies
Procurement Unit	FEMA, State EM, County, City, Airport Procurement, EPA

[a]Because agencies have different names in different states, generic labels are used for some types of agencies.

During pre-planning, local, state, and Federal agencies that have jurisdictional authority during an incident need to identify appropriate individuals who can serve in the UC. Because the makeup of the UC can change as an incident shifts from one phase to another, pre-planning should address possible changes in command.

The physical field location where primary, tactical-level functions are performed is referred to as the Incident Command Post (ICP) (NIMS 2008; DHS 2008). Because the UC for remediation activities is established at the ICP, the selected location requires sufficient space to accommodate all local, state, and Federal representatives serving on the UC. An airport's Emergency Operations Center (EOC) supports the airport's designated agency official in the UC by locating resources, coordinating mutual aid, and facilitating communication with other airport organizations. If the airport EOC were located within the contamination zone following the release of a chemical of concern, then the EOC would relocate to another facility. Thus, it is important for airport managers to identify alternative facilities that can serve as the EOC. The ICP can be established within the airport EOC. However. the functions performed at the airport EOC are separate from UC functions performed in the ICP.

The Secretary of Homeland Security is the Principal Federal Official (PFO) responsible for coordinating all domestic incidents requiring multi-agency Federal response (DHS 2008). The Secretary may elect to designate a single individual to serve as his or her primary representative to ensure consistency of Federal support. Federal assistance for incidents that do not require DHS coordination may be led by other Federal departments and agencies, consistent with their authorities.

In the language of the NRF, an Area Command is established to oversee the management of (1) *multiple incidents* that are each being handled by an ICS organization or (2) *large or multiple incidents* to which *several* Incident Management Teams have been assigned. Within the ICS, the Planning and Operations Sections have the primary responsibility for developing and implementing the various plans that are used to accomplish characterization, decontamination, and clearance (i.e., the Remediation or Cleanup phase of Consequence Management that is the primary focus of this document; see Figure 1-1). The roles of the Environmental Branch (Operations Section) and Environmental Unit (Planning Section) for a terrorist incident are described in EPA 2007 (pp. 21–23) as follows:

> "EPA establishes an Environmental Branch (EB) in the Operations Section to carry out environmental characterization and restoration activities including decontamination of building surfaces, spaces, and sensitive items. The EB is responsible for environmental sampling, air monitoring, waste management and disposal, construction, and engineering inside and outside the hot zone. EPA establishes an Environmental Unit in the Planning Section. The Environmental Unit is responsible for planning and strategy (e.g., site characterization strategies, sampling and analysis plan, quality assurance, laboratory networking, facility decontamination plan, containment/barrier strategies, fumigation options, decontamination verification methods, environmental clearance, re-occupancy plans), and will coordinate with

> Headquarters Environmental Unit for an INS. The Environmental Unit maintains very close liaison with the Operations Section in the development of tactical plans and coordinates with the Scientific Support Coordinator and Headquarters Environmental Unit (if established). The Operations Section has overall responsibility for developing and implementing tactical operations designed to achieve the incident objectives established by the UC."

In addition, the Environmental Unit Leader determines the need for technical specialists, that is, individuals who have specialized knowledge and expertise in any area needed to support the remediation effort. The expertise is not necessarily scientific; for example, a data management specialist might be needed. Technical specialists can function within the Planning Section or be assigned wherever their services are required (EPA 2007).

Another Environmental Unit Leader responsibility is to support a Scientific Support Coordinator (SSC) when one is assigned to an incident (EPA 2009). The SSC is a technical specialist and is defined in the NCP (NCP 300.145) as the principal advisor to the IC for scientific issues. The SSC is supported by a Scientific Support Team and can provide a range of scientific support services to the Federal On-Scene Coordinator (FOSC). Although often seated with the EU to support the overall response effort, the SSC has a primary responsibility to serve the FOSC directly as a staff member. Important functions of the SSC are to gain consensus on scientific issues affecting the response (EPA 2007) and to ensure that different opinions within the scientific community are communicated to the FOSC. The SSC may convene as needed, chair, and direct Technical Working Groups (TWGs; EPA 2007). Given the potentially complex, costly, and time-consuming nature of remediation following a CWA or TIC attack, establishing a TWG, though not required, would contribute to effective and efficient planning for remediation. Table 1-2 identifies areas of technical expertise that might be needed in the ICS or on a TWG. TWG members could be identified in advance, meet periodically, and should review this *Remediation Guidance* document for the purpose of pre-incident preparation.

Table 1-2. Technical specialties that may be needed in a CWA or TIC response.

Areas of expertise	Agencies and organizations providing experts
Organic and reactive chemistry	Environmental Protection Agency, state environmental protection, state and local health agencies, analytical laboratories, national laboratories, universities
Federal and state waste-transportation and disposal requirements	Department of Transportation, waste management board, Environmental Protection Agency, state environmental protection
Ambient air monitoring	State Air Resources Board, Local Air-Quality Management District, Environmental Protection Agency, Environmental Response Team, National Guard Civil Support Teams
Environmental sampling	Environmental Protection Agency, Environmental Response Team, state environmental protection, environmental health department, National Guard Civil Support Teams, Centers for Disease Control
Chemical analysis	Environmental Protection Agency, state and local public health, analytical laboratories
Chemical engineering	Environmental Protection Agency, private sector, universities
Decontamination methods	Environmental Protection Agency, National Decontamination Team, Environmental Response Team, National Homeland Security Research Center, private sector
Risk assessment and toxicology	Environmental Protection Agency, Centers for Disease Control, National Homeland Security Research Center, national laboratories, state and local health agencies, modeling experts, Centers for Disease Control

A Joint Field Office (JFO) may be established to coordinate Federal support for the on-scene response effort and to conduct broader support operations that extend beyond the affected site or facility. The JFO does not manage on-scene response efforts. The governor of the state in which an incident occurs may request that the U.S. President declare a Presidential Disaster Declaration under the Stafford Act. If the request is granted, the Federal Emergency Management Agency (FEMA) issues mission assignments to appropriate Federal agencies to support a response. The EPA would likely receive mission assignments for decontamination and other remediation activities under Emergency Support Function (ESF) #10, “Oil and Hazardous Material Response,” and possibly under ESF #1,”Transportation,” of the NRF.

1.5 Pre-Incident Planning

Reducing the time required to reinstate operations at an airport is a major goal of remediation planning and a theme throughout this document. One of the initial tasks of the IC or UC for remediation will be to set incident-specific objectives. The following checklist of potential objectives is suggested as a starting point and should be modified as necessary:

- Review available health-based guidance levels such as PALs, AEGLs, etc.
- Mobilize necessary resources, including those for characterization and decontamination.

- Salvage essential and sensitive items.
- Address waste disposal issues.
- Arrange for necessary permits and any fees that may be applicable.

Airport management, in consultation with appropriate agencies and technical experts, can address many important functions well in advance of a chemical contamination incident. Table 1-3 identifies essential pre-incident planning activities related to the remediation response structure.

Table 1-3. Summary of concept-of-operations actions to be taken prior to a CWA attack.

Responsible Personnel	Pre-Incident Actions
Airport management	• Identify members of the command structure early in the pre-planning process. Determine which agencies contribute tactical or service resources versus those that supply technical assistance or special expertise. Members of the command structure, as well as facility management, should review this *Remediation Guidance* document. • Identify alternative locations for an Incident Command Post, preferably near the airport, but offsite in the event that an onsite operations center is contaminated. Ensure the ICP has computer hookup and plotter capabilities. • Identify potential members of a Technical Working Group. Encourage members to review this *Remediation Guidance* document. • Identify a primary analytical laboratory that is equipped and trained to analyze environmental samples containing CWAs or TICs of concern. • Train security personnel, and conduct periodic training exercises with likely command personnel, including technical specialists, and other responder and agency representatives. Ensure all such individuals have appropriate health and safety training. • Identify agencies that should be notified of an incident of this type, including the National Response Center (NRC), the Office of Emergency Services (OES) Warning Center, and any appropriate local (e.g., city, county, and state) emergency response agencies. The NRC and OES will take an incident report and notify all appropriate Federal and state agencies, respectively. There is no need to call each agency individually, unless such action is specifically called for in a local hazardous materials response plan. • See Table 2-4 for additional pre-planning actions, some of which will also be useful for first responders (such as rapid access to floor and HVAC plans)/

1.6 Section 1 References

The following sources contain both general and specific information relevant to many of the topics discussed in this section.

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

DOT (2004), *Emergency Response Guidebook* (ERG), developed jointly by Transport Canada and the U.S. Department of Transportation; available at <hazmat.dot.gov/pubs/erg/erg2004.pdf>.

DOT Hazardous Materials Regulations (49 CFR, Parts 100–185).

EPA (November 2004), Environmental Protection Agency, *Environmental Unit in an ICS Structure—Guidance Document*; this draft 19-page document may be available from the your local EPA Region staff.

EPA (2007), *Environmental Protection Agency—Incident Management Handbook;* downloaded May, 2009, from < http://epaosc.net/site_profile.asp?site_id=963>

EPA (2009), *Environmental Protection Agency Incident Command System, Environmental Unit Leader Job Aid*, July 2009; available at <http://epaosc.net/doc_list.asp?site_id=963>.

EPA Field Service Kits, available at <www.static-safe.co.uk/pdf/SSE_9-18.pdf>.

NIOSH (August 2006), National Institute for Occupational Safety and Health, *Pocket Guide to Chemical Hazards*, NIOSH Publication No. 2005-149; available at <http://www.cdc.gov/niosh/npg/>.

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

NRT (February 2008), National Response Team, *Chemical Quick Reference Guides*, (for the G-agents, VX, and HD); available at <www.nrt.org>.

Raber, E., J. M. Hirabayashi, S. P. Mancieri, A. L. Jin, K. J. Folks, T. M. Carlsen, and P. Estacio (2002), "Chemical and Biological Agent Incident Response and Decision Process for Civilian and Public Sector Facilities," *Risk Analysis* **22**(2), 195–202.

Sidell, F. R., W. C. Patrick, T. R. Dashiell, K. Alibek, and S. Layne (2005), *Jane's Chem-Bio Handbook*, 3rd edition, published by Jane's Information Group.

State of California, Office of Emergency Services (OES) (January 2006), *Hazardous Materials Incident Toolkit*; accessed January 2, 2008, available at: <http://www.oes.ca.gov/Operational/OESHome.nsf/Content/333C7C454B5FC40B882571070069A855?OpenDocument>.

USCG (April 2001), *Incident Management Handbook,* U.S. Coast Guard, Washington D.C.; available at <homelandsecurity.tamu.edu/framework/dhls/coastguard/u-s-coast-guard-incident-management-handbook/>.

2 Characterization

Remediation activities begin with the Characterization Phase, which consists of gathering information needed for subsequent activities, including decontamination (Section 3) and clearance (Section 4). Characterization includes assessing the extent of contamination and obtaining positive confirmation of a chemical of concern using a reliable laboratory, if such confirmation was not obtained during the First-Response Phase. Containment and source reduction, in addition to any done during first response, should begin as promptly as possible. Sections 2.2.4 and 3.4.1 discuss these topics. A key element of characterization is environmental sampling of a facility. There may be different plans for different media (e.g., surfaces and air) or different sections of a facility; the exact selection of plans will depend on incident-specific details. Plans are discussed further in Section 2.4.

Section 2 assumes that sampling plans will be developed if not by the EPA, then under its authority. Therefore, both the development and documentation of sampling plans should be consistent with the considerable EPA guidance available on this topic. Key guidance documents include the *Intergovernmental Data Quality Task Force Uniform Federal Policy for Quality Assurance Project Plans—Evaluating, Assessing, and Documenting Environmental Data Collection and Use Programs* (EPA 2005a) and *Guidance for Quality Assurance Project Plans* (EPA 2002). See Annex H for an overview of requirements for sampling plan documentation and additional references.

The command structure described in Section 1.4 is likely to be in place before first-response activities are complete. If a UC for remediation is not yet established, it is established now. If a UC for remediation is already established, this would be a likely time for a transfer of command. For example, some of the agencies serving in the UC for first-response activities (e.g., fire, police, and FBI) may transfer their command roles to Incident Commanders representing other government agencies (e.g., environmental-response and public health agencies) once immediate threats to life safety have abated and first-response objectives have been achieved. An orderly transition from one command to another should take place over a half to full operational period to allow all representatives to be fully briefed.

The UC or organization in charge mobilizes the resources required for characterization and begins to activate resources needed for decontamination and clearance. If possible, resources should be assembled before first-response activities are complete. Data collected during first response are compiled by the Planning Section's Environmental Unit (EU) and assessed. For instance, information from first response (e.g., from first response sampling, photographs, and witnesses) is used to approximate the locations of contamination and determine which areas may benefit from prompt source reduction. A Health and Safety Plan (HASP; Section 2.1.2) will be needed. This plan will likely include a review of the incident perimeter and the exclusion or "hot" (contaminated) zone, contamination reduction (or "warm") zone, and support or "cold" zone that were established by first responders.

Characterization

Positive confirmation of a CWA or TIC begins with proper sampling followed by proper extraction and analysis and full quality assurance in a laboratory that is experienced in analyzing CWAs, their breakdown products, and TICs. Relatively few laboratories can perform the required analyses. Examples include a laboratory that has been certified by the Organisation for the Prohibition of Chemical Weapons (OPCW), an Environmental Response Laboratory Network (ERLN) laboratory, or other public-health-approved laboratories. [In the U.S., CWA laboratory certification is also referred to as Chemical Weapons Convention certification. Examples of such laboratories include those at Lawrence Livermore National Laboratory (LLNL) and the Edgewood Chemical Biological Center (ECBC) at Aberdeen Proving Ground, Edgewood, MD.] It is highly desirable to work with a laboratory that has access to authentic standards of the suspect chemicals and can provide undisputed confirmation of a chemical's identity. The document, Standardized Analytical Methods for Environmental Restoration Following Homeland Security Events (EPA 2011), identifies methods for testing environmental contaminants. Methods listed in the EPA document are undergoing validation with authentic standards of CWAs. Pending results of this work, more laboratories could be in a position to provide chemical analyses during a national emergency. Once the identity of the chemical in question has been unambiguously determined, it may be possible to use field-portable instruments or mobile laboratories to support characterization, provided that the methods used meet incident-specific performance requirements.

Clearance goals should be developed as early as possible because they must be incorporated into characterization activities, decontamination design, and clearance strategy. Characterization sampling and analysis need to use methods and strategies capable of identifying areas in which contamination is above (greater than) clearance goals and areas that are below them. Although decontamination techniques may largely be determined by the best methods available at the time, their selection depends on clearance goals because the techniques must be effective enough to meet such goals. Clearance goals affect clearance strategy because the clearance strategy must be able to demonstrate that clearance goals have been met. For example, if a clearance goal includes a requirement that average post-decontamination surface concentrations must be less than a specified value, then clearance sampling must be designed to estimate the average to within a specified degree of uncertainty. Thus, it is best if the initial assessments described in Section 2.2 take place simultaneously with development of clearance goals described in Section 2.3.

In broad terms, there are two types of decontamination techniques: targeted (or spot) decontamination of surfaces and gas or vapor decontamination in which entire volumes are flooded with a gas or vapor decontamination reagent. The two types of decontamination technique require different kinds of information from characterization. The amount of effort devoted to facility characterization can be flexible. For example, where the presence of contamination is obvious (e.g., bulk CWA or TIC in liquid pools or splattering from a sprayer), formal characterization may not be necessary. However, where contamination is not visually obvious, characterization needs to be well planned.

Suggested characterization strategies are in accordance with the following conceptual model:

In and around the release location, there will be an area of known or assumed contamination. In this area, characterization sampling is focused on source reduction and identifying what types of materials are contaminated. Moving away from the release location are areas where contamination is considered highly likely, but not confirmed. In such areas, sampling is focused on rapidly confirming the expectation of contamination. Next are areas that may or may not be contaminated; the focus is on rapidly finding contamination if present, but because contamination may not be present, the focus is also on beginning to develop some confidence that the areas are clean, if that is the case. Finally, depending on the size of a release and the facility layout and structure, there may be areas relatively distant from the release that are plausibly not contaminated at all. Here, the focus is on generating confidence that such areas are, in fact, not contaminated.

Incident-specific information is needed to make the assessments that are essential to the characterization strategy; such assessments are topic of Section 2.2. The strategy is developed in more detail in Section 2.4.1; see also Section 2.2.9.

The following sections describe activities that take place as part of characterization, including initial startup (Section 2.1), various types of initial assessments (Section 2.2), the development of clearance goals (Section 2.3), and the development and execution of a formal characterization plan (Sections 2.4 through 2.6). Section 2.7 summarizes pre-incident planning relevant to characterization. Decontamination and waste management planning (Section 3) is, and some decontamination and waste management activities may be, conducted during the characterization phase. These activities, especially waste management, will also involve sampling and analysis.

2.1 Initiate Startup Activities, and Mobilize Resources

Characterization activities can begin as soon as contamination by a CWA or TIC is suspected, or immediately upon confirmation of such contamination even if first-response activities are not complete. The UC or organization in charge establishes an ICS structure, which may include technical specialists, and mobilizes other resources (personnel and equipment) needed for characterization. Resource personnel who should be ready to respond on short notice include:

- Sampling teams, which should have up-to-date training.
- Analytical laboratories with experience, certification, and security. If contamination is widespread, requiring many characterization environmental samples, the primary laboratory may have insufficient capacity, and additional laboratories would be recruited.
- Airport personnel who maintain current information on the physical facility, such as architectural drawings and operation of HVAC systems. Copies should be stored offsite.
- Facility HVAC operators or maintenance contractors knowledgeable about HVAC system operation.
- Numerical modeling and sampling design experts.
- Data management and documentation specialists to organize a database for environmental sampling results. Existing tools, used by people familiar with them, are preferred.

- Contractors with experience in planning and performing environmental remediation projects, including a QA/QC plan and using data-quality objectives or equivalent process.
- Contractors to construct containment barriers for contamination and isolation barriers for sensitive equipment, and to conduct prompt source reduction under hazardous conditions.
- Contractors with expertise in waste management, owners of waste-disposal facilities, and wastewater management authorities.
- Experts from the EPA's National Decontamination Team, National Homeland Security Research Center (NHSRC), and Environmental Response Team (ERT), who can provide technical support.

The startup time for characterization will be reduced if resources are identified in advance. Annex D discusses environmental sampling and analysis methods, and Table 3-1 and Annex Table F-5 list available resources for decontamination. Templates to help authorities prepare characterization, decontamination, and clearance plans are in Annexes H, I, and J. Most EPA regional offices maintain a list of qualified environmental remediation contractors. EPA On-Scene Coordinators (OSCs) have access to contractors trained to perform environmental sampling. The EPA National Decontamination Team, which provides technical support to OSCs, is a valuable source of information. The EPA has dedicated contracts in place for the Superfund Technical Assistance and Response Team (START) and Emergency Rapid Response Services (ERRS) for sampling and assessment and for cleanup and disposal activities, respectively. Planners should refer to the EPA Region 9 *Compendium of Special Teams, Assets, and Capabilities*, which briefly describes each special team and asset that can provide technical support to the Federal OSC during a major disaster or hazardous materials emergency. The National Response System (NRS) mechanism by which the OSC mobilizes technical resources is described in the National Contingency Plan (NCP 1994); see <http://www.epa.gov/oem/content/nrs/snapshot.htm> (accessed June 19, 2009) for an overview of the NRS.

Airport planners should be familiar with local resources, including those available through their local EPA offices, and should establish a working relationship with personnel at those offices before an incident. If feasible, airports should have contracts in place with environmental consultants and cleanup contractors for characterization and decontamination work. Another option is for airports to modify their existing environmental cleanup contracts to include CWAs and TICs.

2.1.1 Activate Data Management Systems

Data management systems must be in place before characterization samples are collected. It is imperative to have a data-collection, processing, storage, and reporting system in place that efficiently manages data, ensuring and documenting its integrity. A good data management system helps determine whether analytical data meet measurement quality objectives, tracks samples through the entire process from collection through the return of results from the laboratory, and provides flexible and convenient access to results for the purpose of interpretation. An example is BROOM software from Sandia National Laboratories. EPA Scribe is an EPA data-management system for use by OSCs. Data management is especially important

if sampling teams from more than one outside organization (contractor) collect the samples. The value of sampling is undermined if sampling itself is not well documented. Documentation requirements are described in Annex D, and sampling plan templates are provided in Annex H. The Characterization Sampling and Analysis Plan (SAP), discussed later in this section, should describe how data management is conducted. See Annex H for a template to facilitate preparing a Characterization SAP. Digital photographs of every sampling location can help document the sampling activities. Annex D contains additional details on sample control and documentation.

2.1.2 Write Health and Safety Plan

A Health and Safety Plan (HASP) is required by the Occupational Safety and Health Administration (OSHA) (29 CFR 1910.120) for characterization, decontamination, and clearance activities. The HASP describes physical, chemical, and biological hazards at the site and should include procedures for discovering any unknown hazard. Hazards following a CWA or TIC attack arise not only from the chemical itself but also potentially from breakdown products and decontamination chemicals. The plan describes the establishment of HazMat hot (contaminated), cold (uncontaminated), and contamination reduction (warm) zones for use by hot-zone entry personnel; personal protective equipment (PPE) requirements; personal decontamination procedures (see for example California OES 2006); and emergency procedures to be used by sampling and decontamination personnel. HazMat zones established during the First-Response Phase can be used or modified. Additional zones for more entry points may need to be established. See NIOSH/OSHA (2006) for information about PPE. First responders will have established an incident perimeter and an exclusion or "hot" (contaminated) zone, a contaminant reduction zone (transition area where response personnel are decontaminated), and a support or "cold" zone (where contamination is unlikely), which can be used as starting points for the HASP.

A HASP for an incident involving chemicals of concern at an airport can be written by incorporating several existing documents and templates. One example is a HASP that was prepared for investigations of areas and buildings containing chemicals, including CWAs, at the Rocky Mountain Arsenal. This Defense Technical Information Center (DTIC) document entitled, *Rocky Mountain Arsenal, Procedures Manual to the Technical Plan, Volume 3: Project Health and Safety Plan*, is available upon request and is also available for purchase at: <http://www.stormingmedia.us/09/0911/A091192.html>. Other examples include: a template for a facility contaminated with anthrax, available at <http://www.osha.gov/dep/anthrax/hasp/index.html>; an OSHA electronic template for a general HASP, available at <http://www.osha.gov/dep/etools/ehasp/index.html>; and a recent EPA Environmental Response Team HASP template for chemical, biological, and nuclear incidents, available at: <www.ert.org>. A related document is the EPA's *Health and Safety Manual and Field Guide*, available at: <http://epaosc.org/_HealthSafetyManual/specific.htm>. Finally, EPA Region 9 has developed a *Consolidated Site-Specific Health & Safety Plan* (HASP) template, which is available from EPA Region 9 staff.

A substantial portion of the HASP (such as description of airport facilities, airport areas that can be used to stage personnel and equipment, the surrounding environment, and other site-specific information) can be written prior to an incident. Pre-selection of decontamination technologies, if possible, will also facilitate advance preparation of the HASP. Ultimately the UC, through the Site Safety Officer, is responsible for ensuring the health and safety of all responding entities through a unified HASP. The ICS planning process includes HASP development to ensure that consistent and coordinated health and safety measures are in place for all responding entities. The Site Safety Officer and Logistics Section's Medical Unit create the HASP.

In summary, airport management should identify the characterization resources shown in Table 2-1 in advance of an incident so that such resources can be mobilized immediately. Phone numbers and contacts should be verified at least once a year. Annex K lists contacts useful for all phases of remediation. Figure 2-1 summarizes the pre-incident, startup, and information-gathering activities associated with the Characterization Phase.

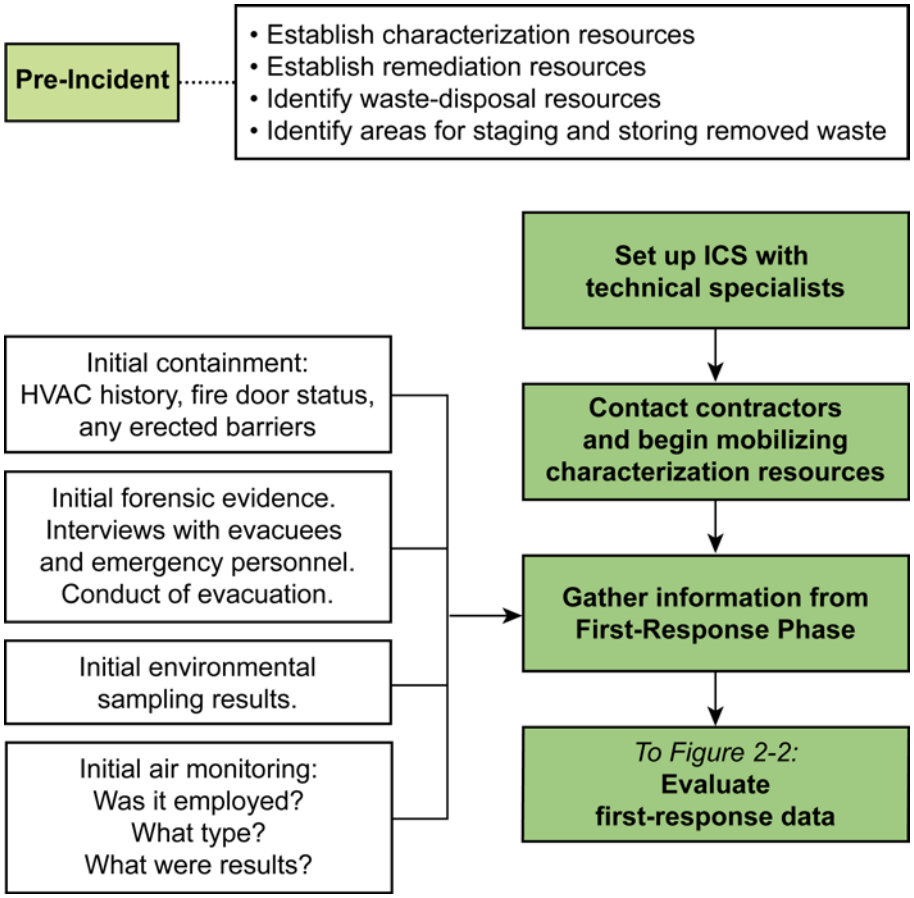


Figure 2-1. Pre-incident actions and startup activities related to characterization and information gathering from first response.

Table 2-1. Site characterization resources to identify as part of pre-incident planning.

Resource	Contact	Phone
Command		
Members of Incident Management Team		
Safety Officer		
State and local public health officials		
Operations Section		
Operations Section Chief		
Sampling team(s) and contractor(s)		
Remediation team(s) and contractor(s)		
Agent air monitoring team and contractor		
Assistant Safety Officer		
Planning Section		
Technical specialists (various; can be assigned to the Planning Section or Operations Section)		
Centers for Disease Control and Prevention (CDC)		
U.S. Environmental Protection Agency (EPA)		
Primary analytical laboratory		
Secondary analytical laboratory		
Air-transport modeling team and contractor		
Specialists with architectural and engineering drawings		
Data management and documentation specialists		
Remediation planning specialists		
Facility engineering and construction team(s)		
Waste-disposal resource personnel		
Wastewater management authorities		
Logistics Section		
Personal protective equipment (PPE) rental		
Other equipment and rental companies (e.g., decontamination supplies, generators, trailers, pumps, loaders, trucks, storage tanks, bins, construction material, blowers, negative air units, and so forth)		

2.2 Perform Initial Assessment

According to EPA Data Quality Objectives (EPA 2006), "The planning team will typically begin by developing a conceptual model of the problem, which summarizes the key environmental release, transport, dispersion, transformation, deposition, uptake, and behavioral aspects of the exposure scenario which underlies the problem. The conceptual model is an important tool for organizing information about the current state of knowledge and understanding of the problem, as well as for documenting key theoretical assumptions underlying an exposure assessment." A risk assessment includes identifying (1) potential sources (chemical(s) of concern, concentrations, time, and known or expected locations of contamination, (2) pathways for contamination (media, methods and rates of migration, time, and loss or gain of functions), and (3) receptors (types, sensitivities, time, concentrations, and numbers) (EPA (1989). The initial assessment guides many subsequent actions, so it is important that it be as thorough and accurate as possible.

Information about potential sources of contamination should be available from the First-Response Phase, which includes forensic investigation. The type of information depends on the method of release (Sections 1.2 and 2.2.1), such as overt or covert; location of release; mechanism of release, aerosol or explosive, and so forth. The assessment of known or expected locations of chemical(s) of concern is discussed in Section 2.2.1 as well as subsequently in Section 2.2.9 in the context of qualitative assessments and numerical modeling. A major airport is a complex facility that will likely be cleaned up in manageable zones or sub-zones. This topic is discussed in Section 2.2.5 and Annexes C and I. Some airport areas, especially those that are separate or distant from the location of an overt release, may be assessed separately. Some information about media that are, or can become, contaminated should also be inherited from the First-Response Phase, especially photographs of visible contamination, if any. This topic is discussed in Sections 2.2.6 and 2.2.7. The topic of exposure scenarios is discussed in Sections 2.2.8 and 2.3.

The FBI has indicated a willingness to share initial environmental sampling data, as appropriate, with the UC. If the information is not made available, airport remediation will be delayed. As a forensic investigation progresses, the FBI may release the facility in stages and allow some remediation activities to begin, such as characterization environmental sampling and source reduction of visible contamination, while it completes the collection of criminal and forensic evidence. In any event, characterization planning can begin before a facility is released. Figure 2-2 summarizes the initial assessment of data and subsequent steps leading to characterization.

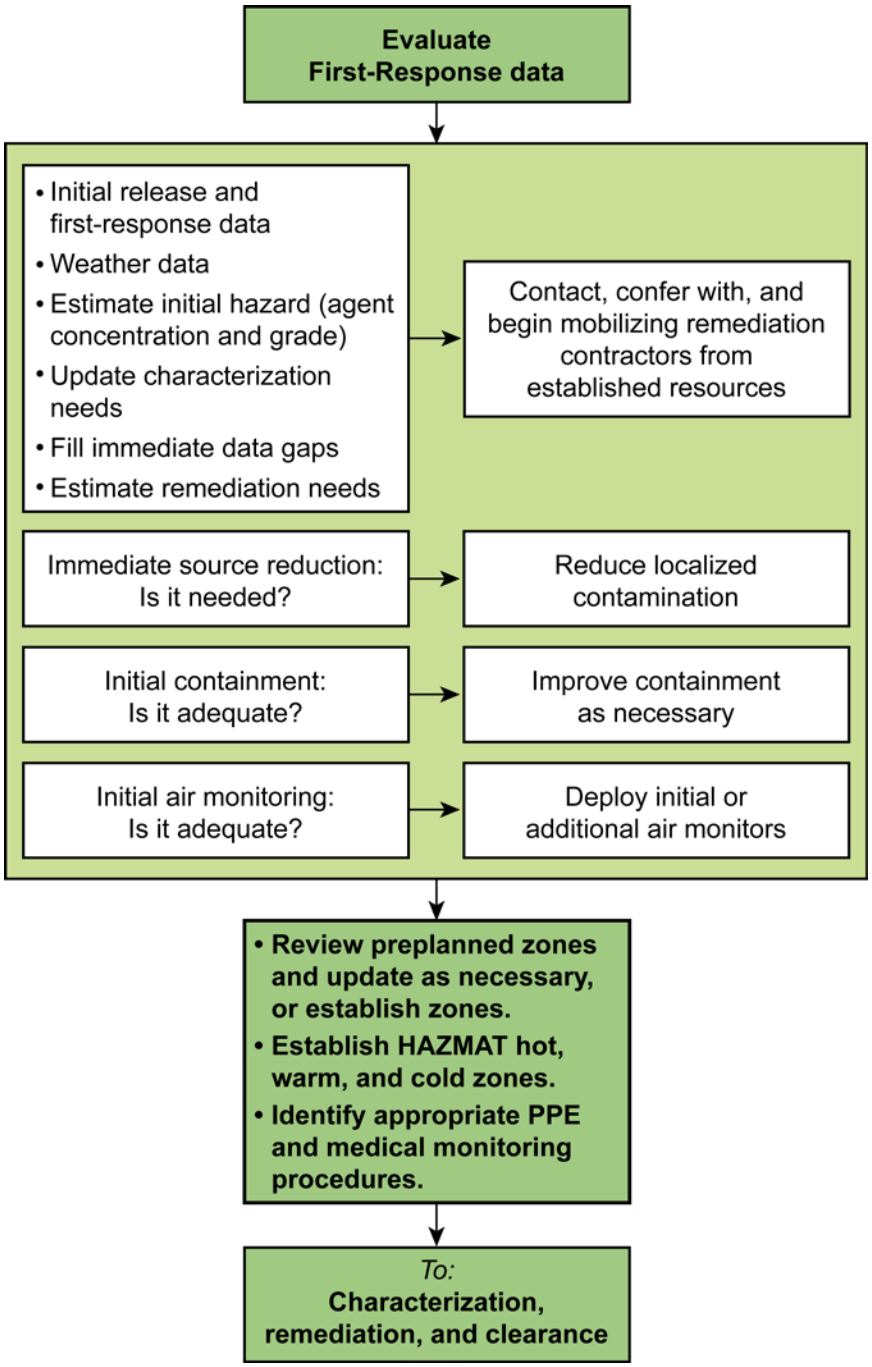


Figure 2-2. Evaluation of first-response data and steps leading to characterization.

2.2.1 Evaluate Initial Release and Any Early Data

Initial environmental sampling data and any other data collected during first response should be compiled by the Planning Section's Situation Unit and turned over to the EU for use in planning subsequent remediation actions. Decision-makers must make judgments about how much

confidence can be placed in answers derived from information collected during the early phases of a response. The more sources that corroborate initial information, the greater the confidence in that information. The process leads to identifying what data must be obtained during characterization and the areas, materials, and critical equipment for which prompt source reduction would speed remediation and reduce costs. Annexes H and I are tools to help with the process.

The kinds of data available at the beginning of characterization depend on the method of release (overt or covert) and the nature of the chemical of concern (immediate or delayed health effects). An observed, overt release is likely to result in an immediate emergency response. Even then, the fact that a CWA or TIC has been released may not be immediately obvious if the chemical of concern has delayed health effects. The greatest differences between overt and covert scenarios are that an overt scenario yields considerably greater confidence about the time and location of release and may provide clues about the amount of CWA or TIC released.

Interviewing first responders and reviewing any photographs, notes, and reports that are included with their data will provide a context for developing and implementing the characterization sampling plan. First responders will have collected information from evacuees, security staff, victims, and medical personnel along with environmental samples, and a laboratory will have tested for the presence of a CWA or TIC. Samples may also be analyzed onsite using portable field instruments. When a CWA or TIC is suspected, first-response samples are likely to include both air and surface samples. Field measurements should be compared with information from the analytical laboratory to ensure they are consistent or that the results can be reconciled (in the event of false positive results or poor detection capability). It is essential that samples be collected and analyzed using methods appropriate for the chemicals of concern; see Annex D.

It is important to unambiguously identify the chemical of concern because its properties, especially volatility and environmental persistence, will help guide estimates of dispersal, sampling and analysis strategies, and decontamination approaches. However, analytical identification of the released CWA or TIC is not a prerequisite to initial actions, such as removing or decontaminating visible puddles or droplets of liquid CWA or TIC on a floor or improving containment. Confirmation of the type of chemical released can be made by direct detection of the chemical itself; however, some CWAs and TICs degrade rapidly after release. In such cases, detection of the degradation products may provide limited evidence of the original chemical's identity. Because field methods are not always completely reliable, unambiguous identification of a chemical of concern requires that a sample be transported to a laboratory with access to authentic standards for analysis.

2.2.2 Evaluate Other Sources of Data

Security camera recordings and eyewitness accounts might provide some information about the extent of contamination. A map of the locations of victims, showing what signs and symptoms were reported and where they were reported, might provide a rough initial estimate of the spatial extent of the release zone. Information about the release device (e.g., its capacity or the amount

of CWA or TIC remaining in it) might provide a rough estimate of the potential quantity released, or at least an upper bound. Data on ambient interior conditions (temperature and humidity, HVAC operating parameters, and time of day) are important for characterization. Modern HVAC systems include data recorders that collect such data for later retrieval. Data on outdoor conditions, such as winds, temperature, and humidity, should also be collected. Such data can be used to model the spread of contamination and help estimate exposure of potentially affected individuals. If other environmental sampling programs exist near the airport, the data should be obtained and reviewed. Pre-event data can help establish the general air quality of the facility and what types of interferents may be present in the environment.

Information about the movement of people or motorized equipment after a release should be sought. For example, contamination may have been initially disseminated from a point source, then spread by foot or vehicular traffic, or it may have been introduced into the HVAC system. Emergency responders may have tracked contamination outside the immediate release location, for example, while searching the facility (first responders may search the entire facility to make sure it is completely evacuated). Different methods of dispersal would result in different patterns of contamination, and sampling should discover the resultant pattern. Such input helps the EU provide information to the UC in planning the characterization sampling and analysis to address such questions as what parts of the airport require decontamination.

2.2.3 Evaluate Immediate or Time-Critical Data Needs

This *Remediation Guidance* anticipates that a thorough and systematic characterization is likely to be needed, at least in some parts of a facility. However, the OSC upon arrival, or the UC or EU, may notice a need for information that can be obtained immediately and before performing complete and properly designed characterization sampling and analysis. For example, collecting samples where liquid contamination is obviously present need not wait until a formal characterization plan has been written and approved. Such data should be collected, but collecting it is not a substitute for full characterization. The time-critical sampling templates in Annex H may be appropriate for such purposes. First responders may have collected samples that still need to be analyzed or samples that were not completely consumed during analysis. In such cases, split samples can be taken from the first responders' samples to help provide early validation of information without re-entering the contaminated area to collect more samples.

2.2.4 Consider Immediate Source Reduction and Equipment Isolation

As characterization of contaminated areas progresses, areas might be identified where prompt source reduction would reduce hazards to personnel characterizing the contamination and also reduce remediation time and costs. Prompt source reduction consists of removing or neutralizing visible and mobile contamination, and removing items or materials that could be sources of secondary contamination. In addition, critical equipment that could later become contaminated can be isolated. Because the nature and extent of contamination could be considered evidence for a criminal prosecution, it is important to coordinate with the FBI Agent In Charge before conducting immediate source reduction. As the EU and Operations Section plan for the main decontamination actions, it may become apparent that removing various items, for example

carpets and furniture, before general decontamination begins will be necessary. It will probably be better to conduct detailed characterization after such items are removed because contamination could be redistributed during removal. Such items should be wrapped or contained, removed, and decontaminated offsite or properly disposed. Section 3.4.1 discusses source reduction in more detail.

While source reduction is taking place, there might be considerable physical disturbance and alteration of a facility, possibly causing redistribution of a chemical of concern, especially in the most affected areas. Detailed characterization in such areas should be postponed until after source reduction and isolation are complete.

2.2.5 Organize Airport into Zones

It will likely be appropriate and expedient to assess the airport area-by-area, referred to as zones. Figure 2-3 shows a hypothetical release of the CWA, sarin, in the ticketing area of LAX TBIT. Such an attack may not affect concourses or other terminals. However, a reasonable presumption might be that the entire ticketing area is contaminated. If such a rough, initial assessment were supported by sampling results, then subsequent management of separate areas would differ (see Section 2.2.9.1 and Figure C-2). Such an approach is also found in EPA guidance regarding environmental remediation, namely, "If the problem is complex, the team may consider breaking it into more manageable pieces, which might be addressed by separate studies." (EPA 2006.)

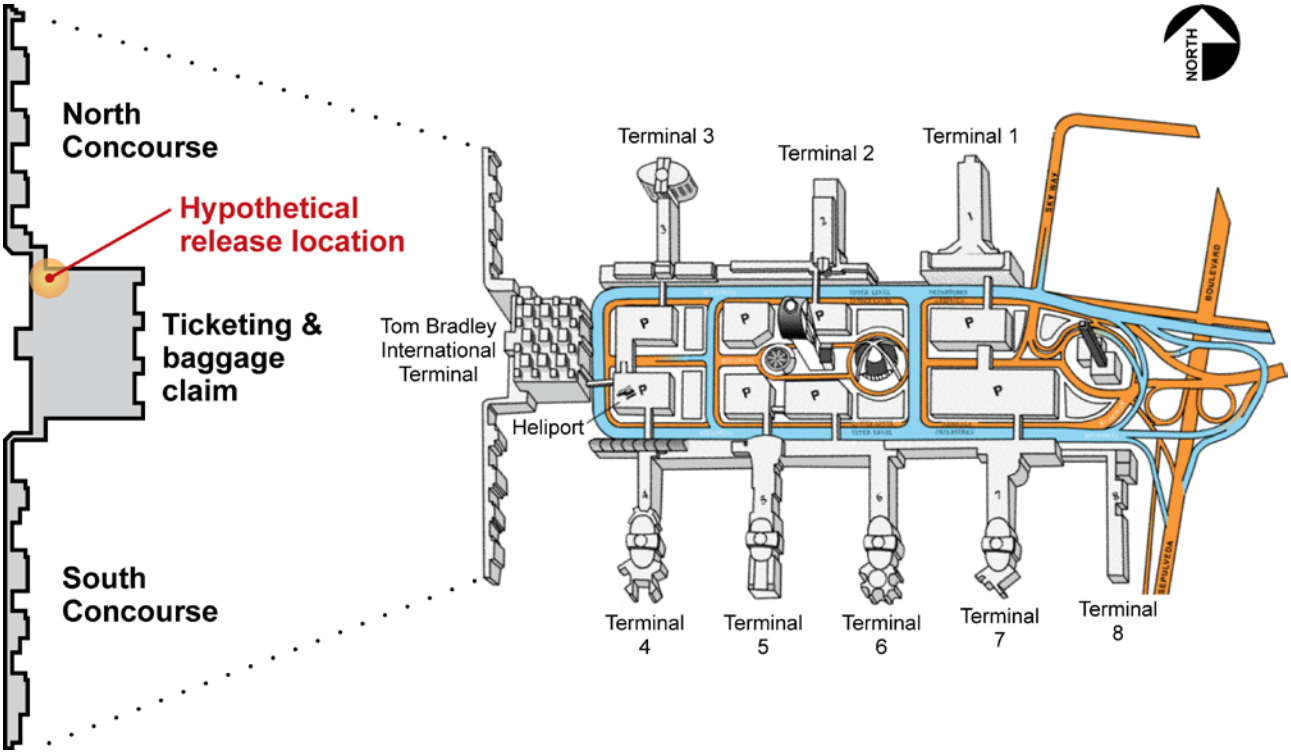


Figure 2-3. Location of hypothetical release in TBIT.

As part of the preparation for a potential CWA or TIC incident, airport planners should assess a facility's layout and identify potential zones. Identifying zones in advance—when access is not complicated by the presence of contamination—will be much easier than after an attack has occurred and will also help in coding and managing the massive amounts of data that will be collected during an actual incident. Consultation with a decontamination contractor and facility engineer familiar with the HVAC system will help determine sensible decontamination zones. Further discussion is provided in Annex C. Annex I contains templates to help with the process.

The physical structure and air-handling design of the TBIT at LAX suggest the three zones shown in Figure 2-4. These example zones are suggested by the physical structure of the building, not by the characteristics of any real or hypothetical incident. The major zones—north, center, and south—would be used for all three major phases, characterization, decontamination, and clearance. Smaller potential sub-zones, such as those delineated by the blue dashed lines in Figure 2-4, can be pre-planned, but their use is more likely to depend on the specifics of an incident. Post-incident zone assessments would also take into account the release location, air-handling configuration at the time of the release, information about potential tracking of contamination, and so forth. At the time that airport management identifies potential zones, it should also identify areas at the airport that can be used for staging incident personnel and equipment, as well as separate areas that can be used for storing waste materials that will be removed during decontamination activities.

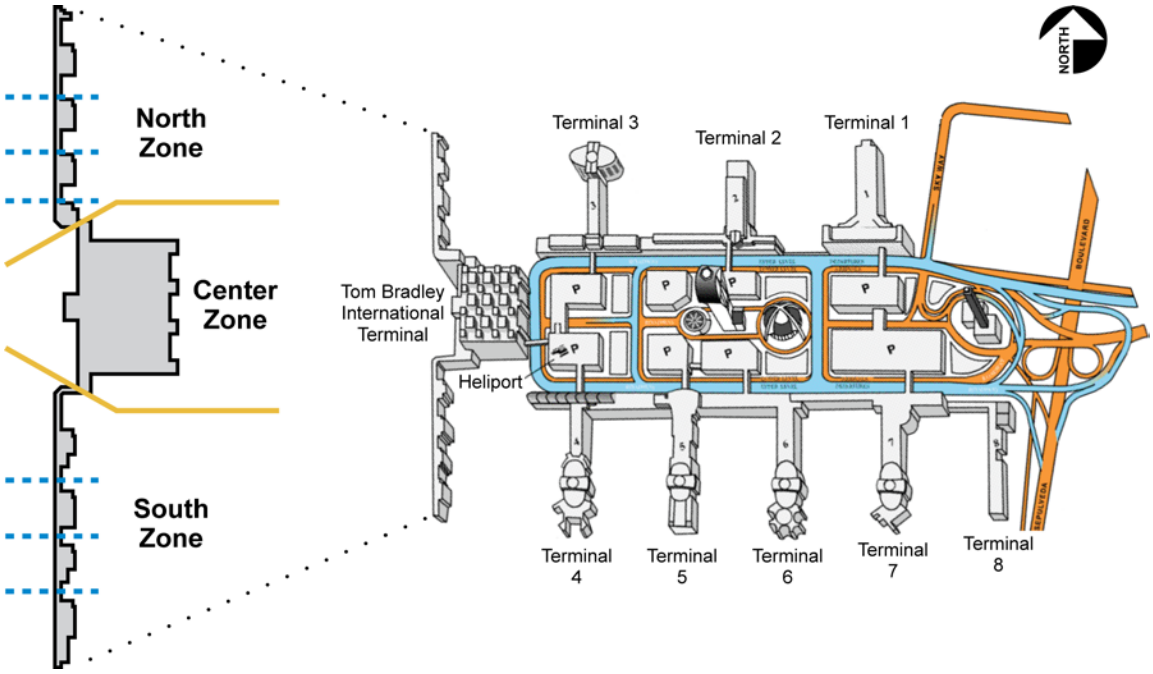


Figure 2-4. Potential decontamination zones and characterization zones at LAX.

2.2.6 Review Existing Containment and Isolation

Minimizing the spread of contamination as soon as possible will reduce remediation time and cost. Measures to prevent the spread of contamination are referred to as containment. Isolation, in contrast, refers to measures taken to prevent the spread of decontamination reagents (e.g., gas or vapor) into unwanted areas. Isolation also refers to measures taken to protect equipment, valuable objects, and similar items from the chemical of concern. Isolation barriers, such as a tent that is impervious to vapors around a baggage scanner, reinforce containment measures such as a barrier dam to prevent the flow of liquid contamination.

The EU should review any containment or isolation measures that were used during the First-Response Phase and decide whether additional containment and isolation are necessary. Containment includes not only physical barriers but also procedures to minimize the potential spread of a CWA or TIC during sampling activities and while people and objects enter or leave hot zones. By the time the UC takes control of a site from the FBI, liquid containment is likely to be a concern primarily for the less-volatile CWAs, such as VX. Similarly, long after the initial release, vapor containment is likely to be a concern primarily for less-volatile chemicals of concern. More-volatile ones will have already disbursed into the air. If monitoring confirms that airborne concentrations of a chemical of concern throughout a facility are less than toxic levels, then responders should consider operating the HVAC system throughout a facility for the duration of remediation. If monitoring shows that airborne concentrations remain present at toxic levels, refer to the discussion of operating the HVAC system in Section 3.4 for guidance. Airports should identify in advance some potential locations for rapid construction of containment barriers. Potential barrier locations include fire doors and connector halls between major terminal areas. In addition to their potential for containment during first response and at the beginning of remediation, such locations might be used later for isolation purposes during decontamination.

If liquid contamination remains, and the preferred action of source reduction to remove, neutralize, or destroy it is not undertaken, then the liquid should be contained in place with barrier dams. The condition of floors and walls in the containment area should be assessed and, if necessary, measures should be taken to prevent leaks through such surfaces. Containing liquids and vapors may require either a sprayable foam or caulking to seal doors and cracks or installation of barriers consisting of plastic polyethylene sheets covered with plywood to prevent puncture. Doors, windows, and external HVAC registers might also need to be caulked and sealed.

In the event that significant emissions of vapors are expected to continue for many days, perhaps from a large pool of liquid in an inaccessible pipe run, and containment of vapors within a building is advisable, negative air units (NAUs, also known as negative air machines, or NAMs) can be deployed and operated continuously in areas of known or suspected contamination. NAUs consist of a fan, ducting, a stack, often a carbon bed, and sometimes a chemical scrubber, a demister, or a HEPA filter. Air within a building or containment volume, such as the interior of a vapor-impermeable tent, is exhausted through the NAU at a rate sufficient to pull a slightly

negative pressure in the contaminated zone (see also Section 3.3 and Annex F). However, the need to procure or fabricate NAUs, ducts, piping, and other major components might limit the ability to field NAUs during the early stages of characterization. Before deciding to install NAUs, their potential to affect the extent of contamination should be assessed. If there is a possibility that the units will move or redistribute a chemical of concern within a zone, especially if the movement takes place after characterization sampling, NAUs should probably not be used.

2.2.7 Evaluate Potential Release to the Outside

The EU must immediately assess the potential for a release of contamination outside the airport buildings. Potential escape paths include HVAC exhausts, open doors or windows, entrances to tunnels, storm drains, sanitary sewers, utility conduits for water and electrical piping systems, and tracking by people and vehicles moving out of a contaminated area. Consideration should be given to the advisability of sealing off potential escape pathways, depending on site-specific conditions. Because HVAC operation can affect interior temperatures, thus volatilization rates, a decision to shut down the HVAC could affect the potential for release to the outside. Evaluation can start with a method to estimate the amount of CWA or TIC potentially released to the outside environment and to determine its likely fate in the environment (see Figure 2-7 in Section 2.2.9). Consider placing air samplers both inside and outside affected building in locations near potential escape pathways (see Section 2.2.10). The length of time that outdoor airborne chemical concentrations are hazardous will depend on the specific chemical released, the amount released, location of the release, and outdoor meteorology. If it is determined that a chemical of concern could escape, or has escaped, then outdoor air sampling is indicated. Because time is potentially a major consideration, it will be important to start outdoor sampling as quickly as possible. Outdoor air dispersion models should also be used to assess potential spread. Modeling resources include the Interagency Modeling and Atmospheric Assessment Center (IMAAC) and National Guard Civil Support Teams.

Aircraft, airport vehicles, rental cars, subways, trains, and the like may have to be grounded and secured because of the potential for cross-contamination. Such actions will probably take place as soon as a CWA or TIC incident has been confirmed. If not, they should be done at this time.

2.2.8 Assess Availability of the Agent to Cause Injury or Disease

The CDC may mobilize its response assets to assist local responders in evaluating health risk and contamination pathways. Expertise can be drawn from the National Institute for Occupational Safety and Health (NIOSH) and the Agency for Toxic Substances and Disease Registry (ATSDR) to conduct preliminary characterization activities. The ATSDR has staff in all EPA Regional Offices to consult on threats to human health associated with releases of hazardous substances during emergencies and remediation. Expertise can also be drawn from OSHA, which has four Specialized Response Teams, one of which is the Chemical Team with expertise in responder health and safety for incidents involving chemicals of concern.

If the results of an assessment show that there is no potential for injury or disease (e.g., the release is totally contained, and the concentration of CWA or TIC is reduced to nonthreatening

levels during first-response activities), then no further action would be necessary. The EU should make a general assessment of exposure potential starting with results from emergency response and forensic sampling data. The EU should work closely with FBI scientists or others and obtain any photographs available showing the distribution of contamination and any other data that might be available on characteristics of the chemical of concern, its amount, the mode of release, and initial sampling results. Such information, together with results from any modeling, is used to determine the immediate and future likelihood of exposure.

2.2.9 Initial Assessment of the Extent of Contamination

The EU should promptly assess the possible extent of contamination beyond what was confirmed during the First-Response Phase. Such an assessment will drive hypotheses that will be tested in the characterization sampling strategies and plans (see Section 2.4). Qualitative or numerical modeling of agent dispersal, or both, can be used for this purpose.

Information on airflow within the affected area at the suspected time of an airborne release aids evaluation of the potential spread of contamination. Such information may be available from airport maintenance and engineering staff. Both volatile and aerosolized chemicals of concern are airborne. In addition to the identity of the specific chemical of concern, its formulation, method of delivery, and quantity used will greatly influence aerodynamic properties and spread. Operation of HVAC systems and the air balance within an airport have a major influence on the spread of volatile CWAs and TICs. For example, if an HVAC system were shut down and then outside temperatures increased, indoor temperatures could then rise, causing an increase in the rate of CWA or TIC volatilization into the air and possibly affecting the extent of contamination or increasing the potential for additional release to the outside. Soon after a release, volatile CWAs or TICs can spread quickly via a mechanical ventilation system, and both volatile and nonvolatile chemicals of concern could be spread by the movement of people and cross-contamination of objects. The quantity released probably will not be known and will need to be estimated.

Weather conditions, including outside wind speed and direction, should also be considered. Portable meteorological stations can be set up to monitor the local microclimate. The National Oceanographic and Atmospheric Administration (NOAA) and National Weather Service (NWS) can mobilize such stations and provide real-time weather monitoring data. Such data would be useful to protect workers and could serve as data input for air-dispersion modeling.

2.2.9.1 Qualitative Approach

As described at the beginning of Section 2, it is likely that the condition of a facility can be qualitatively assessed starting with an area or areas of confirmed (or assumed) contamination close to the release location, referred to as Class 1 zones. Surrounding a Class 1 zone will be areas in which the degree and patterns of contamination are uncertain. Such areas can be subdivided into two classes: Class 2 zones in which contamination is believed to be highly likely, and Class 3 zones in which contamination is considered possible but relatively unlikely. In both Class 2 and Class 3 zones, there is some reason to suspect contamination, but insufficient

evidence to confirm or refute it. Finally, there may be areas that are plausibly not contaminated, referred to as Class 4 zones.

Zones, in essence, implement a data quality objectives process. The conceptual model is that around a release location, concentrations are high, and they gradually decrease with distance from the release point. Decisions to be made depend on expected concentration, as described in Section 2.4. Hence, different sampling strategies are suggested for the four different classes of zones. To summarize:

Class 1 Zone	Known or assumed to be contaminated above clearance goals (the release location and its immediate vicinity).
Class 2 Zone	High likelihood of being contaminated above clearance goals (contamination seems likely due to proximity to release or known dispersion mechanisms, but definitive evidence of contamination does not yet exist).
Class 3 Zone	Low likelihood of being contaminated above clearance goals (contamination is possible, but seems unlikely because of distance from release point, building layout and structure, or absence of known dispersion mechanisms).
Class 4 Zone	Extremely low likelihood of being contaminated above clearance goals.

Although a Class 4 zone is described here as having an extremely low likelihood of being contaminated, one does not necessarily assume Class 4 zones need no further action or assessment. The use of four classes, as opposed to say three, is not meant to be prescriptive; remediation planners can adjust the number and definition of zones to suit the incident. The issue is discussed further in Section 2.4.1, which includes discussion of sampling strategies associated with the different classes.

Factors to consider for initial zone identification include:

- Release location.
- Agent type, especially its volatility, persistence, and material interactions.
- Building layout.
- Ventilation systems, traffic patterns, and any other contamination pathways.
- Time since release.
- Initial response activities (that may have redistributed the agent).
- Within-room features (e.g., furniture, counters, tabletop, and shelf configurations).
- Surface materials.
- Decontamination technology options and their areas of application.

Information on airflow and air balance within the affected area at the suspected time of release and subsequently (first responders may shut down the HVAC system) must be obtained to evaluate the potential spread of contamination. The presence or absence of materials that tend to retain a chemical of concern should be determined

One starting point for classifying a facility into the four types of zones is the relation between the release location and HVAC system, as follows:

Class 1 The release point and areas immediately adjacent to it with a direct flow path connected to the release location. This category includes all areas served by an AHU if a CWA or TIC were released directly into that AHU.

Class 2 All areas served by the same AHU as the release location, including other floors and all AHU zones sharing a common return plenum with the release zone.

Class 3 AHU zones adjacent to the release zone.

Class 4 Remaining areas not connected via a direct flow path to the release zone.

For example, the approach can be applied to a hypothetical building with a single, open interior served by nine AHUs, the zones of which are shown in Figure 2-5. Assume that a release occurred in AHU2 (shaded), and zones AHU1, AHU2, and AHU3 share a common return. Using the ranking system identified above for potential contamination, the area of the release and immediately adjacent areas in AHU2 would be ranked as "known or assumed to be contaminated" (Class 1). The remainder of zone AHU2 would be ranked as "high likelihood of being contaminated" (Class 2). Because zones AHU1 and AHU3 share a common return with AHU2, they would be ranked as Class 2 as well. The AHU5 zone would be ranked as "low likelihood of being contaminated" (Class 3) because it is directly adjacent to the release zone. Areas for AHU4, AHU6, AHU7, AHU8, and AHU9 are ranked as "extremely low likelihood of being contaminated" (Class 4).

AHU1 Class 2	[AHU2 Class 1] Class 2	AHU3 Class 2
AHU4 Class 4	AHU5 Class 3	AHU6 Class 4
AHU7 Class 4	AHU8 Class 4	AHU9 Class 4

Figure 2-5. AHU zones in an example application of an HVAC zone approach for classifying zones to assess the extent of potential contamination by an airborne chemical of concern.

2.2.9.2 Numerical Modeling Approach

A second approach for assessing the extent of contamination is computer-assisted mathematical and physical modeling of dispersion. Such models can help identify areas of greatest expected concentration and help prioritize characterization actions. However, considerable sampling will

always be required. Therefore, an investment in highly sophisticated modeling may not provide a substantial return on investment over simple or conceptual models when the latter are coupled with the necessary on-the-ground sampling. A numerical model approach (e.g., multi-zone airflow and transport analysis software) is complex, and the time required to develop such models can be extensive. Unless a model has been developed as part of pre-incident planning, completion of a viable building model may not be possible within the time required for characterization. However, it may be possible to develop a model in time to assist with clearance sampling design. Expertise in mathematical modeling is available from many sources, including the national laboratories, the National Institute of Standards and Technology (NIST), universities, and private organizations. Qualitative and numerical models can help guide the selection of locations, types, and numbers of samples to be collected. Regardless of the approach used, an understanding of the mechanical ventilation design of a facility, its operating condition at the time of the incident, and ambient conditions is essential.

2.2.9.3 Example of Numerical Modeling

The following is an example of the numerical modeling approach applied to the TBIT. In this example, assume that a robust, multi-zone, airflow and contaminant-dispersion model has been developed for the TBIT. The example illustrates the type of information that can be obtained from such an approach. Recall that the TBIT consists of a main terminal building with two-level concourses extending north and south from the main terminal. Access to concourses is restricted to ticketed passengers only.

Initial Air Modeling in the Example Scenario

A model of the TBIT was used to characterize airflow and contaminant transport for the example scenario. The primary mechanisms for transporting the CWA of concern, sarin, throughout the facility are recirculation of contaminated air and interior air movement between adjacent ventilation zones. For the terminal design and assumed operating conditions, the dominant direction of air movement on the departure and arrival levels is generally from the concourses toward the front (east side) of the terminal and out the main entry doors at the front of the terminal, as shown in Figure 2-6. The terminal is slightly over-pressurized resulting in exfiltration of air out leak paths (doors and windows) in the terminal envelope. If the designed air balance is maintained, airflows throughout the terminal are typically less than 5 ft per second.

CWA Scenario and Impact on Terminal

In this hypothetical scenario, a finite quantity of sarin is assumed to have been released as a vapor over a relatively short time. The release occurs in the public access area of the departure level of the TBIT. It is also assumed that all mechanical ventilation systems were operating as designed, with 20% outside air, 80% recirculated air, and no manipulation of the HVAC system has taken place for at least several hours.

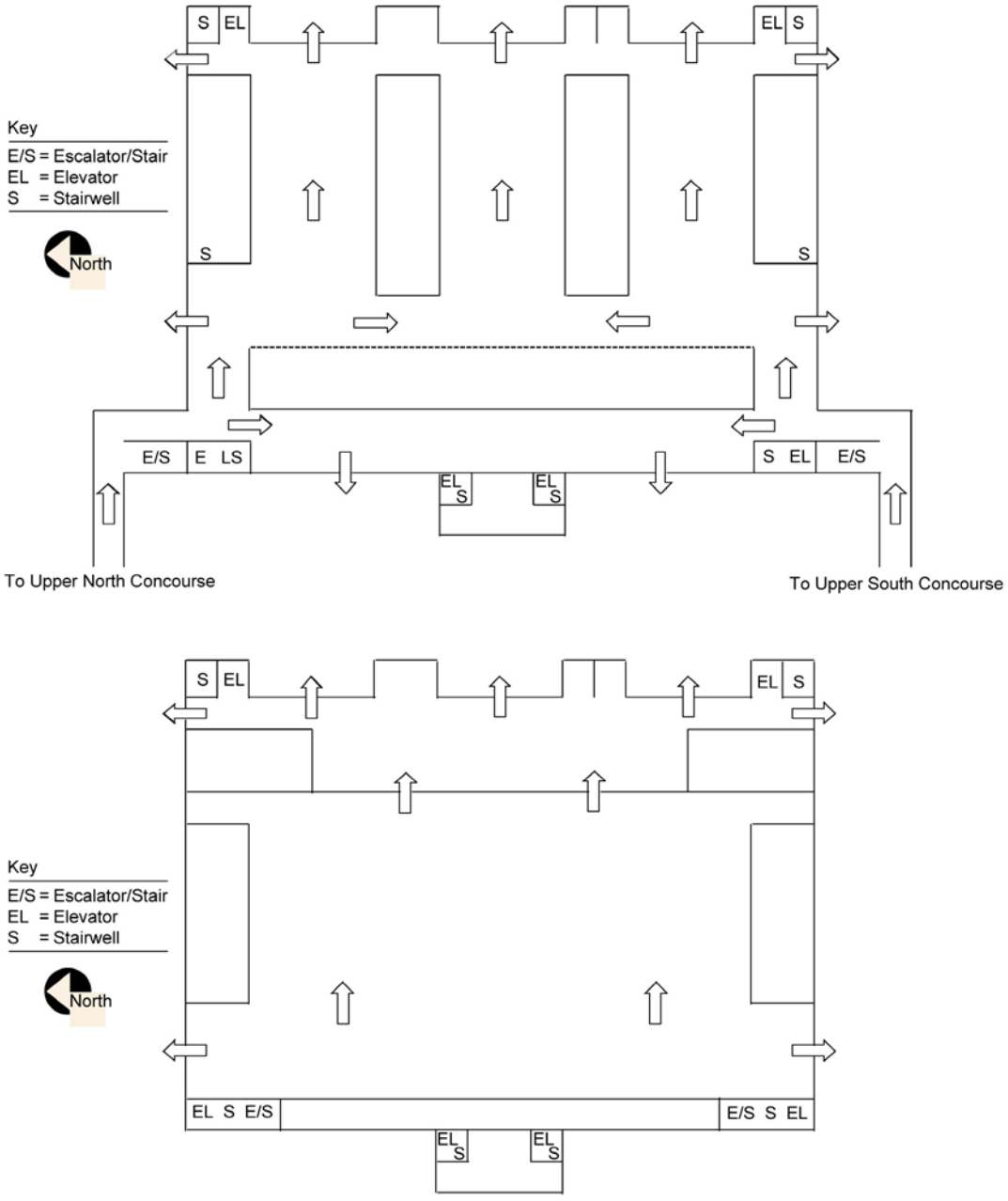


Figure 2-6. Hypothetical scenario: directions of air movement in the main terminal departure level (top), and the arrival level (bottom) of the TBIT.

Mechanical ventilation systems in high-occupancy-density buildings, such as airport terminals, are designed to provide large volumes of outside air and rapid exchange of inside air with fresh outside air. The operational design results in a rapid purging of airborne sarin from the building. Figure 2-7 shows the percentage of airborne sarin remaining in the terminal as a function of time

after release. In this scenario, with the operation of the ventilation system unchanged for several hours, approximately 80% of airborne CWA is purged from the terminal in the first 15 minutes after release. After 60 minutes, less than 5% of the initially released vapor remains airborne in the terminal. This numerical result is specific to sarin released entirely as a vapor, and it would not hold for a chemical of concern with different physical properties.

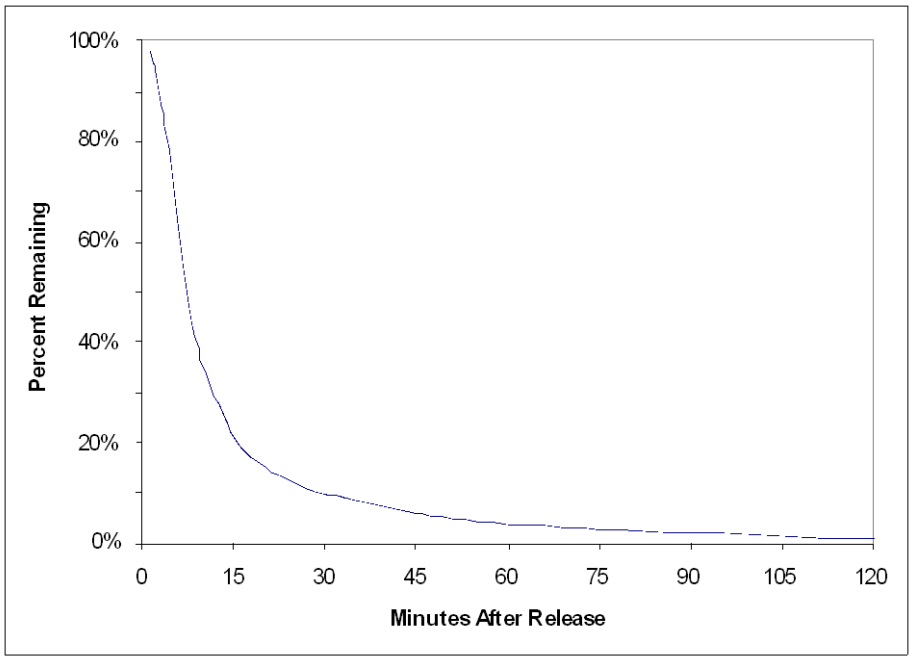


Figure 2-7. Hypothetical scenario: percent of CWA (sarin, released entirely as a vapor) remaining in the building in vapor form from the initial release as a function of time after release.

One metric for assessing the impact of a release on the terminal is concentration–time (*CT*) value. The *CT* value is an indicator of cumulative exposure to the airborne chemical of concern over time for a receptor. For human exposure, the greater the *CT* value, the greater the dose. For objects or surfaces in the terminal, the *CT* value provides a measure of the potential for surface contamination. Actual levels of surface contamination will also depend on physical properties of materials present in the space, the type of chemical of concern involved, and interactions between the two.

The *CT* values for the example scenario were calculated for pre-defined spaces on the departure level, where the hypothetical release of sarin occurred, and arrival levels of the main terminal. The *CT*s values were categorized on an arbitrary scale of low (least exposure to CWA), moderate, and high. The percent of floor area of the arrival and departure levels in each of the three categories is summarized in Table 2-2. The greatest potential exposure and contamination (high *CT* value) was found on 30% of the floor area of the departure level—primarily the area closest to the point of release. Areas farther from the release received less chemical exposures.

No *CT* values fell into the high category on the arrival level, and the two concourses remained free of the sarin in this scenario.

Table 2-2. Hypothetical scenario: percent of floor area contaminated as a function of *CT* value.

	CT value (arbitrary scale)		
	Low	**Moderate**	**High**
Departure level	63%	7%	30%
Arrival level	87%	13%	0%

2.2.10 Assess the Need for Air Monitoring

Air monitoring may have been initiated during first response. If so, location(s) of samplers should be assessed for their appropriateness for remediation activities. Otherwise, the need to establish air monitoring for remediation activities should be considered now. Air sampling near suspected release locations, or throughout an airport if necessary, may help confirm the presence and extent of air-dispersed contamination. Air monitoring is also required if a decision is made to continue to operate an HVAC system during the Characterization Phase because it is necessary to establish whether HVAC operation affects agent air concentrations.

Air monitoring may be needed in (1) the contamination reduction zone adjacent to the hot zone, (2) the support zone, and (3) around the slightly over-pressurized terminal building where there may be exfiltration of airborne CWA or TIC through doors, windows, or other unplanned openings. The first two types of monitoring would be needed to ensure proper levels of PPE in the contamination reduction zone and support zone. The last type of monitoring would be used to characterize any airborne release of CWA or TIC from the indoor environment to the outdoor environment and to validate the results of air modeling. Ongoing air monitoring during remediation can provide additional information concerning the hazard, potential exposure of remediation personnel to the chemical(s) of concern, hazards associated with normal operation of the HVAC system, and effectiveness of remediation activities. Figure 2-8 summarizes considerations relevant to air monitoring.

2.3 Evaluate Clearance and Exposure Guidelines to Establish Clearance Goals

To ensure that characterization and decontamination tasks are conducted appropriately and in a timely fashion, it is imperative that health-based clearance and reoccupation exposure guidelines be incorporated into decision-making as soon as possible. Furthermore, EPA OSCs indicate that they would request clearance goals virtually immediately. Clearance goals need to be identified for all potential populations that could be exposed after facility clearance is granted. Whereas the primary CWA and TIC exposure pathway for all populations examined for the airport release

scenario under consideration is inhalation/ocular, both dermal and ingestion pathways must also be considered. Specifying acceptable levels of residual contamination for each exposure pathway and population is a prerequisite for developing clearance sampling strategies.

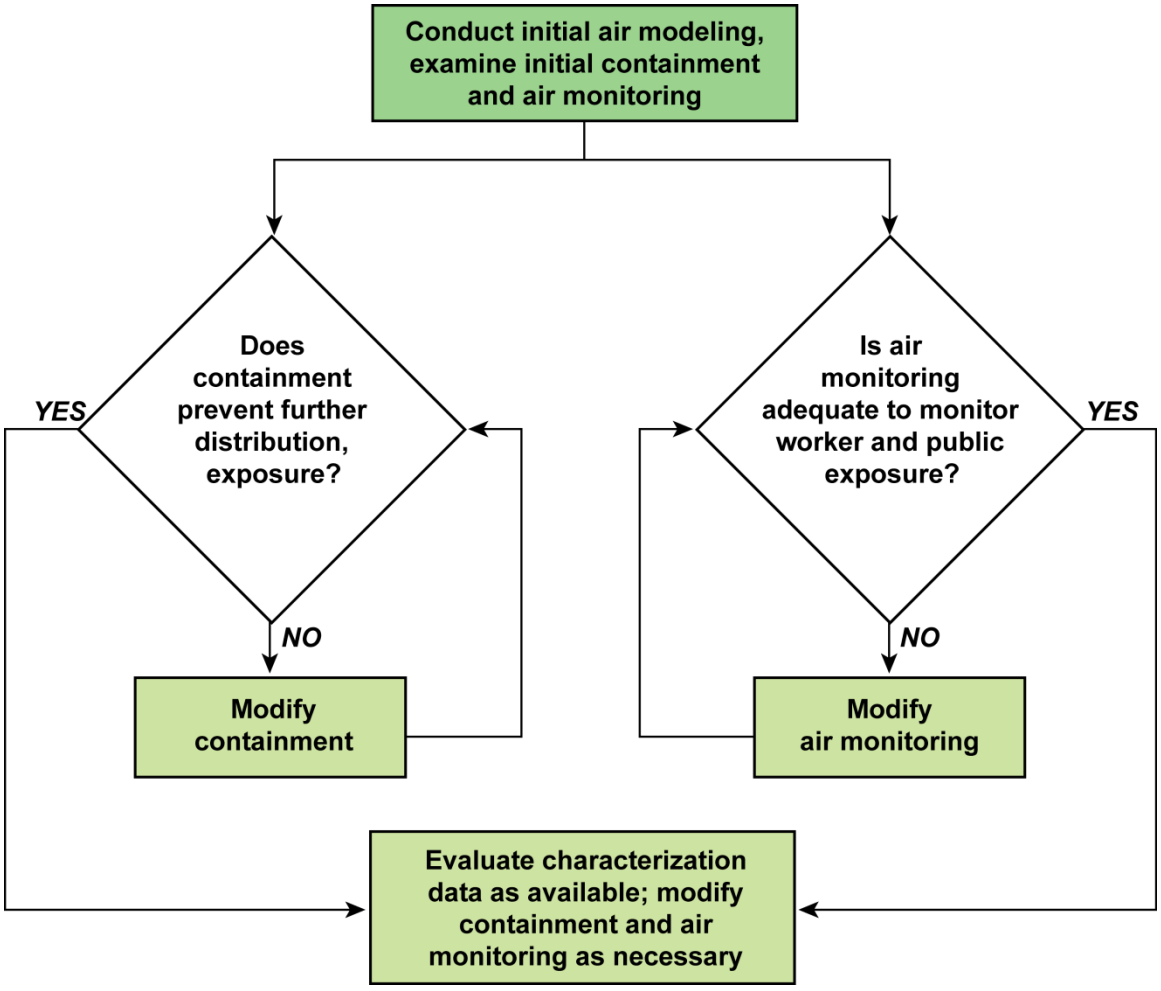


Figure 2-8. Evaluation of air monitoring and agent containment.

For example, surface contamination can contribute to the inhalation exposure pathway from particulate re-suspension and volatilization, to the dermal pathway from transfer to skin with subsequent absorption, to the ingestion pathway from hand-to-mouth and object-mouthing activity, and to direct ocular exposure via hand-to-eye activity (Watson et al. 2001a and b). Therefore, appropriate clearance goals should take into consideration the cumulative effect of all exposures. Recommended sampling strategies in this document thus include sampling of all affected media that are likely to result in exposure. Analytical detection capabilities must be evaluated for their potential to detect chemicals of concern at levels at or below the clearance

goals selected. Acceptable residual levels (clearance goals) should be specified on the basis of compound-specific characteristics of the chemical of concern (see Section 2.3.3) and in measurable units, which depend on the specific exposure pathway selected, such as air or surfaces.

An overall objective for this *Remediation Guidance* is to evaluate and organize existing resources and information to leverage known tools that can reduce the time needed to remediate and restore major airport facilities and critical infrastructure to operational status after a terrorist release of CWAs or TICs, while still being protective of human health and the environment. Thus, emphasis has been placed on a careful consideration of previous studies and exposure guidelines that (1) already exist, (2) are published and accessible to the public today, (3) have undergone peer and public review, (4) are health-based and protective, (5) are compound-specific, (6) have demonstrated utility in practice, and (7) are a reasonable fit to parameters of the airport release scenario for which this *Remediation Guidance* is designed. Relevant work is ongoing in many fields and will continue to inform future evolution of risk and associated clearance goals. Nevertheless, if a chemical terrorist incident should occur tomorrow, it is important to have ready a set of well-understood, defensible, health-protective exposure levels than can be assessed to develop appropriate and reasonable clearance goals for site-specific incidents. Accordingly, Annex G summarizes existing exposure guidelines for air, water, soil, and surfaces for the CWAs and TICs identified as the chemicals of concern in this *Remediation Guidance*. Although only some of the exposure guidelines so identified are intended for use as remediation or clearance goals, others can be used to inform clearance decision-making. In addition, specific CWA and TIC exposure guidelines that have been proposed in the literature are provided in the References (Section 2.7) of this *Remediation Guidance*, and they are discussed later in this section. Some of these proposed values could potentially be used as pre-planning guidance for the airport release scenario under consideration. In the event of an actual incident, clearance goals established for pre-planning purposes can be further augmented with incident- and site-specific parameters and then adjusted as necessary to establish formal clearance goals.

The organization and content of this *Remediation Guidance* are specifically tailored to plausible airborne release scenario(s) of interest at a major airport facility. The TBIT is used as the site-specific example representative of a major airport throughout these discussions. Although the focus is on establishing clearance rationale for a large airport, the information provided in support of this section should be equally applicable to other transportation infrastructure. No bulk containers or bulk liquid releases are assumed, nor is there any assumption of in-terminal "saturation" releases similar to those found on chemical battlefields, CWA burial below ground, continuous cold-weather conditions, or any special-condition releases that would limit known dissipation processes, such as volatilization and hydrolysis. However, the data and references provided in this guidance, and the overall approach used, would be appropriate for virtually all CWA or TIC contamination incidents as an aid in decision-making.

Scientifically appropriate, well-characterized exposure guidelines must be used to ensure that human health is safeguarded without defaulting to overly conservative actions (such as cleaning to non-detection levels) that would divert limited resources without major benefits under the airport release scenario. For an actual contamination incident, site- and incident-specific factors must always be considered, and a risk-based decision process involving key stakeholders must be used.

For any CWA or TIC incident, the criteria for evaluating post-decontamination personnel activities must be in accord with an assessment of the risk for potential residual hazard(s) to employees, including vendors and tenants, at the airport facility. Any exposure assessment should not only be based on the mere presence of employees in the facility and the frequency and duration of time they will be there, but should address the question of how much and for how long a chemical hazard would be expected to persist given implementation of decontamination operations and elapsed time before clearance sampling. Whereas the magnitude of the source term may not always be known with precision, the airport attack scenario(s) evaluated herein do not support a plausible long-term or intermediate-duration hazard for reasons explained in Section 2.3.5.

In discussing the rationale for a reasonable and scientifically supported set of procedures and health-based criteria, this document aims to give decision-makers maximum flexibility by which to weigh numerous considerations (e.g., safety of decontamination personnel, public health, time, funds, resources, and public perception, among others) that must be evaluated.

2.3.1 Applying a Risk-Based Decision Approach

A risk-based decision assessment should be incorporated as a required component of decision-making for ascertaining the adequacy of decontamination processes or treatments, if used, following the release of a chemical of concern. This need—largely in the context of indoor, surface decontamination—was acknowledged by the National Research Council (NRC 2005, pp. 5–6). More generally, a scenario-specific, risk-assessment approach is needed to understand appropriate clearance goals and potential residual health effects regardless of the media that are contaminated (e.g., air, water, or environmental surfaces). Key site-specific parameters and the relations among them in a given scenario must be carefully defined. They include the sources and extent of contamination, applicable receptors, and potential environmental and physical pathways between them (Raber et al. 1999). This type of approach is essential for providing the appropriate information to allow for establishing re-entry and clearance goals. The role of risk-based decision-making applied to remediation and restoration has been used throughout the CERCLA process for contaminant cleanups and involves principles of both risk assessment and risk management. With regard to cleanup from a terrorist incident, much information is available regarding the process as well as documentation of existing regulatory guidelines (see for example Raber et al. 2004; Raber and Kirvel, 2008; and numerous citations in Section 2.3.2). In addition, new studies related to CWAs and TICs, which involve applications and derivations of existing regulatory guidelines as well as new supporting risk assessment models and derivations, have recently been published in the open literature by Watson et al. (2011a and b).

To establish the concentration range that will protect human health, it is necessary to assess both acute and chronic health risks when evaluating other factors to determine a protective clearance goal. Cleanup and decontamination decisions must then be made with input from stakeholders representing both public and regulatory concerns. It is important to recognize that clearance goals will be incident- and site-specific. As such, any process must work to optimize the many decisions that ultimately go into establishing final clearance goals. Optimization activities entail both qualitative and quantitative assessments applied at each stage of site remediation decision-making, from evaluating cleanup options through implementing the chosen cleanup alternative. Relevant risk management decision-making considerations include:

- Potential acute and long-term chronic health impacts, including health effects on key populations, such as pregnant women.
- Damage to water, land, property, and equipment as a function of cost.
- Detectability of the chemical(s) of concern in the contaminated medium and the long-term fate of chemical(s) of concern or degradation product(s).
- Cost and technical feasibility of decontamination or other remediation options.
- Time constraints associated with decontamination or other remediation options.
- Availability of decontamination methods and procedures for the associated sampling, analysis, and verification of decontamination actions.
- Public confidence in the approaches used and the actual methods chosen.
- Socioeconomic effects.
- Aesthetic considerations.
- Other site-specific factors that might be relevant.
- Potential over-reaction that may cause more disorder than warranted.

An important factor underlying each risk-based decision is the uncertainty and reliability of available data. Potential uncertainties in the magnitude and location of residual chemicals of concern, site-specific features, and prediction of natural attenuation or potential dilution effects all contribute to decisions about whether appropriate clearance goals have been reached. In most cases, some type of statistically valid sampling could be used to reduce uncertainties both during site characterization and regarding the likelihood that an appropriate decision has been made. The sampling strategy would take into account the way any decontaminant reagents or treatments, if used, are applied, as well as spatial or volumetric considerations regarding the contaminated site.

2.3.2 Exposure Guidelines for Chemicals of Concern

A limited health-risk assessment must be used to establish clearance goals. Such an assessment begins with a multimedia, multi-pathway, site-specific dose assessment. This means that the ability of a chemical of concern to move into, off of, or through contaminated materials must be determined or assumed. Consideration must be given to the mobility of a chemical of concern under both unusual conditions, such as fires or floods, and mundane ones, such as repainting a building. The toxicology of a chemical of concern must be evaluated and human morbidity,

mortality, and latency of effects must be determined, if known. Integrating multimedia transport and fate with multi-pathway exposure (e.g., inhalation, ingestion, or dermal absorption) and physiologically-based pharmacokinetics (if available) for modeling toxicity should yield an estimate of non-carcinogenic hazard and any other applicable risks, especially from short-term exposures. If possible and appropriate, a longer-term monitoring procedure should be identified so that those individuals given permission to reoccupy a building or structure can be monitored. Such monitoring can be an additional way to ensure the long-term health and safety of the public and facility workers.

Health-based reference values are one of the key inputs in the usual approach to deriving clearance goals and making clearance decisions as discussed in more detail in Annex G. For CWAs and TICs, data from animal models are often relied on as the basis for dose–response or potency information. Unlike biological warfare agents, CWAs have various quantified health-based guidelines that can be considered when setting clearance goals. Reference values have been developed by many different sources and for many purposes. In general, it is recommended that decision-makers select peer-reviewed reference values to use along with appropriate exposure factors when recommending appropriate clearance goals and making clearance decisions for a specific site and incident. However, values may sometimes need to be extrapolated when experimental data are lacking or unavailable. Among the authorities and agencies that have published guidelines for CWAs and TICs are the following:

- Centers for Disease Control and Prevention (CDC) of the U.S. Department of Health and Human Services [DHHS 2002, 2003, 2004].
- Committee on Toxicology of the National Research Council (NRC/COT 2001, 2002, 2003).
- American Conference of Governmental Industrial Hygienists (ACGIH 2003, 2008).
- Agency for Toxic Substances and Disease Registry (ATSDR) of the DHHS (ATSDR 2003).
- U.S. Environmental Protection Agency's Integrated Risk Information System (EPA/IRIS 2006a and b).
- American Industrial Hygiene Association (AIHA 2004, 2007).
- U.S. Environmental Protection Agency, Regions 9 and 3 (EPA 1991; 1996a and b; 2005b).
- U.S. Environmental Protection Agency (EPA 1991, 1996b).
- Regional Screening Levels (RSL) for Chemical Contaminants at Superfund Sites (EPA 2008).
- CDC National Institute for Occupational Safety and Health (NIOSH) (NIOSH/CDC 2008; NIOSH 2008a and b).

Whereas site-, situation-, and population-specific factors must all be considered when selecting "acceptable" clearance goals for the chemicals of concern, various scientifically defensible levels have been applied as appropriate for some CWAs and TICs. Two historical examples within the U.S. where such a process has been applied in the context of CWAs are discussed in Annex G. The first case study involves cleanup of the Spring Valley Formerly Used Defense Site where

more than 1,900 anomalies have been identified, including ordnance and CWA items associated with burials of materials more than 90 years ago. The second case study involves contamination and cleanup of the ESS Pursuit, a fishing and clamming vessel, which encountered a WWI-era munition containing sulfur mustard during clam harvesting in 2010. All future decisions must be made according to the specific characteristics of a given chemical of concern, as described in more detail below.

2.3.3 Characteristics of Chemicals of Concern

Characteristics of the scenario-specific CWAs and TICs summarized in this section have been evaluated elsewhere in numerous publications and in much greater detail regarding mechanisms of toxicity, experimental data, and species susceptibility. Examples include Sidell (1997), NRC/COT (2002, 2003), IOM (1993), Munro et al. (1994), and Watson and Griffin (1992). Consult these reviews and the many original studies cited within them for details.

2.3.3.1 G- and V-Series Agent Characteristics – Nerve Agents

The nerve agents described here include the G-series agents (GA, tabun; GB, sarin; GD, soman; and GF, cyclosarin) and VX. These compounds are all toxic derivatives of phosphonic acid, containing either a cyanide (GA), fluoride (GB, GD, and GF), or sulfur (VX) substituent. They are commonly called nerve agents because of their anticholinesterase properties and effects on the peripheral and central nervous systems. Anticholinesterase effects of nerve agent exposure can be characterized as muscarinic, nicotinic, or central nervous system (CNS) related. Muscarinic effects occur in the parasympathetic system and, depending on the amount absorbed, can be expressed as conjunctival congestion, miosis, ciliary spasm, nasal discharge, increased bronchial secretion, bronchoconstriction, anorexia, emesis, abdominal cramps, sweating, diarrhea, salivation, bradycardia, and hypotension. Nicotinic effects are those that occur in somatic (skeletal–motor) and sympathetic systems, and can be expressed as muscle fasciculations and paralysis. At sufficient exposures, CNS effects can be manifested as confusion, reflex loss, anxiety, slurred speech, irritability, forgetfulness, depression, impaired judgment, fatigue, insomnia, depression of central respiratory control, and death (Somani et al. 1992; Sidell, 1992, 1997; Sidell and Groff, 1974; Opresko et al. 1998; and Bakshi et al. 2000). Low-exposure effects include miosis, a feeling of “tightness” in the chest, rhinorrhea, and dyspnea (Dunn and Sidell, 1989).

The “G” series military nomenclature used by NATO-member nations has historically been considered to be an abbreviation for “German,” with the second letter of the code (A, B, and so forth) identifying the order in which the compounds were found and analytically identified by Allied forces investigating materials located in captured German military facilities at the close of WWII (Sidell 1997). Agent VX was industrially synthesized in the United Kingdom in the early 1950s. The letter “V” is a reported reference to “venomous” (Sidell 1997; Robinson 1967).

The G agents are viscous liquids of varying volatility (vapor density relative to air between 4.86 and 6.33) with faint odors (faintly fruity, spicy, or odor of camphor). Agent VX is an amber-

colored liquid with a vapor density of 9.2 and is considered odorless. Nerve agent vapors possess little to no olfactory warning properties (see Table F-1 in Annex F).

The vapor pressures and acute toxicity of these agents are high enough for the vapors to be rapidly lethal at appropriate doses. It is generally thought that the order of decreasing vapor exposure hazard is: GB > GD > GF > GA >>> VX. Agent GA is expected to present a contact hazard. The vapor density of agent GF is between that of agents GA and GD. Agent VX, with a vapor density greater than that of any G agent under consideration, is approximately 2000 times less volatile than nerve agent GB (DA 1990a, b). As a consequence, agent VX is considered a persistent "terrain-denial" military compound as a surface contact hazard.

Although the principal route of exposure concern is vapor inhalation and direct vapor exposure to tissues of the eye, all the nerve agents discussed here can be absorbed through the skin. One issue is whether percutaneous absorption (i.e., uptake of a substance through intact skin) might contribute significantly to exposure. For agent VX, approximately 100 times greater percutaneous vapor exposure is necessary to attain the same mild toxic effect as that achieved from inhalation vapor exposures (NRC/COT 1997). Such estimates indicate that the vapor inhalation pathway is much more important to consider than the percutaneous vapor pathway. This general relation holds true for the other nerve agents as well as sulfur mustard.

Most signs and symptoms of toxic levels of exposure to a nerve agent usually develop within 60 minutes after exposure. However, effects are well known to occur hours after percutaneous exposure (Watson et al. 1992). The smaller the exposure, the longer the time to onset of symptoms; effects that occur many hours post-exposure are usually nonfatal (Watson et al. 1992).

In addition to the above nerve agents, the VX hydrolysis product known as EA2192 has sufficient toxicity to be of potential concern. It is produced by hydrolysis reactions conducted in the pH range of 7 to 10 (see reviews by Talmage et al. 2007a and b; Munro et al. 1999). Formation is not significant at a reaction pH of <6 or >10 or by decontamination with excess hydrogen peroxide (H_2O_2) in basic solutions (Yang 1999). EA 2192 is a solid, is not an inhalation hazard, is not absorbed through the skin, and is water-soluble. It is toxic via ingestion (although less so than VX) and via injection (Michel et al. 1962; Munro et al. 1999; Hooijschuur et al. 2001; Borrett et al. 2003; Love et al. 2004). Maximal yields of EA 2192 from VX hydrolysis are approximately 20% (Yang 1999), further reducing potential for exposure. If VX decontamination conditions favor formation of EA2192, it would be sensible to monitor for this product in locations where liquid VX was released (see Section 3.5).

Because of its environmental stability and low toxicity, methyl phosphonic acid (MPA), a degradation product of nerve agent GB, may be a useful forensic tool in the event of GB release (see Section 3.5).

2.3.3.2 Sulfur Mustard Characteristics – Blister Agent

As a cell poison and alkylating chemical vesicant, sulfur mustard (agent HD) damages and destroys cells of any epithelial tissue (layers of cells found throughout the body lining cavities, surfaces, and structures) with which it comes in contact. Depending on the magnitude of the dose received, erythema (reddening of tissue), blistering, and other tissue damage can result with increasing dose. Sulfur mustard was developed and used as a CWA by the armed forces of several nations during World War I and has been deployed in more recent conflicts (IOM 1993).

At ambient temperatures greater than its freezing point of 13º to 14ºC (55° to 57°F), sulfur mustard is an oily liquid heavier than, and sparingly soluble in, water (relative density of 1.27) (DA 1996; Budavari et al. 1989; see also Annex F, Table F-1). Because of its low aqueous solubility, sulfur mustard is persistent in the environment. It is sufficiently volatile [vapor pressure 0.072-mm Hg at 20ºC (68°F) and 0.11-mm Hg at 25ºC (77°F)] to produce toxic vapors when temperatures are greater than the freezing point. At air temperatures ≥32ºC (90°F), damaging concentrations can be small, arising from the more rapid development of damage to warm, moist tissues (Watson and Griffin 1992). Sulfur mustard has a garlic-like odor, and reported odor thresholds range from 0.15 to 0.6 mg/m^3 (NRC/COT 2003).

The principal mechanism of toxicity for sulfur mustard is attributed to its capacity as an alkylating agent and consequent ability to react with DNA and RNA, resulting in disorganization of normal cell function. As a consequence, sulfur mustard is considered a cell poison. The epithelium is an important target because of the presence of a proliferating cell layer. Relatively high sulfur mustard concentrations are required to cause human mortality; “battlefield” concentrations (perhaps in excess of 1500 mg-min/m^3) during the Iran–Iraq conflict of the 1980s resulted in mortality rates of 1 to 3% among exposed military personnel (Blewett 1986; Dunn 1986). Such mortality rates are similar to those observed during World War I (IOM 1993). For the lethality endpoint, mustard agent is much less potent **(**by approximately 10^3) than nerve agents under comparable conditions of exposure (Watson and Griffin 1992).

The alkylating reaction of sulfur mustard with cellular constituents is rapid (i.e., cell injury and death occur quickly). Nevertheless, any clinical effects (e.g., conjunctivitis, eye sensitivity to light, skin burns) do not manifest immediately, but develop over hours post-exposure. Such latent effects are characteristic of sulfur mustard exposures (IOM 1993; Watson and Griffin 1992).

2.3.3.3. Hydrogen Cyanide Characteristics – Blood Agent

At ambient temperature and pressure, hydrogen cyanide (HCN, hydrocyanic acid, prussic acid, AC) is a colorless gas or liquid with a boiling point of 25.7ºC (78.3°F). The bitter-almond odor of HCN is detectable by some, but not all, individuals at 0.65 to 4.94 mg/m^3 (ATSDR 2004) (see Annex F, Table F-1). HCN is currently used in various industrial applications, including fumigation, the production of certain resin monomers, and mining (NRC/COT 2002; ATSDR 2004). HCN has been used for gas-chamber executions in several countries (ATSDR 2004).

Toxic effects develop swiftly. Biological effects of HCN result from its ability to rapidly disrupt cellular respiration via inhibition of the enzyme cytochrome oxidase. A volatile toxin [vapor pressure 630-mm Hg at 20ºC (68°F)] with a low vapor density (0.94), HCN will volatilize immediately if released passively from a container or other material. Liquid HCN is extremely unstable, and if introduced into a facility, will either rapidly volatilize or undergo an exothermic reaction upon contact with air and decompose by burning (NIOSH 2008a and b; Aaron 1996).

HCN can be absorbed by inhalation, ingestion, or by dermal contact with either the vapor or liquid (ATSDR 2004; NIOSH 2008a and b). However, the volatility of HCN, coupled with the instability of HCN liquid, suggest that inhalation exposure would be the most important exposure route for an airport release scenario.

HCN crosses mucous membranes rapidly, and HCN entry into the bloodstream after inhalation exposure is nearly instantaneous. Dermal absorption, or absorption across the epithelia of the gastrointestinal tract, is somewhat slower (ATSDR 2004). Inhalation exposure to HCN at sufficiently high concentrations can lead to death within minutes. An average fatal concentration of 600 mg/m^3 has been estimated for a 10-minute exposure. Short-term exposures to lower concentrations (~2.7 mg/m^3) may induce symptoms and signs that include headache, dizziness, confusion, nausea, and vomiting (NIOSH 2008b). The principal targets of acute, high-level inhalation exposure are the respiratory, central nervous, and cardiovascular systems.

Although HCN can be dermally absorbed in large quantities, available data rarely distinguish whether exposure was to liquid or vaporous HCN. There is one anecdotal report of men with respiratory protection who apparently incurred significant exposure to HCN vapor via dermal absorption across unprotected skin (ATSDR 2004). Very high concentrations of HCN vapor (>343,000 mg/m^3) were lethal to experimental animals exposed over 2% of their bodies (AIHA 1994).

2.3.3.4. Cyanogen Chloride Characteristics – Blood Agent

Cyanogen chloride (CK) is a colorless gas at ambient conditions [vapor pressure of 760-mm Hg at its boiling point of 13.8ºC (56.8°F)] with a highly irritating odor and an odor threshold of 1 ppm (ATSDR 2004). Cyanogen chloride is used in various industrial processes and was historically deployed as a military poison gas by several nations (ATSDR 2004). A 10-minute exposure to 5 mg/m^3 has been characterized as intolerable because of the irritant properties of the odor. Given the physical form of CK, inhalation would likely be the most important route of exposure for an airport scenario. If formulated into an aqueous solution, CK can be absorbed via ingestion, although there are little toxicological data on the effects of this route of exposure or time to onset of symptoms. Data characterizing dermal irritation or dermal absorption of the vapor are not readily available.

Exposure to cyanogen chloride vapor produces both the effects of cyanide poisoning and symptoms of lung irritation. At low concentrations (~2.51 to 50.3 mg/m^3) over brief exposure durations, eye contact produces tearing, with spasm and eyelid closure. Principal effects on the

respiratory tract are pulmonary irritation, with pulmonary edema developing at exposures between 50 and 300 mg-min/m^3 **(**AIHA 1998). At greater concentrations, the cyanide (CN^-) moiety inhibits cellular respiration, with a concentration of 120.63 mg/m^3 reportedly fatal to humans after 30 minutes, and 399.5 mg/m^3 fatal within 10 minutes (AIHA 1998; Opresko et al. 1998).

2.3.3.5 Phosgene Characteristics – Choking Agent

Phosgene (CG) is a colorless, reactive gas with a vapor pressure of 1215-mm Hg at 20ºC (68°F) (EPA 1986) and a vapor density of 3.4 (Lipsett et al. 1994). In the U.S., phosgene is used to synthesize other chemicals or products (NRC/COT 2002). Phosgene also has a history of military use as a gaseous warfare agent during World War I. Phosgene odor (described as resembling new-mown hay) is generally perceived at concentrations >1.67 mg/m^3 and recognized at concentrations >6.25 mg/m^3. Eye, nose, throat, and bronchiolar irritation occur at concentrations greater than 12.5 mg/m^3 (AIHA 2002).

Inhalation of phosgene vapor is the primary exposure route for this agent, and lungs are the principal target organs. Phosgene-related tissue damage is caused primarily by acylation of tissue macromolecules in the alveolar region of the lung. HCl production from phosgene hydrolysis may also contribute to its toxicity, particularly when phosgene contacts and dissolves in the aqueous layer of the eyes and mucous membranes. Chronic, low-level inhalation exposure to phosgene can cause pneumonitis that can progress to pulmonary edema (AIHA 2002). Acute, low-level phosgene exposure (>30 ppm-min, equivalent to >125 mg-min/m^3) can damage the lung; acute high-concentration exposures (e.g., >150 ppm-min, equivalent to >625 mg-min/m^3) can lead to irreversible pulmonary damage or death (NRC/COT 2002). There is a latent period, ranging from several hours to 24 hours, between the time of phosgene exposure and development of pulmonary edema; the length of the latent period is considered inversely proportional to the exposure concentration (Diller 1978; Frosolono and Pawlowski 1977).

2.3.4 Summary and Definitions of Existing Health Standards and Guidelines.

For the reader's convenience, Table 2-2 briefly describes the various standards or guidelines that can be used for risk assessment and risk management decisions for CWA and TIC response and recovery. Definitions of guidelines are from the literature and websites produced by the originating agency or stakeholder group. More details and additional descriptions can be found in Annex G.4.

Table 2-3. Definitions of health standards or guidelines.

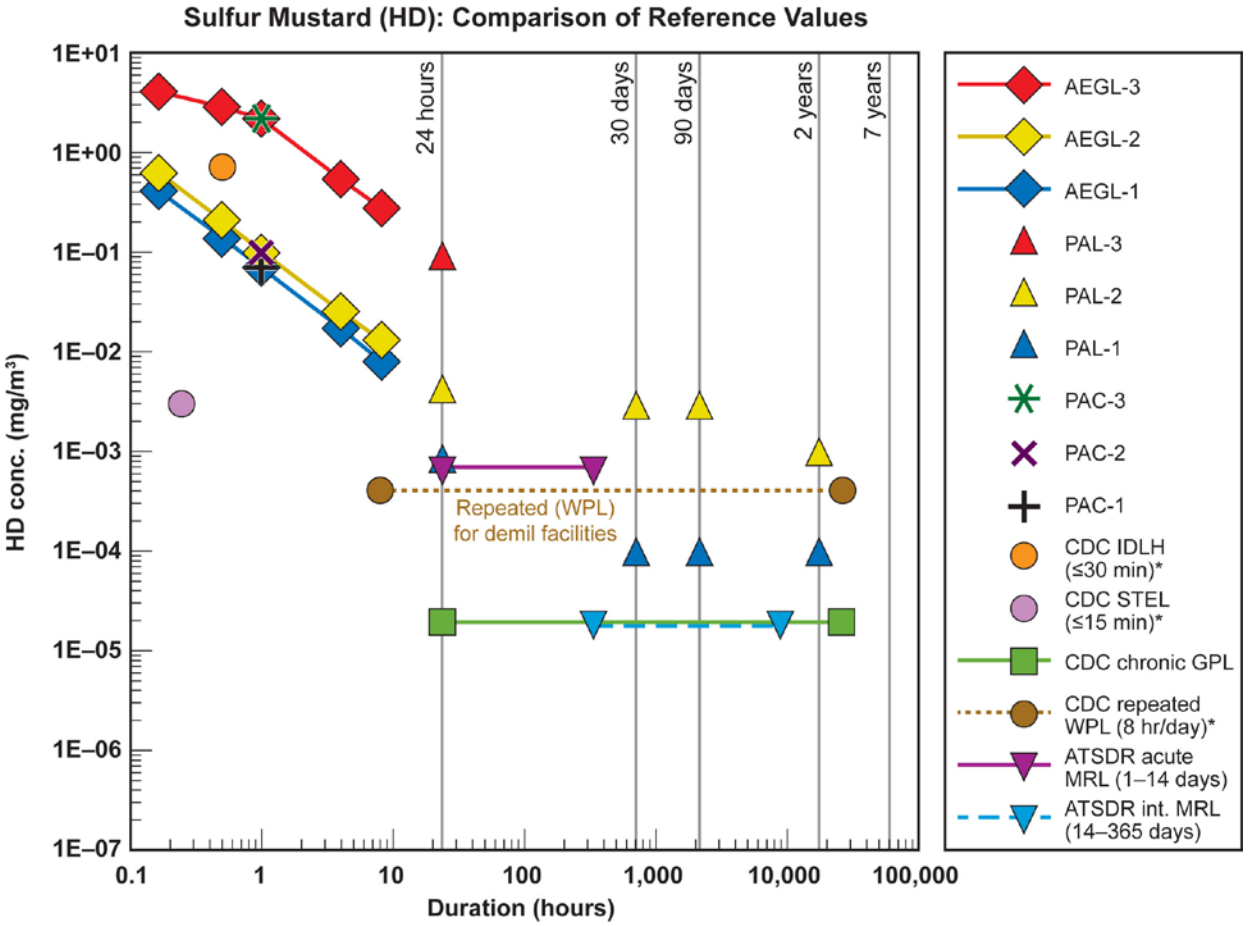
Term	Definition
Airborne exposure limit (AEL)	General term used by the CDC and Army to refer to a set of exposure limits (concentrations in mg/m^3 for various exposure frequencies and durations) specifically developed for application to CWA (nerve and blister agents) demilitarization facility management, where chronic, daily CWA exposures and routine operations are assumed during ongoing CWA munitions (e.g., bombs, land mines, and rockets) destruction. See http://www.cma.army.mil/.
Acute Exposure Guideline Levels (AEGL)	Federally endorsed guidance criteria for assessing and managing single-exposure emergency events, such as accidents or intentional terrorist attacks. See http://www.epa.gov/opptintr/aegl/.
General population limit (GPL)	The airborne exposure limit for chronic, long-term, general population exposures (e.g., 24/7 for years) expressed as an atmospheric concentration in mg/m^3. See www.osha.gov/SLTC/emergencypreparedness/cbrnmatrix/nerve.html.
Health-based environmental screening level (HBESL)	Concentration of a chemical in environmental media that, if not exceeded, is unlikely to present a human health hazard for specific exposure scenarios. See www.environmental.usace.army.mil/guide_risk.htm.
Immediately dangerous to life or health (IDLH)	Maximum concentration of a chemical from which an individual with no personal protective equipment could escape within 30 minutes without escape-impairing signs or symptoms or irreversible health effects. See http://www.cdc.gov/niosh/idlh/idlhintr.html#CNU and USACHPPM (2008).
Lowest adverse effect level (LOAEL)	Lowest dose of a chemical in a study or studies that produces statistically or biologically significant increases in frequency or severity of adverse effects between an exposed population and its appropriate control. See http://cfpub.epa.gov/ncea/iris/index.cfm.
Maximum contaminant level (MCL)	Highest level of a contaminant or naturally occurring mineral allowed in U.S. domestic drinking water from distributed systems. MCLs are enforceable EPA standards for water-treatment utilities. EPA has not promulgated MCLs for CWAs; values can be calculated using DOD-derived toxicity values and EPA equations.
No observable adverse effect level (NOAEL)	That dose of chemical at which there are no statistically or biologically significant increases in frequency or severity of adverse effects seen between the exposed population and its appropriate control. See http://cfpub.epa.gov/ncea/iris/index.cfm
Permissible exposure limit (PEL)	Used by OSHA, NIOSH, and in standards in occupational settings. Concentration of a substance in commerce to which most workers can be exposed without adverse effects averaged over a normal 8-hr workday or 40-hr workweek, as defined in the *Federal Register*. See www.osha.gov/SLTC/pel/.
Preliminary Remediation Goal (PRG)	Human health-risk-based concentration designed to be used as a guideline in screening-level evaluations of contaminated sites. Many civilian and military authorities currently develop PRGs (see also RSL, below). See http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/index.htm.

Table 2-3. Continued.

Term	Definition
Provisional Advisory Level (PAL)	Three levels (PAL 1, 2, and 3) for the general public applicable to emergency situations are distinguished by the degree of severity and type of toxic effects and are developed for 24-hour, 30-day, 90-day, and 2-year drinking water and inhalation exposure durations (Adeshina et al. 2009). See also http://www.epa.gov/nhsrc/news/news121208.html.
Provisional peer reviewed toxicity value (PPRTV)	Values developed by EPA's Superfund Health Risk Technical Support Center for a specific chemical when requested by the EPA Superfund program. See for example http://www.epa.gov/oswer/riskassessment/sghandbook/pdfs/pprtv-dbcp.pdf (PPRTV database is currently accessible only to EPA computers).
Reference concentration (RfC)	An estimate of a continuous inhalation exposure for a given duration to the human population (including susceptible subgroups) that is likely to be without an appreciable risk of adverse health effects over a lifetime. See http://cfpub.epa.gov/ncea/iris/index.cfm.
Reference dose (RfD)	Estimate of a daily exposure level for the human population, including sensitive subpopulations, that is likely to be without an appreciable risk of deleterious effects for chronic exposures during a lifetime. See www.epa.gov/iris/rfd.htm.
Regional Screening Level (RSL)	Human health-risk-based concentration designed to be used as a guideline in screening-level evaluations of contaminated sites and developed by EPA Regions 3, 6, and 9 in 2008. As of October 2010, SRLs are accepted by most EPA regions (see also PRG, above). *For* RSLs for several TICs see http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/index.htm.
Short term exposure limit (STEL)	Concentration to which workers can be exposed continuously for a short time without irritation; chronic or irreversible tissue damage; or narcosis of sufficient degree to increase the likelihood of accidental injury, impair self-rescue, or materially reduce work efficiency. See NIOSH 2011, www.osha.gov/SLTC/emergencypreparedness/cbrnmatrix/nerve.html, and *The Medical CRPN Battlebook, Technical Guide 224* (USACHPPM 2008).
Surface Removal Contaminant Levels (SRCL)	An exposure limit for analytes expected to persist on surfaces, expressed in units of mass of analyte per surface area sampled. SRCLs unique to the present analysis are calculated in Watson et al. 2011a and b.
Time-weighted average (TWA)	An exposure concentration averaged over a designated time. TWA refers to a time-weighted average sometimes associated with STELs and WPLs for example.
Worker population limit (WPL)	Concentration at which an unprotected worker can operate safely 8 hr per day, 5 days per week, for a working lifetime, without adverse health effects. WPLs for CWAs have been developed by the CDC for specific application to CWA munitions demilitarization facility workers. See www.osha.gov/SLTC/emergencypreparedness/cbrnmatrix/nerve.html.

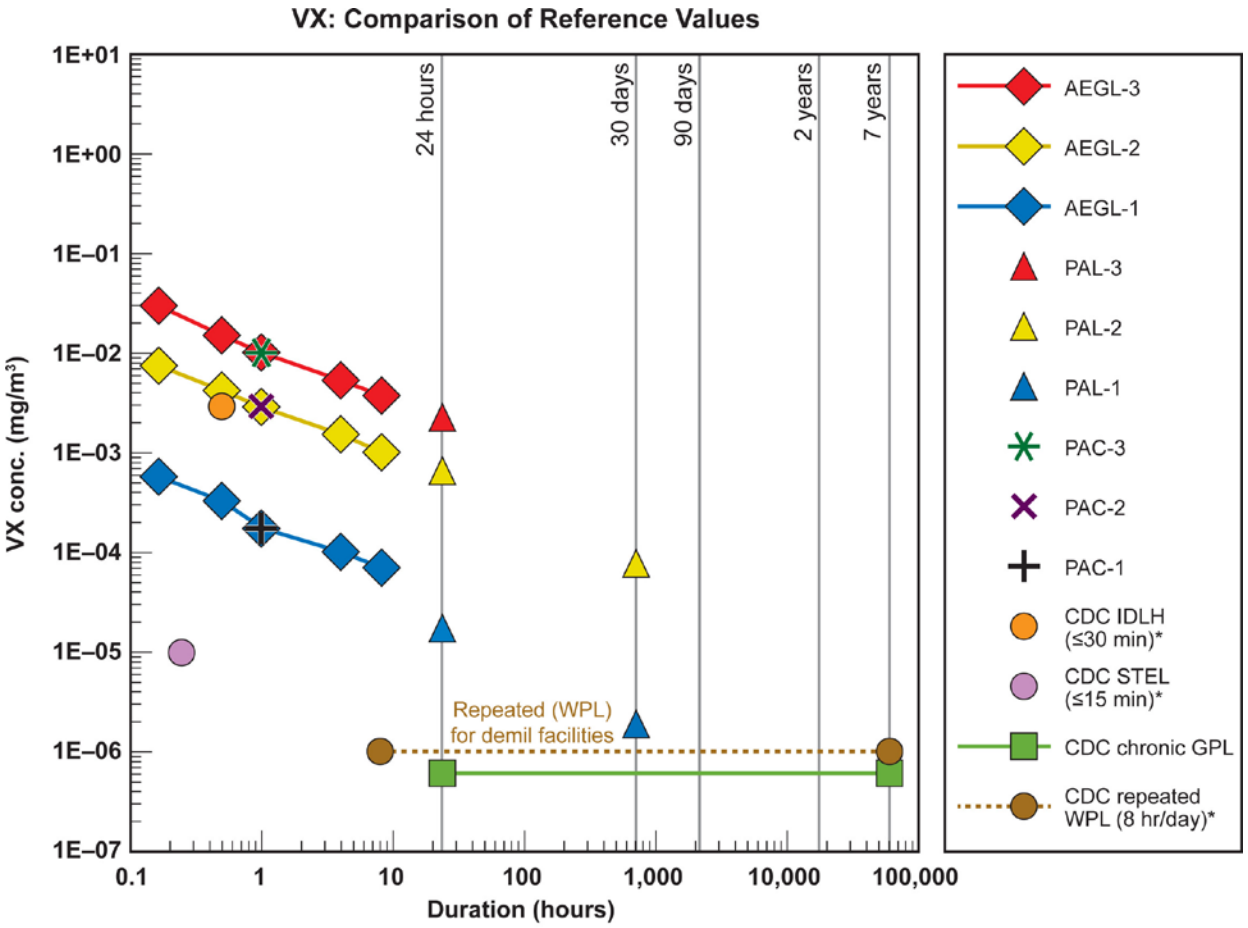
For purposes of understanding the relative values of the various guidelines, refer to Figures 2-7 though 2-9. The three illustrations show the relative concentration levels for CWA inhalation/ocular exposures as a function of time or duration and highlight the importance of making informed and realistic incident- and site-specific risk management decisions.

Figure 2-9. Comparison of reference values for sulfur mustard vapor exposures.



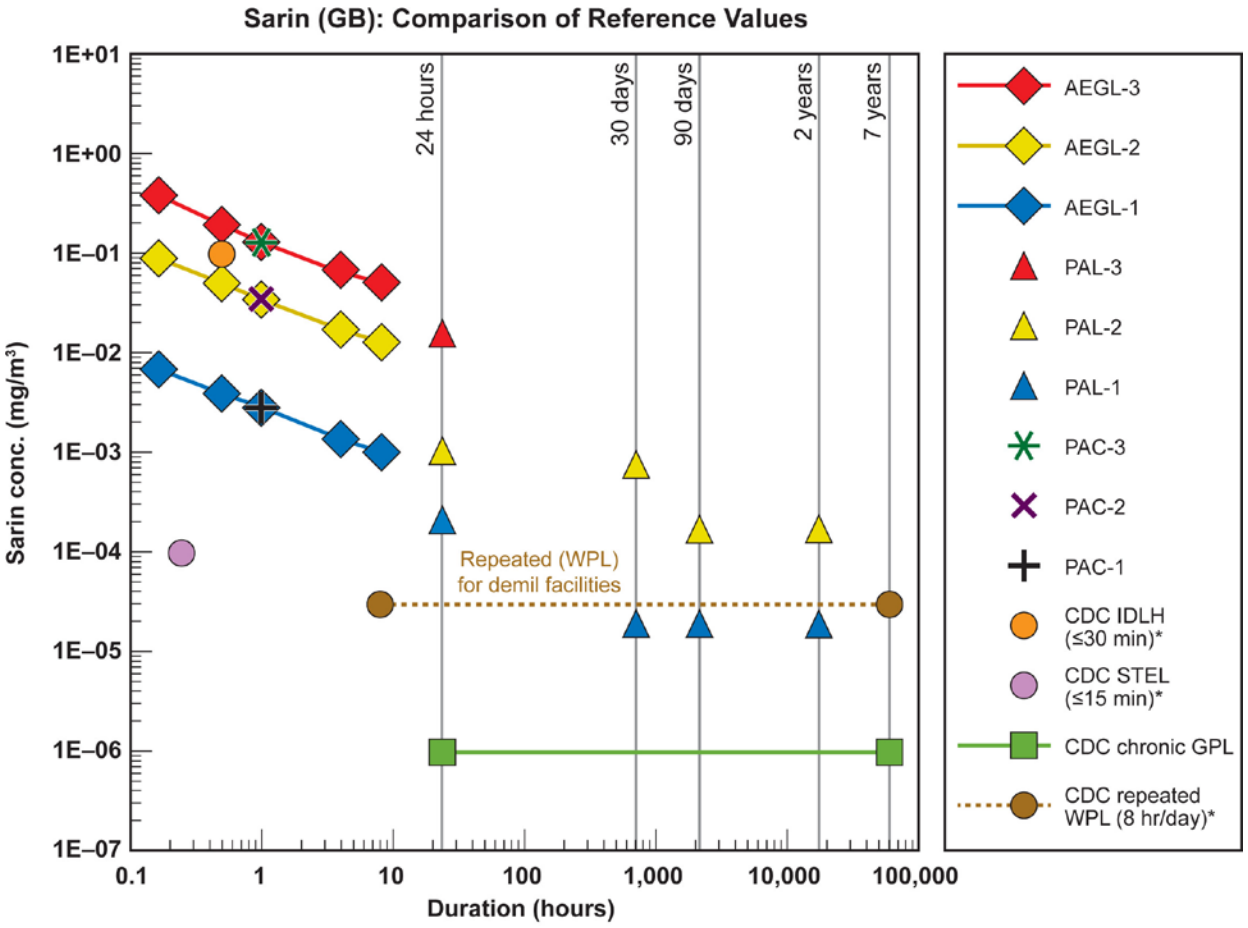
* CDC recommends use of WPL, STEL and IDLH only for CWA demilitarization facility employee or agent transport employee protection during CWA munitions demilitarization program (69 FR 24164–24168, 3 May 2004). CDC considers three years as maximal duration of potential continuous exposure for HD munition demilitarization facilities.

Figure 2-10. Comparison of reference values for VX.



* CDC recommends use of WPL, STEL and IDLH only for CWA demilitarization facility employee or agent transport employee protection during CWA munitions demilitarization program (68 FR 196: 58348–58351, 9 Oct 2003). Seven years is considered maximal duration of potential continuous exposure for nerve agent munition demilitarization facilities.

Figure 2-11. Comparison of reference values for sarin vapor exposures.



* CDC recommends use of WPL, STEL and IDLH only for CWA demilitarization facility employee or agent transport employee protection during CWA munitions demilitarization program (68 FR 196: 58348–58351, 9 Oct 2003). Seven years is considered maximal duration of potential continuous exposure for nerve agent munition demilitarization facilities.

2.3.5 Significance of the Release Scenario to an Exposure Analysis and Clearance Decision

Whereas the primary pathway for CWAs and TICs for all populations is inhalation/ocular, dermal and ingestion pathways also need to be considered. Specifying acceptable exposure levels for each pathway and population is a prerequisite for developing clearance sampling strategies. *Remediation Guidance* requirements that are to be met prior to airport reentry and occupancy by unprotected persons include (1) completion of both active and passive decontamination, and (2) certification that clearance goals are attained in air and on surfaces by sampling and analysis of samples taken from airport areas (see Section 1).

The following two principal populations should be considered in developing clearance guidelines:

- **Restoration and recovery personnel, airport employees, and vendors**—Restoration and recovery personnel include occupational populations that repair, maintain, or service airport components and facilities (e.g., restore power and water, repair or replace carpet and furniture). Such personnel, along with airport employees and vendors, would begin tasks only after a chemical of concern is removed or neutralized, decontamination is complete, and monitoring has characterized atmospheres to verify that no hazard is present above clearance goals.

- **Transit passengers**—Members of the general public (including individuals of all ages and infirmities) who occupy airport terminals for limited times as they change flights, collect baggage, and perform other activities common to aircraft passengers. An evaluation of estimated stay times of transit passengers in LAX was conducted, and stay times are expected to be similar to those in other large U.S. airports. The estimated stay times can be used as surrogates for conservative "exposure" assumptions. Specifically, domestic and international passenger survey data collected in 2005 from key LAX airport terminals found that between 80 and 90% of all passengers spent ≤120 minutes in the most heavily used LAX terminals (CAM 2005). Although the time needed to undergo airport security and screening procedures has changed in the years since 2005, most passengers spend ≤4 hr in terminal transit.

Some concern has been expressed that airport employees, vendors, and tenants who perform duties every sequential day within an airport facility should not be considered members of the public for the purpose of setting clearance goals. Such concerns center on assumptions that employees, vendors, and tenants would undergo long-term CWA or TIC exposure for years in an airport workspace. Such an assumption does not take into account the requirements of source removal, neutralization, decontamination, and other measures that are to be met before reentry by these populations, as summarized above. With successful decontamination of the CWA or TIC and its continued degradation over time, there is no expectation that long-term exposures can occur. This assessment is consistent with recent appraisals developed by the California Environmental Protection Agency as guidance for remediation of former clandestine methamphetamine laboratories (Salocks 2008, 2009). Airport atmospheres are not considered

comparable to those found in industrial chemical settings involving manufacture or processing of TICs or CWAs in quantity over years.

A CWA or TIC release and associated response at an airport, such as that in the scenario described in Sections 1.2 and 1.3, would be somewhat analogous to a HazMat response. However, unlike remediation of typical Superfund sites or compliance monitoring for facilities with a long-term, continuous source, the release scenario under consideration is a single, short-term release of acutely toxic chemical vapor and aerosol. No bulk or liquid source is assumed. Furthermore, the scenario incorporates active intervention to terminate a release from a terrorist device during the emergency response phase, followed by source removal and neutralization. There is no assumption of, or potential for, continuous release from the device, nor is there a potential for continuous replenishment of a chemical of concern from an external source into airport atmospheres or onto airport surfaces. The potential for exposure to aerosol or liquid droplets of persistent compounds is constrained by decontamination operations that occur before clearance sampling takes place. The majority of chemicals of concern analyzed in this *Remediation Guidance* are volatile (see Section 2.3.3 and Annex F), and airborne releases for most of them are known to degrade swiftly. Depending on ambient conditions of temperature, moisture, airflow, and other parameters, vapors for many compounds would dissipate rapidly and exhibit little to no persistence (see Table F-1 in Annex F and additional information on chemical and physical properties provided in NRC/COT 2002, 2003, and reviewed in Watson et al. 2006, Munro et al. 1994, Watson and Griffin 1992, and others). Rapid dissipation in air and from many surfaces is most likely for the non-persistent compounds, such as the G-series nerve agents, hydrogen cyanide, phosgene, and cyanogen chloride. The less-volatile vesicant agent sulfur mustard and nerve agent VX are more persistent and require special consideration.

The California Office of Environmental Health Hazard Assessment, in collaboration with the California Air Resources Board, and California Department of Public Health, has developed guidelines for establishing preliminary indoor clearance levels for use during cleanup of an airport within the State of California (Riveles et al., 2011). The guidelines are based on existing toxicology studies and are available upon request from the authors.[1] An additional treatment of the specific scenario under consideration can be found in Watson et al. (2011a and b) which includes: key assessment considerations and the decision criteria for multi-pathway exposure routes, and example exposure guidelines for the primary degradation products of interest. The values provided in these reports are not intended to be directly applied as clearance levels but, instead, can serve to inform the derivation of individual site-specific, risk-based, pre-planning values using the U.S. EPA methods as exemplified in the two case studies cited in Annex G (Sections 6 and 7).

However, in all cases of an actual CWA or TIC release, final clearance-goal decisions will be those made by responsible site-specific authorities, and they would reflect multiple operational

[1] Exposure Modeling Section Chief; State of California Office of Emergency Response, Office of Environmental Health Hazard Assessment, and California Department of Public Health.

factors as well as considerations of acceptable risk and situation-specific socio-economic concerns.

2.4 Plan for Characterization Environmental Sampling

Rapid remediation is a high priority. Because resources will be limited, characterization sampling must be centered on well-defined goals. Resources will be used most efficiently if sampling remains focused on gathering *essential* information. Characterization sampling should consider the following three purposes:

- To gather information needed to design the decontamination approach.
- To gather information for future comparison with clearance sampling results.
- To understand the fate and transport of a chemical of concern.

The approach is simple: Work through the airport systematically and thoroughly, zone-by-zone (Section 2.4.1). Zones should be assessed simultaneously to the extent possible and if resources are sufficient. Within a suspect area or zone, work from the outside inward, toward the suspected source. In each area:

- Assess existing information, including the likelihood of contamination.
- Decide what information is needed (i.e., clearly specify the purpose of sampling).
- Decide how to sample to answer questions, test hypotheses, or support decisions. Both judgmental and probabilistic sampling may be required.
- Combine assessments and selections of sampling zones and units into a written sampling plan.
- Obtain necessary approvals.
- Execute the plan.
- Assess the sampling results, and perform more sampling if necessary, or move to the next phase of remediation.

All characterization sampling should be designed to answer specific questions identified before sampling begins. Initial environmental sampling, conducted during first-response activities, provides preliminary hypotheses about the extent of contamination. During characterization, hypotheses are tested, further hypotheses are developed and tested, uncertainty is reduced, and a more complete assessment of the condition of the facility is developed. Sampling to be done for this purpose is documented in a Characterization Environmental Sampling and Analysis Plan (SAP). Technical specialists in the Planning Section and the EU coordinate with sampling team members in the Operations Section to develop and write the Characterization SAP. It is important that these groups closely collaborate on strategies documented in the plan. Upon completion, the SAP becomes part of the next operational period's IAP, which is reviewed and approved by the UC. The Characterization SAP describes the sampling strategies that are selected, specifies where to sample, and includes a variety of supporting information. Annex H includes a template to assist in developing the Characterization SAP.

Section 2.4.1 outlines a process to systematically assess an airport zone-by-zone, identify decisions that need to be made in each area and the information necessary to support those decisions, and decide how to gather the information through sampling. Potential sampling locations should be assessed for the likelihood that they will support necessary decisions or answer characterization questions. Sampling plan templates in Annex H can be used to help develop sampling plans. Included are a checklist for initial information gathering, data-quality objective (DQO) and Quality Assurance Sampling Plan (QASP) templates for time-critical sampling, and a combined Quality Assurance Project Plan (QAPP) and Field Sampling Plan template for more thoroughly planned sampling. Figure 2-12 summarizes the principal activities that take place during the Characterization Phase.

2.4.1 Develop Characterization Strategies

A suggested approach to characterization sampling is to use the four classes of zones described in Section 2.2.9. Characterization sampling falls into two broad categories: (1) ad hoc sampling to support source reduction and decontamination design, especially in the vicinity of the release, and (2) planned and detailed characterization in surrounding areas.

2.4.1.1 Ad hoc Sampling to Support Source Reduction in Class 1 Zones

In the immediate vicinity of a release, materials and surfaces suitable for source reduction may be identified by physical evidence, such as visible liquid, spatters, and security video recordings. Collect samples as needed to find items and materials to remove and to guide the decontamination or removal of such surfaces and materials.

2.4.1.2 Detailed Characterization in Class 2, 3, and 4 Zones

Class 2 Zones. Contamination is considered likely in Class 2 zones, so characterization should continue with sampling designed to confirm this expectation as quickly as possible. The process begins with judgmental sampling of materials and surfaces where a chemical of concern is expected to be present and to have persisted. Sampling includes permeable materials that, if contaminated, are likely to be outgassing. Air sampling can also be used. A detection in an air sample implies the presence of contaminated materials in the vicinity of the air sampling device.

If judgmental samples fail to find contamination greater than specified in clearance goals, random sampling (probably grid-based) should be used to make a more thorough search for contamination. Specific approaches for random sampling in Class 2 zones are discussed in Annex C. If grid-based sampling is selected, see Section 2.4.3 for suggested grid spacing.

If contamination is still not found, the area should be protected from cross contamination, if possible, and set aside for later clearance sampling as deemed necessary. If contamination is found, the area is reclassified as a Class 1 area and dealt with as such. Further sampling can be conducted to support additional source reduction, followed by planned decontamination.

Figure 2-12. Major activities during the Characterization Phase.

Class 3 Zones. Contamination is considered possible but unlikely in Class 3 zones, so characterization should continue with sampling designed to develop confidence that the area is not contaminated. A combined judgmental and random sampling approach (Sego et al. 2010; Annex E) will reduce the total sample load, provided that reliable information is used to place the judgmental samples. Judgmental sampling includes materials and surfaces where contamination is expected to persist and permeable materials, if contaminated, are likely to be outgassing. Air sampling may also be used. A detection in an air sample implies the presence of contaminated materials in the vicinity of the air sampling device.

If contamination is not found, the area should be protected from cross contamination, if possible, and set aside for a later review of the confidence achieved during characterization, and possibly for clearance sampling. If contamination is found, the area is reclassified as a Class 1 zone and dealt with as such. Further sampling may be conducted to support additional source reduction, followed by planned decontamination.

Class 4 Zones. Contamination is considered highly unlikely. The EU may decide that no further sampling is necessary. Otherwise, a purely judgmental approach (sampling in locations where the chemical of concern is expected to persist, or air sampling) or combined judgmental with random sampling approach would be appropriate (Annex E).

As for Class 2 and 3 zones, if contamination is found by either judgmental or probabilistic sampling, the area is reclassified as a Class 1 zone and dealt with as such. Further sampling may be conducted to support additional expedient decontamination, followed by planned decontamination. If contamination is found in a Class 2, 3, or 4 zone, then adjacent zones may by implication be more likely to be contaminated than previously thought, and a reassessment of their classifications would be appropriate.

For Class 2, 3, and 4 zones, if contamination is not found at this time, decision-makers might consider concluding that a given zone does not need decontamination. However, deciding that a zone needs decontamination is easier, in many respects, than deciding it does not. Concluding that a zone does not need decontamination, when there is even a small possibility that it may have been contaminated, involves an assessment of risk that is best handled with technical data and reviews. It is essentially equivalent to making a positive clearance decision during the Characterization Phase. Before making such a decision, the EU should determine the strength of evidence and amount of sampling support that is necessary.

The templates in Annexes H and I are intended to support and document the zone classification process. They provide a structure designed to help the Planning Section and technical specialists work through an airport area-by-area and zone-by-zone. The templates:

- Provide a mechanism for tracking objects and structures in an airport.
- Ensure that all types of items, materials, and structures are considered, even if not all are sampled.

- Save time by ensuring that sampling tasks are done systematically and thoroughly.

By using the templates, the Planning Section will:

- Assess the likelihood of contamination in each zone.
- Decide what information is needed to support decisions in each zone.
- Decide how to sample to gather that information.
- Define decision points to cease characterization sampling if data warrant gas or vapor decontamination or the complete removal of items.

2.4.2 Additional Considerations for Characterization

Characterization environmental sampling is often described as being done to assess the nature and extent of contamination. The "nature of contamination" is described by the identity of a chemical of concern and type of contaminated materials. The phrase, "extent of contamination," suggests a sampling strategy whose purpose is to locate the approximate boundaries of contamination. It is necessary to decide how precisely the extent of contamination needs to be determined. For example, is it necessary to determine such a boundary to within 5, 25, or 100 feet? In contrast, the search for extent could be just sufficient to decide in each zone whether or not decontamination is needed. More comprehensively, the search for extent could be done to compare characterization samples with future clearance samples or to learn about how the CWA or TIC was dispersed.

The most efficient characterization strategy depends on the dispersal pattern and decontamination method. For example, residuals of a chemical of concern might be identified at locations other than those where release devices were found. In such cases, there would be reason to suspect the presence of one or more unknown, relatively small areas having high levels of contamination. The areas could be dealt with using a localized decontamination method, which would require that characterization sampling be designed to yield a high likelihood of discovering all such hot spots. In contrast, assume that the release locations are known and (1) the chemical of concern is present only in an area surrounding the release locations, (2) the concentrations gradually decrease from the release point, and (3) only the area with concentrations exceeding a clearance goal needs decontamination. In such cases, characterization sampling designed to estimate conservatively the boundaries of the area would be preferred to sampling designed primarily to locate a hot spot. If the decontamination design depends on the highest range of concentrations in given materials within any small area, then sampling must be designed to find the corresponding sub-area or areas with the highest range of concentrations in those materials.

If a gas or vapor decontamination method is under consideration, then precise determination of the extent of contamination is not needed within a zone that will be treated as a unit. If there is much uncertainty about the spread of CWA or TIC after its initial release, then sampling must

have a much broader scope unless the entire suspect area is to be treated. Therefore, an early characterization priority is to determine the likely decontamination method or methods. This determination, in turn, depends on CWA or TIC properties and distribution. The entire remediation effort should be viewed as an integrated process rather than as strictly sequential steps.

The following determinations are key during characterization and in shaping the decontamination strategy:

- Deciding which areas of the airport require decontamination and which do not.
- Deciding what decontamination methods should be employed, given the type of chemical of concern, levels and locations of contamination, and types of materials contaminated.
- Deciding what materials, equipment, items, and surface types require decontamination in place versus removal and disposal, or removal and treatment.
- Identifying area(s) with the greatest predicted or confirmed concentrations of CWA or TIC.
- Identifying area(s) with the greatest potential for exposure to the public or airport workers.
- Identifying area(s) that are above and below risk-based exposure guidelines adopted as clearance goals.

The area(s) of greatest concentration and the area(s) of greatest potential for exposure may not be the same, and the potential for exposure may differ for different chemicals of concern. For example, ticket counters, boarding gates, and baggage claim carousels are likely to pose the greatest exposure potential, whereas the greatest agent concentration may be on exposed surfaces near the release point or within HVAC ducts. Both types of areas must be considered when developing sampling plans for characterization. All sources of information should be used, including:

- Locations of the release or releases, known or suspected.
- Estimates of the extent of contamination from the operating parameters of HVAC systems at the time of release, either known or suspected.
- Estimates of areas to which contamination may have been carried by methods other than the HVAC systems, such as tracking by foot traffic or any other means.
- Expected contamination patterns from airflow model results, if available.

2.4.3 Select Sampling Locations

Given that zones have been identified for sampling, and a sampling strategy has been selected (as suggested in Section 2.4.1), the next step is to select specific sampling locations. Sampling locations should be chosen not only with spatial extent in mind, but also to take into account persistence of the chemical of concern and its interactions with materials. At any given location, surface, bulk, and air samples may be considered (see also Section 2.4.4).

- Surface samples provide data directly relevant to clearance goals specified in units of surface concentration, if any, at a particular location.
- Bulk samples yield information regarding how much of a reservoir the material at a particular location provides for chemicals of concern. If a large reservoir is present, decontamination is indicated.
- Air samples provide data directly relevant to clearance goals specified in units of air concentration, if any. A detection in an air sample also indicates that the chemical of concern is being released into the air from a source or sources somewhere in the vicinity of the air sampling device.

Table 2-4 provides guidance on the types of materials for which surface samples are more or less likely to result in detection following vapor exposure of the material to a chemical of concern. When choosing sampling locations, materials identified with an “H” (high likelihood of detection) are preferred.

To help keep track of the different types of surfaces and materials that might be sampled, the templates in Annexes H and I use the term “sampling unit.” A sampling unit is a sub-portion of a sampling zone—such as walls or floors, or materials like furniture or caulking—that is sampled and evaluated collectively. Everything in a sampling unit should interact with the chemical of concern in the same (or a similar) way. With definitions of site-specific sampling units in hand, the EU or Sampling Group, or both, will be in a position to systematically consider each one in relation to the goals of characterization and to choose an appropriate sampling design for each unit. In particular, sampling units can form the basis for stratified sampling (see Annex E).

Table 2-4. Likelihood of successful detection by surface or bulk sampling 24 hr after exposure[a] of surface to vaporous or liquid contamination.[b,c] Assumes that any gross (bulk) contamination is removed before sampling.

	Tabun (GA)	Sarin (GB)	Soman (GD)	Cyclosarin (GF)	VX	Sulfur mustard (H/HD)	Hydrogen cyanide[f] (AC)	Cyanogen chloride[f] (CK)	Phosgene[f] (CG)
	Vap/Liq	Vap/Liq	Vap/Liq	Vap/Liq	Vap/Liq	Vap/Liq	Vap/Liq	Vap/Liq	Vap/Liq
Structural Materials									
Impermeable and nonporous									
Steel[d]	L / L	L / L	L / L	L / L	L / H	L / L	L / L	L / L	L / L
Glass[d]	L / L	L / L	L / L	L / L	L / H	L / L	L / L	L / L	L / L
Permeable or porous									
Concrete[d]	L / H	L / H	L / H	L / H	L / H	L / L	L / L	L / L	L / L
Wood	? / H	L / H	L / H	? / H	L / H	? / H	L / L	L / L	L / L
Wall, Floor, Ceiling, and Counter Coverings									
Impermeable and nonporous									
Stainless steel[d]	L / L	L / L	L / L	L / L	L / H	L / L	L / L	L / L	L / L
LAX phenolic wallboard	L / L	L / L	L / L	L / L	L / H	L / L	L / L	L / L	L / L
Metal screens and grates (clean)	L / L	L / L	L / L	L / L	L / H	L / L	L / L	L / L	L / L
Permeable or porous									
Vinyl tile[d]	H / H	H / H	H / H	H / H	L / H	H / H	L / L	L / L	L / L
Ceramic tile (polymeric coating)	H / H	H / H	H / H	H / H	L / H	H / H	L / L	L / L	L / L
Acoustic tiles	H / H	H / H	H / H	H / H	L / H	H / H	L / L	L / L	L / L
Gypsum wallboard[d]	H / H	H / H	H / H	H / H	L / H	H / H	L / L	L / L	L / L
Baseboard (polymeric)	H / H	H / H	H / H	H / H	L / H	H / H	L / L	L / L	L / L
Paint	H / H	H / H	H / H	H / H	L / H	H / H	L / L	L / L	L / L
Fire-retardant insulation	H / H	H / H	H / H	H / H	L / H	H / H	L / L	L / L	L / L
Blown insulation	H / H	H / H	H / H	H / H	L / H	H / H	L / L	L / L	L / L
Silicon sealant	H / H	H / H	H / H	H / H	L / H	H / H	L / L	L / L	L / L
Dust and dirt	H / H	H / H	H / H	H / H	L / H	H / H	L / L	L / L	L / L

Table 2-4. Continued.

	Tabun (GA)	Sarin (GB)	Soman (GD)	Cyclosarin (GF)	VX	Sulfur mustard (H/HD)	Hydrogen cyanide[f] (AC)	Cyanogen chloride[f] (CK)	Phosgene[f] (CG)
Utility Runs									
Impermeable and Nonporous									
Galvanized steel ductwork[d]	L / L	L / L	L / L	L / L	L / H	L / L	L / L	L / L	L / L
Metal pipes (copper, iron, brass, steel)	L / L	L / L	L / L	L / L	L / H	L / L	L / L	L / L	L / L
Bare metal wires (copper, steel)	L / L	L / L	L / L	L / L	L / H	L / L	L / L	L / L	L / L
Permeable or Porous									
Flexible ductwork[d]	H / L	H / L	H / L	H / L	L / H	H / L	L / L	L / L	L / L
Fiberglass insulation	L / L	L / L	L / L	L / L	L / H	L / L	L / L	L / L	L / L
Grime	H / H	H / H	H / H	H / H	L / H	H / H	L / L	L / L	L / L
Wire coating and electrical insulation	H / H	H / H	H / H	H / H	L / H	H / H	L / L	L / L	L / L
Pipe insulation	H / H	H / H	H / H	H / H	L / H	H / H	L / L	L / L	L / L
Removable coverings and furniture[e]									
Permeable or Porous									
Carpet	H / H	H / H	H / H	H / H	L / H	H / H	L / L	L / L	L / L
Wood furniture	H / H	H / H	H / H	H / H	L / H	H / H	L / L	L / L	L / L
Rubber escalator railing[d]	H / H	H / H	H / H	H / H	L / H	H / H	L / L	L / L	L / L
Urethane escalator railing	H / H	H / H	H / H	H / H	L / H	H / H	L / L	L / L	L / L

[a]Physical state of chemical of concern contacting surface. “Vap” refers to vapor; “Liq” refers to liquid.

[b]Likelihood of detecting a CWA or TIC on or in exposed, clean material from surface or bulk sample. L = Low; H = High.

[c]Experimental data have only been determined for GB, HD, and VX. Values for AC, CK, and CG were estimated from physical properties of these compounds. Values for GD were estimated on the assumption that GD would have a similar vapor pressure and volatility to GB. Values for GA and GF were estimated by assuming that they have similar vapor pressures and volatilities to H/HD.

[d]Materials included in the test program with chemicals of concern or surrogates.

[e]Removable items and materials may be surveyed for off-gassing of chemical with field instruments and quickly removed if off-gassing occurs.

[f]Sampling for corrosive breakdown products.

Specific sampling locations can be chosen by judgmental or statistical methods, or both. Judgmental sampling is effective when the source of contamination is known and supporting forensic data are available. This approach relies on existing information about the incident to identify locations where additional sampling is expected to answer specific characterization questions. Judgmental sampling can be used to sample items or areas most likely to be contaminated to quickly determine if the zone is contaminated. If contamination is found, then the area of contamination may be further delineated, if necessary for the anticipated decontamination method. If no contamination is found, additional statistical sampling may be required to achieve an acceptable level of confidence that no contamination exists, as described above for Class 2, 3, and 4 zones (see also Annex C, Figure C-2).

A random approach can be used when little or nothing is known about where a release occurred, as might be the case following a covert release, or if sampling is done in zones where information about probable locations is weak or uncertain (for example, in zones distant from the release; see Class 4 zones in Section 2.2.9.1). Statistical sampling is appropriate for quantitative comparisons with clearance goals specified according to risk-based exposure levels. Combined judgmental and statistical sampling approaches may also be appropriate.

A sampling grid can be designed to yield a high probability of discovering a surface hot spot of a given size or to increase confidence that a large proportion of the surface area within a zone is uncontaminated. The EU would need to specify the size of the grid and the probability of discovery or desired degree of confidence. A suggested starting point would be to design a grid that has a 95% probability of detecting a hotspot that is larger than 1% of the available surface area (for example, approximately 100 samples spaced approximately 25 feet apart on a 49,000 square foot surface). Statistical sampling for comparison with clearance goals requires that the EU specify an acceptable degree of uncertainty in the comparison. This kind of statistical sampling can help when deciding how much characterization sampling is enough. For more information on sampling strategies, including suggestions for sampling locations, see Annexes C, D, and E.

2.4.4 Select Sampling and Analysis Methods

When selecting an appropriate type of sample, several factors must be considered, the most important of which is to define the purpose for collecting that sample. For example, if the goal is to determine concentrations of a chemical of concern to which one might be exposed when breathing, it is appropriate to collect an air sample. Detection of a chemical of concern in an air sample indicates that there are sources of the chemical in the general vicinity of the sampler, but it does not pin down the exact location or provide a precise location of a decontamination boundary. If a goal were to detect the presence of sorbed chemical of concern, then solid samples (including chips, bulk materials, and soils) would be collected and analyzed. To assess contact hazards, surface samples would be collected. Because “decontamination” can refer to removal, cleaning, or sealing of materials, surface and bulk sampling are appropriate for obtaining a direct indication of which materials need decontamination and where. Surface sampling can also indirectly address air issues (inhalation hazards) because chemicals of concern may volatilize off

some materials under certain conditions. Because surface, bulk, and air samples all provide relevant, but different, types of information, this *Remediation Guidance* suggests that all three should be used to obtain complete characterization.

Consultation and coordination with a qualified laboratory or qualified chemical-analysis professional is essential when selecting the sampling and analysis methods. To the extent possible, sample collection and analysis should be done by trained teams using approved and validated Standard Operating Procedures. Many sampling methods are available, depending on the chemical(s) of concern and media to be sampled (see Annex D).

Once the type of sample is selected, a sampler carefully collects a sample using a method that ensures that a representative sample will be taken, preserves the chemical of concern in the sample, and ensures that sample integrity is not compromised by outside contaminants (see Annex D). All samples should be collected as documented in a Standard Operating Procedure (sampling SOP). For example, an SOP for a wipe sample should specify the size of the surface area to be wiped. Personnel who perform sampling and analysis must be trained in techniques for sample collection and techniques to detect chemicals of concern, respectively.

Many analytical methods can be used to detect and measure CWAs and TICs. The selection of an appropriate detection technique depends on the analyte to be detected, detection levels required, how quickly analytical results are needed, and the degree of analytical accuracy desired. In particular, the laboratory must be able to assess samples using methods with limits of detection less than the selected clearance goals (see Section 2.3). Such a requirement minimizes uncertainty about potential health impacts associated with negative results (nondetections). Because clearance goals are incident-specific, and probably will not be available at first, initial characterization samples should use detection limits that are as low as possible, at least for samples outside the immediate release location (i.e., where environmental levels might be relatively low). Detection limits below clearance goals is an absolute requirement for clearance sampling. Real-time (field) methods include those using flame photometric detectors, ion-mobility spectrometers, and mass spectrometers. The main advantage is that such methods can be performed by operators with minimal training to provide data in the field. Laboratory methods include gas chromatography coupled with flame photometric detection, mass spectrometry, tandem mass spectrometry, and others (Annex D). Whereas laboratory-based methods typically provide a greater level of confidence about chemical identification and quantification, and they can detect very low concentrations of chemicals, such methods must be performed by highly trained operators in a laboratory. Because samples must be transported to the laboratory, and some preparation of a sample is required before analysis, test results will be not be immediately available. Results are likely to be reported several days (or several hours, in special circumstances) after samples are submitted for analysis.

No single recommendation for sampling and analysis methodology is made in this *Remediation Guidance* because any incident 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, if there is minimal interference from other compounds in the environment and detection limits are low enough. If the use of field instruments is not appropriate, then laboratory-based analytical methods must be used. Because of their ability to unambiguously identify and quantify chemicals of concern, laboratory-based, mass-spectrometric analytical techniques are preferred.

The sampling and analysis methods chosen will depend, in part, on the specific chemical of concern. If the chemical of concern happens to be a regulated TIC, it is likely that formally validated methods (e.g., the EPA Test Methods) are available that can be used for chemical analysis. Many qualified commercial laboratories use such methods. However, if the chemical of concern is a CWA, at present no formally validated methods exist that can be applied to analyze the samples. Experiments are currently being conducted to verify that selected CWAs on selected surfaces can, in fact, be detected at concentrations less than possible health-based guidelines, which could be adopted as clearance goals. The EPA is also currently verifying, through multi-laboratory efforts, analysis methods for selected CWAs. If the outcome of this work is successful, the methods will be published, and commercial laboratories will be able to employ validated methods for selected CWAs. If validated methods are not available, then best practices or newly developed and documented (but unvalidated) methods adapted from the chemical literature might need to be applied by a qualified laboratory. Annex D contains more information about available analytical methods; see also EPA (2008b).

In general, when working with an analytical laboratory to resolve sampling and analysis issues, the analytical laboratory should provide:

- Appropriate guidance on sample collection, including the types of samples to be collected, the quantity of sample needed, and any required sample preservation.
- Well-documented sample-preparation methods.
- Well-documented analytical procedures.
- Proof that desired detection limits can be achieved.
- A documented QA/QC program.

In addition, relatively few laboratories are qualified to perform analyses of CWAs. If large numbers of samples are collected, a bottleneck may ensue. One way to reduce the bottleneck would be to allow additional laboratories to perform analyses. Such an approach would introduce the possibility that multiple methods, possibly with different detection limits, might be used. This situation would, in turn, introduce difficulties in comparing results, performing statistical analyses, and interpreting the results for the purpose of planning decontamination (or later, clearance). Thus, the selection of laboratories and methods must be carefully planned and controlled.

2.4.5 Prepare Incident-Specific, Operational, Characterization Environmental Sampling and Analysis Plan

The Characterization Sampling and Analysis Plan (Characterization SAP) is the responsibility of the EU. The EU develops the SAP in cooperation with the Sampling Group in the Operations Section, other elements of the Operations Section, and technical specialists, as needed.

The SAP should employ a data quality objectives (DQO) process and be written in the context of a Quality Assurance Project Plan (QAPP) that meets requirements in the *Uniform Federal Policy for Quality Assurance Project Plans* (EPA 2005a). The sampling plan templates in Annex H are based on templates from EPA Region 9. The Region 9 templates were designed to combine, "in a short form, the basic elements of a Quality Assurance Project Plan (QAPP) and a Field Sampling Plan (FSP) [to] meet the requirements for any U.S. Environmental Protection Agency (EPA) Region 9 funded project in which environmental measurements are to be taken." Annex H provides an overview of the requirements for quality assurance documentation for sampling plans.

Upon completing the draft of the Characterization SAP, an internal review is initiated. Upon approval of the plan by the UC, characterization commences. There is no requirement that a single, written plan be generated for an entire airport. For example, the TBIT could have separate, written plans for the central building and each concourse. Whether or not such an approach is appropriate would depend on the details of an incident. Annex H contains templates designed to help in preparing incident-specific sampling plans.

2.4.6 Conduct Characterization Environmental Sampling and Evaluate Results

The Sampling Group within the Operations Section of the Incident Command Structure implements the Characterization Environmental SAP. Upon completion of characterization activities, results are evaluated for completeness by the EU, with input from the TWG, if such a group is formed. If necessary, the Characterization SAP is revised, and additional characterization is done.

2.5 Pre-Incident Planning

Table 2-5 identifies the essential pre-incident planning activities related to site characterization.

Table 2-5. Summary of characterization-related actions to be taken prior to a CWA or TIC attack.

Responsible Personnel	Pre-Incident Actions Related to Characterization
Airport management	• Identify and document characterization, decontamination, and clearance resources; see Table 2-1. • Ensure appropriate data-management systems are in place. • Create a new, or review an existing, HASP. • Prepare template for a Characterization SAP that can be customized to fit an incident. • Identify and document potential characterization and decontamination zones within airport buildings. • Identify and document sampling units. • Identify and document areas at the airport that can be made available for staging personnel and equipment. • Identify and document areas that can be used for storing waste materials. • Identify potential waste-disposal locations, capacities, types of wastes accepted, and contact information for the waste facilities. • Consult with state solid- and hazardous-waste management officials and waste-disposal facilities on regulatory and facility requirements. • Make accessible all facility architectural and mechanical drawings, including utilities such as HVAC, electrical, and plumbing. Make drawings available in an electronic format that can be used with GIS and Geo-Spatial mapping tools. Store copies offsite. • Periodically update all HVAC blueprints and operating parameters. Store backup copies, including electronic blueprints, offsite. • Periodically update building vulnerability assessments, and correct any deficiencies. • Make accessible any HVAC airflow modeling. Store copies offsite.

2.6 Summary

The major Characterization Phase activities include gathering available information (as characterization begins), identifying early ad hoc decontamination activities (source reduction and containment), assessing the condition of the facility, refining that assessment through sampling, and gathering information needed to develop a decontamination plan. Table 2-6 identifies key activities and responsible parties. Timely completion of the characterization activities described in this section is critical for rapid and cost-effective remediation.

Table 2-6. Summary of actions during the Characterization Phase showing the approximate sequence of actions.

Responsible Personnel	Action
Planning Section: Situation Unit Leader	Compile all analytical and observational data and reports created during first response, and provide the information to the Environmental Unit.
Unified Command (or IC or appropriate Unit Leader in a large incident)	Mobilize as necessary pre-identified resources for characterization activities, including: • Appropriate analytical laboratories (e.g., ERLN, OPCW, or certified laboratories). • Environmental sampling teams. • Cleanup contractors with decontamination and disposal resources. • Data management and documentation specialists. • Air-dispersion modeling resources. Activate technical specialists (i.e., TWG) and special teams (e.g., EPA NDT); establish NIMS ICS organization; establish lines of authority and responsibilities. Begin notifying resources for remediation, clearance, and waste management.
Site Safety Officer	Create and implement a Health and Safety Plan (HASP). The Logistics Section's Medical Unit Leader develops the medical plan, which may become part of the HASP.
Facility Manager	Provide detailed blueprints of areas of operation, HVAC systems, and any video surveillance systems to the Planning Section's Documentation Unit and the Situation Unit Leader.
Planning Section Chief	Consider and recommend to the UC an incident objective for immediate containment of contamination and source reduction, if needed. Implement any recommended containment, source reduction, and removal actions. Depending on actions completed during first response: • Assess potential transport of contamination outside the facility. • Evaluate the need for air monitoring. • Evaluate the need for conceptual or mathematical modeling. Recommend, if needed, air modeling of CWA or TIC movement throughout the facility to estimate initial extent of contamination.
Operations Section Chief	Identify waste-disposal facilities and capacities, if needed.
Planning Section: Environmental Unit	Using input from the Sampling Group and TWG: • Evaluate exposure guidelines, and develop measurable clearance goals, as appropriate and considering the results of characterization. • Develop a characterization sampling strategy to support remediation activities. • Organize airport into characterization zones. • Select sampling locations for each zone. Write an incident-specific Characterization SAP identifying all goals.
UC	Review and approve the clearance goal(s) (identified in the IAP).
Operations Section: Entry Group	Perform air monitoring to detect CWA or TIC spread and potential exposure. Ensure containment of the chemical of concern, and establish isolation for gas or vapor decontamination, if such action is needed.
UC	Approve the Characterization Environmental SAP, attached to IAP.
Ops Section: Sampling Group	Implement the Characterization Environmental Sampling and Analysis Plan.
Analytical laboratory	Analyze samples using standard protocols to meet characterization objectives.
Planning Section: EU	Using input from the TWG, evaluate results of characterization. Recommend additional characterization activities to the Operations Section, as needed. Report to the UC.

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3 Decontamination

The goal of decontamination is to remove as quickly as possible sufficient contamination from an airport so that, after clearance and any necessary reconstruction and refurbishment, normal operations can resume. Decontamination strategies can involve prioritizing critical operations at an airport to facilitate the resumption of those operations and to minimize the potential for adverse health effects. Decontamination commences with source reduction, which includes removing or decontaminating visible CWA or TIC on surfaces to reduce the contamination load and secondary dispersion of chemicals of concern, and separating salvageable from nonsalvageable items. For CWAs and TICs, incident-specific decontaminating reagents and delivery systems are selected, depending on the nature and extent of contamination and other site parameters identified during characterization. Hands-on experience with many decontamination agents and delivery systems in civilian settings is limited to a few types of clean materials under simulated building conditions. Therefore, when remediation schedules permit, pre-testing decontamination reagents and systems is advisable when decontamination includes large areas or critical components, or when it involves a new combination of materials, building conditions (e.g., localized dust and grease), or decontamination systems.

Once specified performance and design criteria for any decontamination action are met, the effectiveness of decontamination must be confirmed by the clearance process described in Section 4. Figure 3-1 summarizes major activities during the Decontamination Phase. The issue of “How clean is clean enough?” and the sampling and clearance methods by which the answer is determined are key to establishing effective and successful remediation (Raber et al. 2001).

Decontamination activities are documented in the Remediation Action Plan (RAP), and steps must be taken when implementing the plan to prevent further environmental impacts. Some decontamination technologies, such as liquid bleach, require little site preparation; others, such as gas or vapor decontamination, may require more extensive preparation. Performance criteria for various decontamination approaches are assessed by monitoring key process variables specific to the decontamination strategy selected, such as temperature, contact time, and concentration of a gaseous reagent, if used. Although clearance activities take place after decontamination actions are completed, clearance sampling should be planned concurrently with decontamination. In the end, remediation must be defensible to regulatory agencies and to the public. It is important to anticipate the issues of concern and to educate all relevant parties on the various technologies employed and the clearance process to be used.

A detailed RAP cannot be developed for an airport in advance of an attack. Specific choices depend on the nature of the CWA or TIC released, location of release, extent of contamination, and all other parameters that are the focus of characterization. Thus, this section addresses the nature of actions to be taken and decisions to be made in devising an optimal decontamination

approach. Details on specific decontamination reagents, techniques, and applications are provided in Annex F.

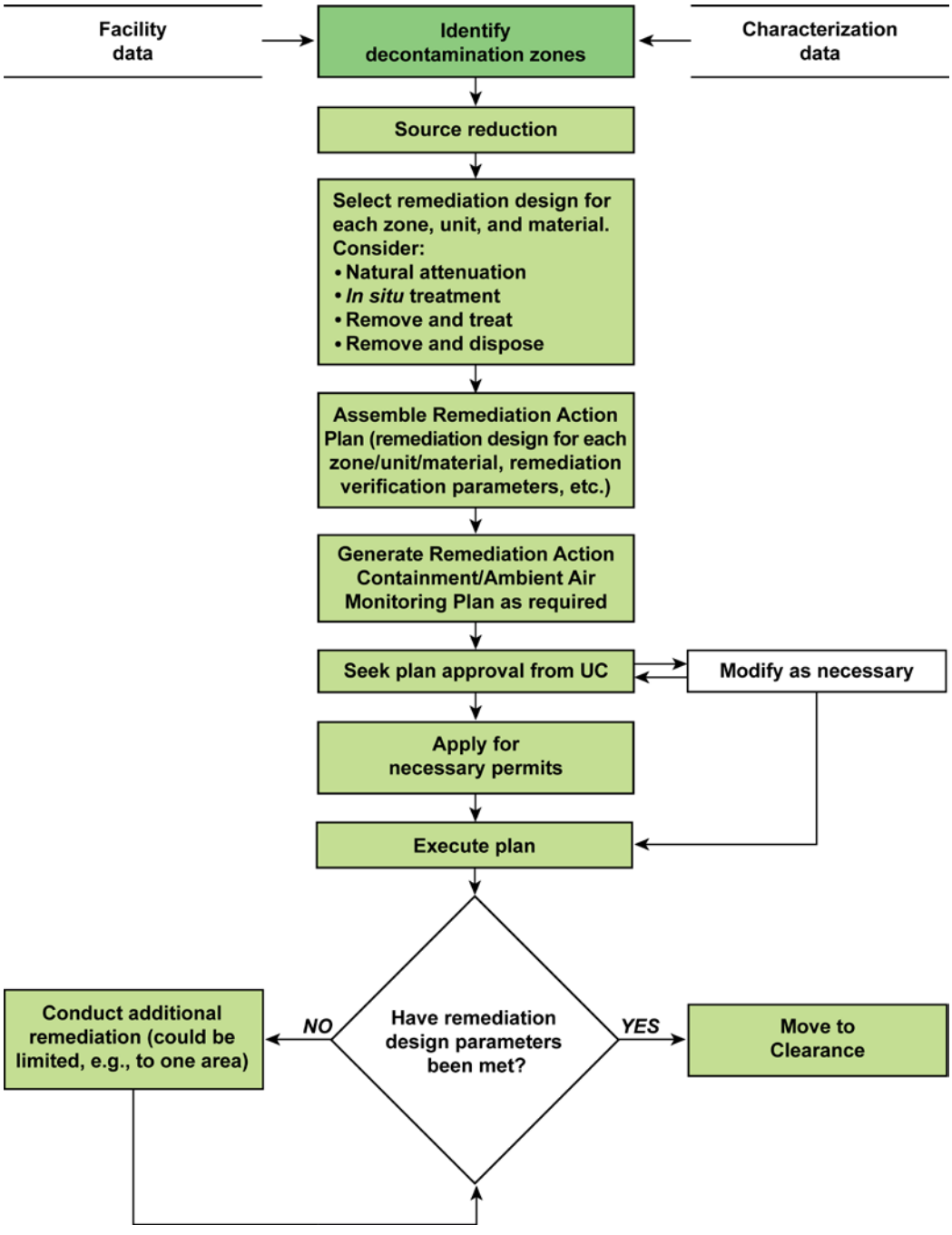

Figure 3-1. Major activities during the Decontamination Phase.

If additional types of contamination were present (i.e., a multiple release incident with radiological or biological agents in addition to chemical), each type of contamination would need careful consideration when planning the decontamination strategy. Cleanup procedures that can address multiple contamination classes simultaneously would be expected to result in important remediation efficiencies. Additional operational considerations would need to be evaluated to prevent adverse outcomes from competing contamination characteristics, such as the spread of one type of contamination while cleanup of another type proceeds. A similar evaluation would be needed following the coincident release of more than one type of CWA or TIC.

3.1 Evaluate Decontamination Capabilities

Several decisions must be made by airport personnel well in advance of implementing an incident-specific RAP in response to a terrorist attack. Such decisions regarding decontamination capabilities include:

- Equipment to have on hand, either for general use, such as ventilation fans and blowers, or dedicated to decontamination, such as carbon air filters and absorbent spill kits with vapor suppression.
- Extent and types of decontamination supplies to store.
- Location and number of staging areas or warehouses for equipment and supplies.
- Selection of potential contractors to employ as members of the decontamination team.
- Identification of potential waste-disposal facilities.
- Consideration of waste-related transportation requirements and costs, which may be substantial.

For more details on such issues, see Annex F. Decontamination-related decisions can have a major impact on waste-disposal costs and present substantial nontechnical (e.g., legal and regulatory) challenges at the time that disposal takes place. Table 3-1 lists the types of resources (agencies, teams, and technical contacts) that should be identified by airport personnel in advance.

3.2 Evaluate Monitored Natural Attenuation

Natural attenuation in the context of this *Remediation Guidance* document refers to a decrease in concentration of a hazardous substance, including CWAs and TICs, into less hazardous concentrations via natural environmental mechanisms such as heat, light, or volatilization. Natural attenuation may be assisted by increased outdoor air exchange and increased temperature. If natural attenuation is employed, its progress and effectiveness must be continually assessed through appropriate sampling and monitoring. Monitored natural attenuation should be considered as an option along with other decontamination approaches within a risk-based framework.

For incidents involving only volatile or short-lived CWAs or TICs, such as the cyanides or some of the nerve agents, monitored natural attenuation could eliminate acute and chronic impacts. For such threats, many of the more aggressive decontamination activities described in this section

might not be required, and re-entry and resumption of airport operations might be allowed after sufficient time for monitored natural attenuation and upon confirmation by clearance sampling. For low-volatility or long-lived CWAs and TICs, such as VX, monitored natural attenuation alone may not be an option. Purity of a chemical of concern can also alter the effectiveness of natural attenuation by enhancing reactivity or inhibiting volatilization and should be evaluated for potential deviations from expected persistence characteristics. For a major incident requiring aggressive decontamination technologies, at least some natural attenuation will likely occur during the days or even weeks of characterization and remediation planning preceding the start of engineered decontamination technologies. Such natural attenuation should be assessed through monitoring.

Table 3-1. Site decontamination resources.

Resource	Contact	Phone
EPA On-Scene Coordinators		
National Decontamination Team		
National Homeland Security Research Center		
Facility engineering and construction team(s)		
Decontamination team (may include decontamination reagent suppliers and contractors)		
Environmental consultants and architectural and engineering firms		
Structural engineer to assist in RAP development		
Primary analytical laboratory		
Secondary analytical laboratory		
Sampling team(s) and contractor(s)		
Centers for Disease Control and Prevention (CDC)		
Personal protective equipment (PPE) rentals		
Fumigation companies for tarp and enclosure rentals		
Sources of Baker tanks (multiple sizes), secondary containment materials, and related items		
Sources of negative air units and heaters, if used		
State solid-waste management division		
Local wastewater treatment facility		

Natural attenuation may be more rapid if clean air from the outside is exchanged with contaminated air inside. If contaminated indoor air is allowed to escape to the outdoors, monitoring the concentration of escaping air is necessary to determine the hazard level. If

escaping air has the potential to be hazardous, facility remediation teams should capture and/or treat the air before releasing it to the outside.

Even for the more volatile CWAs or TICs, it is possible that a toxic chemical could adsorb onto or absorb into some of the materials found in an airport and then gradually be released. In some cases, such processes can slow natural attenuation resulting from volatilization. Surfaces with material properties that make adsorption or absorption of chemical contamination more likely should receive particular attention when monitored natural attenuation is employed to ensure that residual contamination levels actually achieve clearance criteria.

Monitored natural attenuation should also include monitoring for toxic degradation products. Depending on the reactions occurring, degradation products of CWAs and TICs are somewhat less toxic to much less toxic than parent compounds. However, because they are typically less volatile, the degradation products can also be more persistent. Such considerations suggest that clearance guideline levels selected also be protective against exposure to degradation products resulting from the initial contamination.

3.3 Contain and Isolate Decontamination Zones

Containment to prevent the spread of a CWA or TIC to uncontaminated areas of an airport begins during first response and continues during characterization (Section 2.2.6). If any containment barriers were employed during earlier phases, they must be reviewed for adequacy to contain contamination for the duration of a possibly lengthy decontamination phase. If they are also used to isolate contaminated areas and equipment during decontamination, they must be reviewed for adequacy to serve as isolation barriers for the decontamination approach selected.

Containment areas set up during characterization may also correspond to designed isolation zones used during decontamination. In some instances, smaller isolation zones may be desirable, especially when using volumetric decontamination technologies. For instance, a whole room is likely to be the smallest space designated initially as a containment area during characterization. A smaller section of the room could be used as an isolation zone (such as the space above a false ceiling) to reduce the quantity of decontaminant required for volumetric treatment with gas or vapor. Minimizing treatment volumes is especially critical for gases or vapors that rapidly cool and condense, such as steam, or decompose, such as hydrogen peroxide. Containment barriers constructed for an initial and noncorrosive chemical release at room temperature may be inadequate as isolation barriers for high-temperature or corrosive gases or vapors used for decontamination purposes. In such cases, specially constructed isolation barriers are required, and their seals must be tested for leak-tightness. Annex F provides more details on isolation barrier technology.

3.4 Develop the Decontamination Strategy

Decontamination planning activities can begin when data are obtained from site characterization actions identifying the areas and types of materials requiring decontamination. This effort by the

EU culminates in preparing an incident-specific Remediation Action Plan (RAP). Developing the RAP is a coordinated effort by the Planning and Operations Sections. The RAP describes a decontamination strategy that consists of the following:

- Facility-specific information, summary of the contamination incident, members of the project team, and a summary of characterization sampling and air monitoring results.
- Alternatives to engineered decontamination actions, if any, such as monitored natural attenuation.
- What facilities and areas need to be decontaminated.
- What materials and structural components are decontaminated in situ, removed, or both.
- Which surface decontamination technologies are to be used.
- Whether gas or vapor-phase decontamination technologies are to be used.
- Whether structural components and materials to be treated are chemically compatible with the selected decontamination reagents.
- Any pre-decontamination work required, such as sealing off or partitioning areas.
- How the effectiveness of decontamination will be monitored.
- Specification of decontamination process parameters, and their acceptable ranges.
- Specifications of clearance goals to be met.
- Reference to an Ambient Air Monitoring Plan, if one is needed, to monitor for any uncontrolled release of decontaminant outside a treatment area.
- A description of decisions regarding operation of the HVAC system.
- Selection of staging areas.
- Specification of waste-storage areas.
- Discussions of waste disposal and safety.
- Reference to the Clearance SAP, a HASP, and an Ambient Air Monitoring Plan, if required.
- A thorough description of actions to be taken, the order in which they are to occur (project schedules), and specification of who will perform them.

The areas requiring decontamination will likely have been determined after sampling and analysis are completed during characterization. If decontamination technologies have been established in advance (see Section 3.1), then the RAP can be prepared more rapidly. The remainder of this section describes assumptions, decisions, and the timing of decisions that shape the components of a decontamination strategy.

As discussed in Section 1, for a major incident, the initial release of a site by law enforcement officials could occur days, or even weeks, after the initial release of contaminant. For volatile chemicals such as sarin (GB) and semi-volatile chemicals such as soman (GD) and mustard (H), experimental data suggest that natural attenuation (both volatilization and degradation) will have reduced air and nonpermeable surface concentrations to very low levels. Vapors from chemicals with very low volatility, such as VX, will have a very slow evaporation rate and therefore will

remain a contact hazard on surfaces for weeks or months, if the contamination does not degrade or is not decontaminated. The UC may decide to operate or not operate the HVAC system, depending on indoor air concentrations (discussed in Annex F) and whether the air in the HVAC system is to be treated before return or release. If vapor concentrations of a CWA, TIC, or decontamination reagent within an isolation area are expected to persist above toxic levels for an extended time, or if the area is to be filled with a decontaminating vapor or gas, then NAUs should be used in that area to control air emissions. The use of NAUs may require changes in the operation of the HVAC system, such as installing filters to reduce emissions of toxic chemicals to the atmosphere.

3.4.1 Perform Source Reduction

Initial source reduction may commence during first response or characterization activities of an incident, as discussed in Section 2.2.4. The objective of source reduction is to decrease the amount of gross contamination in a facility by removing or decontaminating quantities of materials that would likely result in greater spread of contamination or pose difficulty when the main decontamination activity commences. Before decontamination, decisions need to be made concerning what materials and structural components will be decontaminated for reuse either onsite or offsite, and what will not be reused, but will be packaged—either with or without prior decontamination—and removed for disposal either as waste or through recycling. Understanding a facility and its contents, as well as making general decisions about decontamination and disposal before an incident, will expedite source reduction. Nonessential items removed for disposal are treated differently from essential items removed for offsite treatment and returned for reuse. A facility's structural components and essential items are likely to be decontaminated for reuse. Removable materials (flooring, false ceilings, acoustic tiles, and low-end computers) can be decontaminated, packaged, and transported for disposal according to requirements identified in Section 3.5. A qualitative cost–benefit analysis should be part of the decision process related to retention versus disposal of items, or costs can rise unnecessarily. For many substrates, such as carpet, chairs, partitions, acoustic ceiling tiles, waste containers, and benches, the best approach may be to physically remove and properly dispose of the items, then replace them with new ones after clearance. Use of a portable shredder could help to decrease both disposal volumes and costs. Shredding would also help prevent the unintended removal of discarded items from landfills and the subsequent reuse of remediation waste materials by scavenging companies or individuals. Source reduction during the Decontamination Phase is performed by the Operation Section's Decontamination Group working with the Disposal Group.

For facilities at which gas- or vapor-phase decontamination is to be conducted, source reduction of materials that will remain onsite (e.g., equipment) and structural elements of the facility may include prior surface treatment. Details on surface treatment are in Annex F.

Sensitive equipment, such as computers, electronic and electrical circuit boards, high-voltage power lines, and electronic control panels, are not amenable to aqueous decontamination systems. The problem of sensitive equipment is discussed below and in Annex F.

Removal of any contaminated material will require transportation to an approved treatment and disposal facility after it has been decontaminated. The Department of Transportation (DOT) and individual states have many requirements for pre-treating and packaging materials prior to leaving a contaminated facility, labeling packages for transport, and transporting material to approved facilities (see Section 3.5.4). The separate category of personal or valuable items that could be removed for offsite decontamination is discussed below and in Annex F. Additional details related to waste management and disposal are provided in Annex L.

Many items selected for removal, decontamination, and disposal will be inexpensive items made of plastics, polymers, and porous materials (e.g., chairs and ceiling tiles), and sampling such items after decontamination to prove there is no residual CWA or TIC can be prohibitively expensive or burdensome. It might be necessary to categorize certain removed, decontaminated materials as having residual levels of CWAs or TICs for purposes of packaging, transportation, treatment, storage, and disposal. Such an approach could potentially lead to extended times to achieve final waste disposal. Thus, it is critical to establish dialogues with state solid-waste management officials and waste-disposal facilities during remediation planning. It is also important to select appropriate staging and waste storage areas so that the timeline for waste disposal does not adversely affect the timelines for clearance and restoration of a facility.

3.4.2 Select Decontamination Technologies

The selection of decontamination technologies depends on the specific CWA or TIC used in an attack, items to be decontaminated, and the materials involved. A large airport contains many different types of areas that may need to be decontaminated. Areas range from large, open atria often found in terminal buildings and ticket counter check-in areas; to long, relatively narrow boarding gates; to a variety of concessions that include restaurants and retail outlets. Most areas can be considered enclosed or semi-enclosed spaces. In addition, airports have specialized equipment, such as baggage handlers and large, industrial AHUs that may potentially complicate decontamination efforts. A substantial portion of the baggage handling system may be located on the runway level in open or semi-enclosed spaces. Finally, sophisticated computers that control baggage flow, gate schedules, and passenger flow, along with complex security screening machines, may need to be decontaminated.

Because of the complex landscape, three types of decontamination technology might be required:

- Exposed-surface decontamination reagents for large-area surface cleaning, which must address both nonporous and porous surfaces.
- Gas- or vapor-phase decontamination reagents to ensure that air-handling systems along with hidden and hard-to-reach spaces are sufficiently decontaminated, and a method to contain and control the gases.
- Technologies to decontaminate sensitive electronic equipment and small, personal, or valuable items, such as baggage and artwork.

Figure 3-2 shows at a high level a series of questions that should help identify classes of decontamination methods that will be needed for a specific incident. The questions are also

shown in Figure F-1 of Annex F, along with additional factors that should be considered. These figures do not imply a particular order in which to use the methods. Decontamination methods can be deployed in different orders, depending on incident-specific conditions. For example, monitored 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 gas- or vapor-phase decontamination 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 the contamination was known to be located on accessible surfaces.

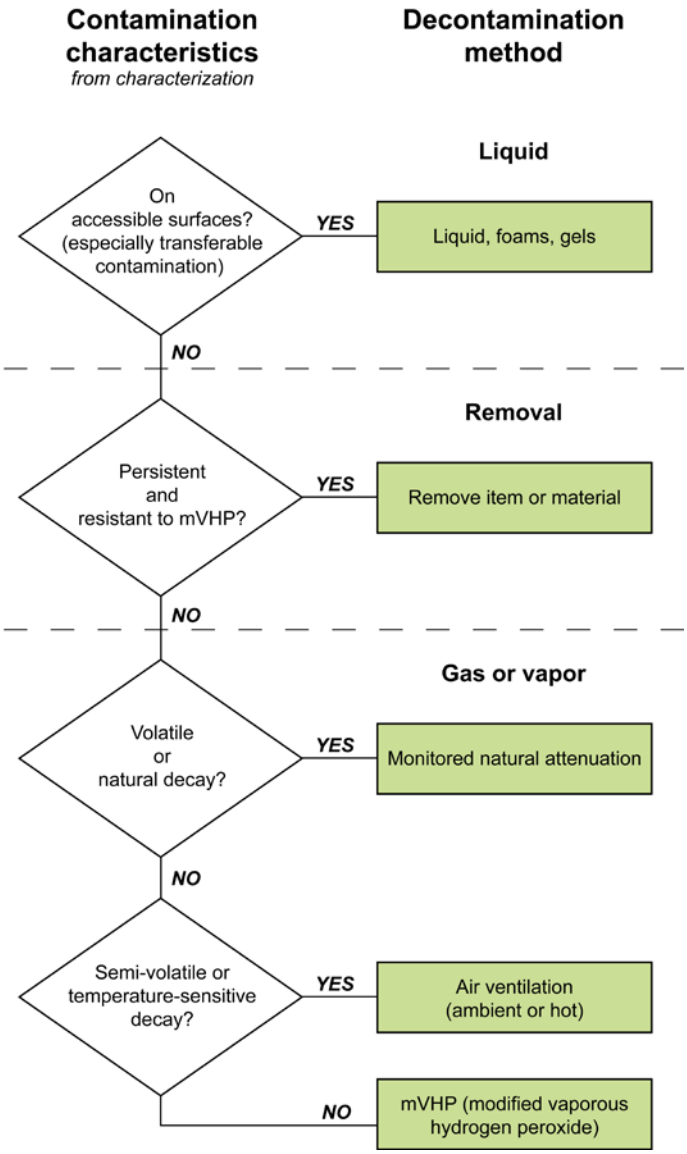

Figure 3-2. Outline of a process for selecting decontamination methods for an incident.

3.4.2.1 Surface Decontamination Reagents

Surface decontamination is the most straightforward and best-understood decontamination technique for buildings and their contents. Early scientific research was geared toward surface methods because of their ease of use. Research in this area has been conducted by many government agencies and the private sector, and developments continue to take place. Surface decontamination reagents are best suited for reuse of nonporous and nonpermeable surfaces where decontamination formulations have easy access to the chemicals of concern. Surface decontamination reagents are also generally applied to waste decontamination, including porous and permeable surfaces. Porous and permeable surfaces are more difficult to decontaminate for reuse and may require multiple applications of such reagents or disposal if the surface decontamination reagents are ineffective at achieving contamination levels that meet clearance goals. Of the many acceptable reagents available for gross decontamination of surfaces, the following should be considered initially:

- For surfaces on which corrosion is not a consideration, use a solution prepared by mixing 1 part household bleach (5% sodium hypochlorite) into 9 parts water.

- For surfaces on which corrosion is an issue, use a chemical decontamination solution or foam that is noncorrosive.

The hypochlorites, which include household bleach, (see Table 3-2) are readily available, known to decontaminate nonporous and impermeable materials of chemicals of concern (as well as biological warfare agents), and are fast acting. They are also quite corrosive. Free-standing liquid contamination on all types of surfaces can be treated with bleach to make materials safer to handle. Impermeable and nonporous surfaces that can be decontaminated for reuse with household bleach include glass, steel, other metals such as copper pipes, and some rigid plastic surfaces. Residual chlorine may need to be rinsed from waste materials prior to disposal, especially if the waste is to be incinerated. Large quantities of rinse water, in addition to the original waste, may need to be pH-adjusted so it is not caustic before being disposed. The wastewater would need to be monitored and managed to meet all regulatory requirements (see Section 3.5).

Commercially available aqueous-based foams include Sandia DF200 foam and Allen Vanguard's SDF™ foam. DF200 has been tested against several CWAs and is commercially available from several suppliers (see Table 3-2). The foam is designed for use on walls and other vertical surfaces, or nonporous and nonpermeable surfaces that would be corroded by bleach, such as unprotected metal surfaces. Another suitable reagent is the nonaqueous GDS 2000. The advantages and disadvantages of each are summarized in Table 3-2. Annex F provides a more detailed description of these and other potential decontamination reagents and their effectiveness for decontaminating substrates for safer handling prior to disposal and reuse.

Table 3-2. Advantages and disadvantages of four surface decontamination reagents for nonporous and impermeable materials for reuse.

Decontamination option	Advantages	Disadvantages	Availability
Household bleach (5% sodium hypochlorite in water) diluted by adding 1 part bleach to 9 parts water	Aqueous. Fast acting and effective on nonporous and nonpermeable substrates. Requires only water for dilution. Easily dispensed by spraying, mopping, or scrubbing. Inexpensive and widely available.	Requires washing/rinsing of surfaces. Corrosive and not suitable for sensitive equipment, such as computers. Residual liquid collected may require waste handling. Potentially toxic byproducts. Finite shelf life.	Commercial. Widely available at supermarkets and general stores.
Sandia National Laboratories (SNL) Decon Foam 200	Aqueous. Relatively fast acting and effective on nonporous and nonpermeable substrates. Low corrosivity and nontoxic. No discernible residue. Used as foam, spray, or fog/mist. Good shelf life. Minimal environmental impact.	Binary system requires mixing. 6- to 10-hour wait for foam collapse. More expensive than bleach and less widely available.	Commercial. EasyDECON from Envirofoam Technologies, or MDF-200 from Modec Inc.
SDF™ Foam	Aqueous. Relatively fast acting and effective on nonporous and nonpermeable substrates Low corrosivity and nontoxic. Applied with existing equipment. Compatible with painted surfaces, materials, personnel, and the environment. Used as foam or spray. Can be shipped and stored as concentrate.	Dried residue may require rinsing. Two-part formulation requires mixing with water. More expensive than bleach and less widely available.	Commercial. Allen-Vanguard.
GDS 2000	Nonaqueous solution. Relatively fast acting and effective on nonporous and nonpermeable substrates Potentially more effective on permeable materials, such as paint coatings or polymeric materials, than aqueous solutions.	Post-treatment washing with water or steam recommended, especially indoors. Potentially damaging to polymeric materials. Cannot be shipped or stored in concentrated form. More expensive than bleach and less widely available.	Commercial. Kärcher Futuretech.

After completing the planned surface decontamination operation, it is good practice to validate its effectiveness before proceeding to rigorous clearance sampling. If the surface

decontamination were only partly effective, such a survey would limit or eliminate the time and expense associated with demobilizing and remobilizing a decontamination team and its equipment. If the decontaminated materials are nonporous and the chemical of concern is sufficiently volatile, a portable instrument that can attain detection limits sufficient to meet clearance goals can be used immediately after surface decontamination is completed. Portable instruments that may be considered for this purpose are listed in Annex D (see Tables D-4 and D-5). If detection limits for a portable instrument are greater than the numerical clearance goals, or if materials are porous or permeable, it would be necessary to collect samples for laboratory analysis.

Hand application, as described in Annex F, can be used for small areas where source reduction is required. Handheld or backpack applicators are sufficient to apply surface decontamination reagents to medium-size areas requiring only local decontamination. Equipment appropriate for such local decontamination includes handheld devices (similar to fire extinguishers), such as the airless Wagner Power Painters (handheld model) or the equivalent and Graco Electric Airless Paint Sprayer (Model XR7 on wheels) or the equivalent.

3.4.2.2 Gas and Vapor Technologies

Gas or vapor technologies flood volumetric spaces with either a gas or a vapor to reduce or eliminate surface and subsurface contamination. Although no gas or vapor technology has yet been demonstrated as effective on all materials found in an airport, the leading technology candidates are monitored natural attenuation, enhanced natural attenuation using hot air, and oxidants such as modified vaporous hydrogen peroxide (mVHP®) or chlorine dioxide. Many aspects of the following discussion of active ventilation also apply to passive natural attenuation, which relies on natural ventilation. Experimental studies performed for this *Remediation Guidance* document demonstrated that natural attenuation can be accelerated by actively ventilating a building, especially with hot air up to approximately 140°F (60ºC). Exhaust air from active ventilation or other gas and vapor technologies may require monitoring and filtration or other treatment. EPA (2009, 2010) and DoD (2007) studies have examined the potential for mVHP® and chlorine dioxide to be used for CWA remediation, but such testing has demonstrated limited efficacy for many materials used with indoor facilities. An EPA study (2009) did demonstrate the decontamination efficacy for chlorine dioxide vapor with 80% humidity for VX, but the same conditions were not substantially more effective for other CWA decontamination compared to natural attenuation.

Ventilation. Ventilation (in this case, replacing indoor contaminated air with uncontaminated air) can be an inexpensive method for large-scale decontamination. Ventilation is most promising for remediating an indoor volumetric space that contains primarily hard surfaces and is contaminated with a volatile or semi-volatile chemical. For example, sarin is a good candidate for decontamination by ventilation because it is generally considered nonpersistent in that it evaporates and hydrolyzes relatively quickly. HD may also be effectively removed using ventilation unless gross quantities are present, whereas VX is too nonvolatile for ventilation to be effective. Emissions controls might be required for the ventilated exhaust, depending on air

contamination levels, to prevent any hazard from spreading into the environment surrounding a building. Possible emissions controls include containment of indoor air within the structure or treatment of the ventilation exhaust with an activated carbon bed. See Annex F for more discussion of when ventilation may be appropriate.

When ventilation is appropriate, a facility HVAC system could be used to help remediate a building, although supplementary fans might be needed to ensure that locations in a facility where air is stagnant have sufficient air circulation. Use of an HVAC system for ventilation should be carefully evaluated to ensure that such use does not spread contamination into uncontaminated areas of a facility. If ventilation at ambient temperatures is too slow, devices that produce hot air could be used to facilitate volatilization from surfaces. One such device is a facility's own heating system, which heats air to above ambient temperatures simply by increasing the temperature setting on a thermostat. Other devices include gas and electric space heaters available from local suppliers. Engineering requirements have not been established for implementation of hot air decontamination, but it would be important to ensure that the amount of heat provided and the distribution of heat create uniformly heated areas. Careful planning and evaluation would be required to heat spaces to more than 120º to 140ºF (49º to 60ºC) 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 is also important because the combination of hot and humid air can facilitate corrosion.

For ventilation to be most effective, easily removable, contaminated, porous materials and materials that have an affinity for chemicals of concern, such as carpets, would be removed before or during ventilation. Materials that have an affinity for chemicals of concern prolong decontamination using ventilation because they would likely absorb the chemicals then slowly release them back into the air. Except for a few chemicals—namely gaseous ones that do not have an affinity for surfaces—removing contaminated porous and permeable materials will greatly reduce the remediation time. Porous materials and permeable ones that have an affinity for chemicals of concern may be partially decontaminated in place before removal to facilitate handling by decontamination workers. It is recommended that they be completely decontaminated before removal from an airport facility for practical considerations, such as the prevention of cross-contamination and secondary source production, and to facilitate waste handling and transportation. As discussed in Section F.3 in Annex F, extended monitoring or aggressive surface treatment may be required for painted and concrete surfaces.

The results of recent experimental studies on the effectiveness of ventilation for volatile and semi-volatile CWA surface contamination (specifically, GB and HD) suggest that ventilation can be highly effective for impermeable surfaces. Ventilation was also effective for porous and permeable surfaces contaminated by CWA vapors, but typically significant amounts of residual CWA remained on porous and permeable materials contaminated by liquid CWA after extended ventilation. Dry, hot-air ventilation facilitated volatilization for all vapor-contaminated surfaces and resulted in lower residual contamination levels from liquid contaminated surfaces, but did

not typically eliminate significant CWA residual contamination from liquid contaminated surfaces. Hot air with a relative humidity of ~50% reduced the persistence of GB faster than dry hot air, but did not have a significant effect on the persistence of HD on surfaces. The use of ventilation requires careful evaluation of whether the combination of hot and humid air enhances corrosion and if exhaust air requires treatment before discharge to the surrounding environment.

Annex F contains more details on the Ambient Air Monitoring Plan (AAMP), including exhaust air, which is prepared by the EU. To expedite remediation, airports can develop the framework of an AAMP as part of pre-planning.

mVHP® and ClO_2. The two leading candidates of vaporous oxidants, modified vaporous hydrogen peroxide (mVHP®, commercialized by STERIS International) and chlorine dioxide (commercialized by Sabre Corp.), are intended to provide broad-spectrum decontamination of CWA. At present, mVHP® involves flash vaporization of an aqueous peroxide mixture that is then mixed with a small quantity of ammonia and delivered to the decontamination area. The mixture is likely to be near or greater than saturation in air, and may require humidity control before and during treatment. Hydrogen peroxide decomposes to water and oxygen, and it leaves no residue while minimizing corrosion and optimizing the distribution of decontamination chemicals. STERIS, a leading commercial supplier of the standard, commercially available vaporous hydrogen peroxide technology (VHP®), developed mVHP® with the Edgewood Chemical and Biological Center (ECBC). Substantial efficacy of mVHP® for decontamination of CWA contaminated indoor surfaces has not been demonstrated.

The ClO_2 generation process used by Sabre Corp. involves a vacuum-driven chlorine dioxide generation systems that uses both a 25% aqueous sodium chlorite solution and chlorine gas. The generator operates by water flow over an ejector that creates a vacuum and draws precursor chemicals from their storage points and through a reaction column where the chlorine dioxide reaction takes place. Chlorine dioxide is mobilized from the reaction column and into the water stream where it is immediately diluted and flows to the point of application. The humidity in the air is typically high (such as 80% RH) for ClO_2 vapor decontamination; therefore, any potential facility impacts from an augmented humidity would need consideration. ClO_2 vapor for decontamination of CWA contaminated indoor surfaces has only demonstrated substantial efficacy for VX.

Verification of Gas or Vapor Decontamination. The gas- or vapor-phase decontamination process is verified by using two methods: process monitoring (monitoring the concentration of treatment gas and relevant environmental parameters, such as temperature and relative humidity) and efficacy verification. Efficacy is verified by analyzing air and surface samples for the concentration of CWAs or TICs. Because there is limited experience with these methods for CWA applications, it is also suggested that monitoring for toxic degradation products is necessary, which is discussed in more detail in Section 3.5.3. Annex F contains more detail on verifying procedures used when decontaminating materials with gases or vapors.

Ambient Air Monitoring. As with direct ventilation, the use of gas or vapor decontamination requires monitoring of ambient air to ensure that the CWA, TIC, or treatment gas does not escape a facility in concentrations that may be a hazard to the surrounding population. Annex F contains more detail on the ambient air monitoring plan (AAMP). The EU prepares the AAMP. To expedite the remediation process, airports can develop the framework of an AAMP as part of pre-planning.

Decontaminating with Gases or Vapors. Annex F contains a detailed comparison of many technologies that can be considered when decontaminating surfaces with gases or vapors. The technologies so identified have recently been evaluated to a limited extent for CWAs or TICs. For surfaces contamination by volatile and semi-volatile CWA vapors, ventilation should be considered—either at ambient temperature or at an elevated temperature—as a rapid and efficient approach to volumetric decontamination.

For areas that are not well suited for ventilation, including more heavily contaminated or inaccessible surfaces, volumetric options are limited. Vapor-phase decontamination with ClO_2 or mVHP® may be considered, but it is recommended that pilot testing at the facility be conducted to demonstrate efficacy before the technology is deployed facility-wide. The oxidative vapors can be applied within confined spaces and are one of the few gas- or vapor-phase decontamination options to consider for sensitive-equipment vapor decontamination. Although the technology may not be effective in achieving clearance goals under all contamination situations, it might provide a reasonable alternative for consideration compared to demolition and disposal for the most difficult locations and equipment. Widely distributed, multiple generators of hydrogen peroxide are required for large spaces and for spaces with large areas of concrete surfaces. Concrete rapidly reacts rapidly with vaporous oxidants; therefore, maintaining adequate concentrations of decontamination vapor on or within concrete is unlikely. For inaccessible locations where chemicals of concern could persist, such as pipe and electrical traces, hot-air decontamination may be preferred over vaporous oxidants because oxidant concentrations are difficult to maintain in extended runs of a few dozen feet or longer.

3.4.2.3 Decontamination of Sensitive Electronic Equipment and High-Value Items

Few technologies are available to decontaminate sensitive equipment; the most promising ones on the horizon are in early stages of development and testing. Aqueous-based decontamination systems are typically inappropriate, as is any procedure that corrodes, leaves a residue, or chemically reacts with component parts. However, aqueous systems could be used to decontaminate the outside cases of sealed electronic equipment. Large airports should identify electronic equipment deemed absolutely necessary to facility operation and plan for replacements in the event of contamination. Vendors should be contacted as part of airport pre-planning activities to establish priority procurement for replacement, or temporary loan, of critical equipment.

For sensitive equipment, it is more practical to use decontamination technologies that physically remove the contamination, rather than in situ neutralization, because reaction-based decontamination has the potential to react with sensitive components. Such applications should generally be relatively small-scale, where capturing and treating exhaust or waste streams is easier. Section F.3.5 in Annex F summarizes the data available on performance of such technologies with HD, VX and the G agents.

If waiting for the monitored natural attenuation of contamination is unacceptable, then the treatment selection depends on the characteristics of both the contaminated material and chemical of concern. Large items that cannot be moved should be treated as discussed for volumetric spaces (see the section immediately above). For any gas- or vapor-phase technology, the effectiveness of decontamination throughout the interior of large pieces of equipment (such as CTX machines) must be validated because equipment can have many areas of stagnant air and many materials with a range of chemical affinities for the chemical of concern. For equipment with inaccessible locations, monitoring of off-gassing may suffice for validation of decontamination. Surface sampling will be needed to validate decontamination of areas of sensitive equipment that pose the potential for contact hazard.

Smaller items that are easily moved can be treated using either commercially available, industrial cleaning systems (often used for degreasing) or the solvent bath technology developed by ECBC. The latter is in the early stages of commercialization, and only prototype systems are currently available. Valuable artwork or irreplaceable personal possessions should be set aside for later decontamination. Decontamination of such items depends on the materials that make up the item and will likely need to be assessed on a case-by-case basis. Good ventilation of certain items for days or even weeks, especially at elevated temperatures, may suffice for decontamination; however, successful decontamination would still need to be verified.

3.4.3 Evaluate Potential Environmental Impacts

Decontamination actions must be implemented in a manner that prevents the release of harmful concentrations of decontamination reagents, chemicals of concern, or byproducts to the environment. Liquid waste streams resulting from the application of a liquid decontamination reagent, or from the removal of some other type of decontamination reagent from airport surfaces, will need to be well-characterized. Reagents that are acidic, caustic, or have strong oxidizing properties are of particular concern for the environment. If appropriate, and permission is granted by local sanitary agencies, such reagents can either be discharged to the sanitary sewer or otherwise contained and handled as a special waste. For discharging in sanitary sewers, such reagents may require treatment to reach nonacidic levels that meet local wastewater discharge requirements. Airports must identify the location of drains or other connections that would provide a route for liquid wastes to enter the environment, if not contained. Where such exit routes exist, measures should be taken to protect the exits, such as plugging storm drains prior to the start of surface decontamination activities or containing flows from the decontamination area before discharge to the environment. Resultant waste materials can be removed using wet/dry vacuums or mops, or by wiping down surfaces. If a centralized containment or staging area has

been established, the materials can be rinsed into the containment area where wastewater can be characterized, pumped, and properly disposed. Taking such measures before waste is released to the environment can potentially save large expenditures of resources that would otherwise be required to remediate contaminated areas once harmful quantities of reagent are released into the environment. If a harmful release does occur, stakeholder and regulatory requirements must be met to mitigate any damage to the environment.

Gas- and vapor-phase decontamination technologies have the potential to emit treatment gases into the air. An AAMP may be required to ensure that releases do not exceed levels of concern to regulators and do not present any health risks.

Reactive decontamination methods produce degradation products. To ascertain the potential hazard from degradation products, and the need for further treatment to avoid adverse human health or environmental effects, it is prudent to contain and monitor all runoff generated by any decontamination procedures used.

3.5 Select Waste Management Strategies

This guidance document stresses the importance of initiating discussions with waste-disposal facilities, wastewater treatment facilities, and state solid-waste management authorities as part of preplanning. It is essential to predetermine disposal options for potentially contaminated materials because identifying facilities where waste will go may require significant time and detailed discussions with the facilities given the unique nature of the waste.

3.5.1 Review Current Regulatory Guidelines for Waste

The NRF directs the EPA to respond to releases of hazardous materials, including CWAs and TICs, in accordance with the National Contingency Plan (NCP; ESF #10–Oil and Hazardous Materials Response Annex; see DHS 2008). The NCP provides a streamlined process to quickly address an incident; relief from administratively burdensome processes, such as permits for onsite treatment of hazardous wastes removed from a contaminated facility; and relief from regulatory provisions determined to be impracticable during an urgent response to a chemical attack. (See 40 CFR 300.415(I); 55 *Federal Register* 8666, 8695, March 8, 1990; and <http://www.epa.gov/superfund/action/guidance/remedy/overview/removal.htm>.) The NCP also provides waivers to regulatory provisions under specific circumstances. An example is the "Greater Risk to Health and the Environment" waiver that waives a regulatory requirement when compliance with the requirement will cause a greater risk to human health and the environment than noncompliance. (See CERCLA Section 121(d)(4); 42 U.S.C.A. §9621(d)(4); 40 CFR 300.430(f)(1)(ii)(C); 55 *Federal Register* 8666, 8747, March 8, 1990; and <http://www.epa.gov/superfund/action/guidance/remedy/supersede.htm>.) Per Section 300.400(e)(1) of the NCP, the EPA and the OSC are exempt from Federal, state, or local permits for any portion of any removal or remedial action conducted entirely onsite. "Onsite action" is defined as the areal extent of contamination and all suitable areas proximal to the contamination necessary for implementing a response action. However, the EPA and OSC must meet the

substantive provisions of permitting regulations that are applicable, relevant and/or appropriate requirements (ARARs) as much as practical given the exigencies of the situation. Refer to Annex L for more details on the regulatory guidelines associated with waste management.

Regulation of wastes resulting from a CWA or TIC attack will primarily be directed by the Resource Conservation and Recovery Act (RCRA) for solid wastes and hazardous wastes, and by the Clean Water Act if wastewater is discharged to a Publicly Owned Treatment Works (POTW) or surface water body, or by equivalent state laws. Most states are authorized by the EPA to implement the RCRA hazardous waste program in lieu of EPA implementation. Under RCRA, states so authorized can be more—but not less—stringent than the EPA; thus, for any remediation activity, state regulations and state agencies should be consulted. Most states follow the format of Federal RCRA regulations. States such as California are more stringent for wastes that are considered hazardous.

If wastewater or recovered decontamination fluids are discharged to a POTW, the waste stream must meet pretreatment requirements of a local POTW and any other acceptance criteria in the POTW permit. Discharges directly to a surface water body must meet requirements of the National Pollutant Discharge Elimination Program (NPDES) program, which are site-specific depending, in part, on the classification and criteria of the surface water body and characteristics of wastewater. Among other issues, pretreatment requirements before disposal of some wastes vary from state to state and should be verified during the planning process. Many POTWs sell sludge residues for land application in agricultural settings. The POTW must be contacted before any sewer discharge of aqueous residues from a facility-decontamination process to ensure such discharges meet facility-specific waste acceptance criteria that may be predicated on subsequent uses for sludge

3.5.2 Consider Types of Expected Waste Streams

Table 3-3 shows a preliminary characterization of expected waste streams under Federal RCRA requirements. This table is based on the decontamination technologies outlined in Annex F (see Tables F-2 and F-3) and additional assumptions identified in Table 3-3 footnotes of the likely waste streams and level of decontamination provided by the decontamination technologies.

Following decontamination using the technologies discussed in Annex F, it is incumbent on the generator (usually the airport) to sample materials and make a hazardous waste determination. Under RCRA regulations, decontamination is not considered to be treatment. Instead, decontamination would be considered a new point of generation, requiring characterization of resultant waste streams and proper disposal or treatment based on applicable Federal, state, and local requirements. This document provides some guidance on Federal requirements; however, state and local requirements can be more stringent, and it is therefore important to check with the state in which the decontamination activity is taking place. For example, Utah, Colorado, and Oregon (among others) list nerve agents and their breakdown products as hazardous wastes on their state RCRA lists. Under Federal RCRA regulations, a waste may be considered hazardous if it is listed on one of the lists found in the regulations (listed wastes) or if it meets one of the characteristics (characteristic waste).

Table 3-3. Expected waste characterization of treatment residues and facility components.[a]

CWA or TIC	Type of Waste[b]	Bleach solution in water	Sandia Foam	Modified VHP	Monitored natural attenuation, dry hot air, or hot and humid air
Tabun (GA) Sarin (GB) Soman (GD) Cyclosarin (GF) VX Sulfur mustard (HD) (see Section 3.5.2)	Decontamination materials	Potential corrosivity[c]	Not hazardous	Not hazardous	Not hazardous
	PPE and building waste	Not hazardous [d]	Not hazardous	Not hazardous	Not hazardous
Hydrogen cyanide (AC) CAS 74-90-8	Decontamination materials	Potential corrosivity[c,e]	Not hazardous [e]	Not hazardous [e]	Not hazardous [e]
	PPE and building waste	Not hazardous[d,e]	Not hazardous [e]	Not hazardous [e]	Not hazardous [e]
Cyanogen chloride (CK) CAS 506-77-4	Decontamination materials	Potential corrosivity[c,e]	Not hazardous [e]	Not hazardous [e]	Not hazardous [e]
	PPE and building waste	Not hazardous[d,e]	Not hazardous [e]	Not hazardous [e]	Not hazardous [e]
Phosgene (CG) CAS 75-44-5	Decontamination materials	Potential corrosivity[c,e]	Not hazardous[e]	Not hazardous [e]	Not hazardous [e]
	PPE and building waste	Not hazardous[d,e]	Not hazardous [e]	Not hazardous [e]	Not hazardous [e]

[a] The following assumptions were made regarding the nature of remediation activities:
- Wastes will not include any pure CWA or TIC.
- Decontamination is performed until all CWA or TICs have been reacted to completion.
- Potentially toxic degradation products are neutralized or reacted to nontoxic degradates by decon.
- Decontamination wastes include spent decontamination fluids, PPsE, cleaning materials (rags, mops) and items in an airport hub that will be disposed and not reused (i.e., potential waste items could include decontaminated furniture, passenger luggage, computers, upholstery, carpet, drywall, and so forth).

"Not hazardous" in this table does not mean "nonhazardous" in the usual sense. It means not defined as "hazardous" according to a particular Federal definition and as discussed in Section 3.5.2.

[b] Decontamination materials means any recovered, spent decontamination solution or material. PPE and building waste means used PPE, carpet, furniture, computers, telephones, and other facility components.

[c] Spent bleach solution with a pH <2 or >12.5 is considered hazardous waste (exhibits corrosivity). Once pH is adjusted, the solution would not be a hazardous waste (no corrosivity). The solution would then exit RCRA hazardous waste regulation and be regulated as a nonhazardous waste.

[d] After decontamination, any bleach solution remaining on an item would react with the item (e.g. furniture). The item would unlikely have a pH sufficient to be considered corrosive under the hazardous waste characteristic.

[e] HCN, CK, and phosgene are P listed wastes if they are commercial chemical products that are discarded or spilled in essentially pure form. However, in an emergency, such as a terrorist attack, specific information on the manufactured chemical composition of the released material would be inconclusive or unavailable. Residuals derived from treatment would be managed as characteristic waste according to the constituents present at the time the waste material is transported or disposed, provided the material exhibits a characteristic of hazardous waste; otherwise RCRA requirements would not apply. See Annex L for details.

3.5.2.1 Listed Wastes

Although hydrogen cyanide, cyanogen chloride, and phosgene are found on the RCRA P list, this list applies only to commercial chemical products that are discarded or spilled in essentially pure form. A pure form is not likely to be the case in an incident such as a terrorist attack. Other agents considered in this *Remediation Guidance* document are not RCRA listed wastes.

3.5.2.2 Characteristic Wastes

As stated, it is incumbent on the generator to test waste streams resulting from decontamination activities to ensure that they do not exhibit any RCRA characteristic. In particular, for decontamination using Sandia Foam, modified VHP, monitored natural attenuation, hot air, or steam decontamination, it is important to test the resultant waste streams to ensure complete removal of CWA or TIC and any degradation products as well as the decontamination reagent, if used. Given the nature of waste materials in the scenario under consideration, it may be very difficult and expensive to completely sample to ensure complete destruction of the agent in all wastes; therefore, it may be more cost effective to dispose of such material as hazardous waste without testing.

For decontamination using bleach solution in water, decontamination material wastes from all CWA or TIC types are likely to be corrosive, that is, to meet the corrosivity characteristic. Decontamination materials include spent decontamination fluids, PPE, cleaning materials (e.g., rags and mops), and items in an airport that will be disposed and not reused (potential items could include decontaminated furniture, passenger luggage, computers, upholstery, carpet, drywall, and so forth). Specifically, spent bleach solutions with a pH <2 or >12.5 are considered hazardous waste. Once the pH is adjusted, the solution would still fall under Land Disposal Restrictions (LDR) [see CRF 262.3(g)(3)].

PPE and building wastes (used PPE, carpet, furniture, computers, telephones, and other facility components) decontaminated with bleach are likely to be considered nonhazardous because any bleach solution remaining on an item would likely react with the item (e.g., furniture). The item would be unlikely to have a pH sufficient to meet the characteristic.

3.5.3 Consider Principal Degradation Products

CWA degradation has been previously examined in many studies characterizing agent fate, and results are compiled in reviews by Munro et al. (1999) and Talmage et al. (2007a and b), among others. Research is ongoing. Principal degradation products of the nerve agents of concern and of sulfur mustard agent HD have been identified on the basis of environmental persistence, toxicity, or both (Talmage et al. 2007a) and are summarized in Table 3-4 along with comparisons to other commercial compounds for perspective. Previous analysis indicates that degradation of GA (tabun) results in no products of potential concern regarding persistence or toxicity (Talmage et al. 2007a; Munro et al. 1999). Most CWA degradation products are water-soluble but exhibit low vapor pressures and are thus of little consequence as a source of vapor inhalation or ocular exposure. The ingestion of degradation products is an unlikely possibility under the airport release scenario, but such a possibility is nonetheless considered for completeness.

To meet potential waste-management determinations and landfill agreements with state and Federal agencies, reference dose (RfD) input to standard EPA exposure models (such as the *Regional Screening Levels for Chemical Contaminants at Superfund Sites*; EPA 2008) is often used. To facilitate such determinations when necessary, published estimated RfDs (in mg/kg/day) are provided as examples in USACHPPM 1999 and Talmage et al. 2007a on the basis of findings from the literature (e.g., Yang et al. 1988, 1992; Yang 1995; Munro et al. 1999; Reddy et al. 2005).

CWA degradation products of particular interest are methyl phosphonic acid (MPA) and S-(diisopropylaminoethyl) methylphosphonothioic acid (EA2192). MPA (CH_5O_3P), a hydrolysis degradation product of nerve agents GB, GD, GF, and VX, is stable under a wide variety of environmental conditions but is not very toxic [oral toxicity rank of 2, or "slightly toxic" by clinical toxicity rankings of Klaassen et al. (1986) and Gosselin et al. (1984)]. MPA is not considered to pose a vapor hazard (vapor pressure of 2×10^{-6} mm Hg; see Table 3-4). As a function of its environmental stability and low toxicity, MPA possesses considerable forensic value and was used by police authorities as conclusive evidence to identify sites where the Aum Shinrikyo cult had either manufactured or tested sarin prior to the cult's chemical terrorist release of GB in the Tokyo subway system in 1995 (Tu 2007; Crothers et al. 2008). In addition to its forensic value, MPA can also be used as a well-characterized monitor of the hydrolysis degradation reaction. Isopropyl methylphosphonic acid (IMPA) and ethyl methylphosphonic acid (EMPA) exhibit oral toxicity rankings (slightly toxic) similar to MPA.

Table 3-4. Properties of principal CWA degradation products (commercial compounds are provided for comparison).

Degradation product[a] (formula, CAS number)	Parent CWA	Persistence [b]	Acute toxicity (oral LD_{50}) (mg/kg)	Toxicity rating[c]	Vapor pressure[d] (mm Hg)	Water solubility[d] (mg/L)
MPA (solid) (CH_5O_3P; 993-13-5)	GB, GD, GF, VX hydrolysis	High	5000 (rat) >5000 (mouse) [a]	Slightly toxic (#2)	2×10^{-6}	$> 1.0 \times 10^{6}$
EMPA (liquid) ($C_3H_9PO_3$; 1832-53-7)	VX hydrolysis	Moderate	Considered similar to IMPA [a]	Slightly toxic (#2)	3.6×10^{-4}	1.8×10^{5}
EA 2192 (solid) ($C_9H_{22}NPO_2S$; 73207-98-4)	VX hydrolysis (pH 7–10)	Moderate	0.630 (rat) [a]	Supertoxic (#6)	Not detectable; 5.1×10^{-6} (est.)	Infinitely soluble
IMPA (liquid) ($C_4H_{11}PO_3$; 1832-54-8)	GB hydrolysis	High	6070–7650 (rat) 5620–6550 (mouse) [a]	Slightly toxic (#2)	1.2×10^{-2} (est.)	5.0×10^{4}
Thiodiglycol (liquid) ($C_4H_{10}O_2S$; 111-48-8)	HD hydrolysis	Moderate	6610 (rat) [a]	Slightly toxic (#2)	2×10^{-5}	Miscible
Aspirin (50-78-2)	Not applicable	—	50-500 [e]	Very toxic (#4) [e]	2.5×10^{-5} (calc.)	4.6×10^{3}
Table salt (NaCl; 7647-14-5)	Not applicable	—	3750 (rat) [e]	Moderately toxic (#3) [e]	1.0 at 865°C	3.6×10^{5}
Saccharin (soluble) (128-44-9)	Not applicable	—	5000–15000 [e]	Slightly toxic (#2) [e]	Sublimes in vacuum	4.3×10^{3}

[a] Degradation products selected on the basis of environmental persistence, toxicity, or both from Talmage et al. (2007a, Table 1, Ch. 4); Munro et al. (1999); Reddy et al (2005); Capacio et al (2008, Table 19.2, Ch. 19).

[b] Persistence ranking based on chemical/physical properties and degradation data/estimates; mod = weeks to months, high = months to years (Talmage et al. 2007a).

[c] Klaassen et al. (1986, Table 2-2, p. 13).

[d] Munro et al. (1999); Howard and Meylan (1997); Michel et al. (1962); Rosenblatt et al. (1995); Hazardous Substances Data Bank, U.S. National Library of Medicine, Bethesda, available at <www.toxnet.nlm.nih.gov/cgi-bin/sis/search>, accessed August 2008.

[e] Gosselin et al. (1984).

The VX hydrolysis product, EA 2192 ($C_9H_{22}NPO_2S$), is produced during VX hydrolysis reactions conducted within the pH range of 7 to 10 (Talmage et al. 2007a and b; Munro et al. 1999). EA 2192 is a white solid, possesses low vapor pressure, is stable (Michel et al. 1962; Szafraniec et al. 1990), and is water-soluble (Small et al. 1984). Oral toxicity data for the LD_{50} endpoint indicates that EA 2192 is approximately 6 times less toxic than the parent agent VX. EA 2192 is not an inhalation hazard and is not absorbed through the skin in aqueous or alcohol solutions (Michel et al. 1962). Although it presents a potential, but remote, ingestion exposure concern when present, EA 2192 is not significantly formed at pH <6 or >10, where the hydrolysis reaction produces diisopropyl ethyl mercaptoamine and EMPA. As a consequence, it is highly advised that the pH of the VX decontamination reaction be closely monitored to ensure maintenance at pH <6 or >10. Production of EA 2192 can also be prevented by nucleophilic decontamination of VX with excess H_2O_2 in mildly basic or basic solutions (Yang 1999). Documented hydrolysis reaction yields of EA 2192 from the parent VX are less than 25% (Michel et al. 1962; Szafraniec et al. 1990; Yang et al. 1993, 1995), thus further reducing the potential for exposure.

Incomplete oxidation or incomplete dechlorination during decontamination of HD could lead to the generation of the toxic intermediate reaction products mustard sulfone ($C_4H_8SO_2Cl_2$, CAS No. 471-03-4; a product of incomplete oxidation reaction with supertropical bleach) or divinyl sulfone ($C_4H_6SO_2$; CAS No. 77-77-0; an intermediate product of HD dechlorination) (Small 1984; Munro et al. 1999). These compounds are volatile and are not considered persistent. Photochemical oxidation of divinyl sulfone occurs within hours, and volatilization from potentially contaminated soil or water is significant. Divinyl sulfone is not unique to HD decontamination but is produced commercially and used during processing of cotton textiles (HSDB 2008). Production of, and potential exposure to, these sulfone intermediates under the airport scenario can be prevented by monitoring the oxidation and dechlorination of HD so that decontamination reactions go to completion.

As data allow, and as recommended by the California EPA, compound-specific subchronic reference doses have been estimated for the principal degradation products and incorporated into calculations of example surface removal contaminant levels (see Watson et al. 2011a and b). Additional information on degradation compound toxicity is available in Munro et al. (1999) and Talmage et al. (2007a).

3.5.4 Characterize Waste, and Select Appropriate Disposal Facilities

All wastes generated from a decontamination activity must be analyzed to determine if they are hazardous wastes and to ensure that they are handled safely during storage, handling, transport, and disposal. Determining whether a solid waste is classified as a hazardous waste is prescribed by 40 CFR 262.11(c)(1). Such determination can be made subjectively from knowledge of the waste characteristics or by analytical testing of the waste. A solid waste could also be conservatively assumed to be a hazardous waste without any knowledge of its characteristics or analytical testing. However, such an option is unlikely to be used because in this context the final disposal facility will likely require characterization of the waste. The determination is made when waste is

generated and the documentation of a plan for analytical testing of waste is captured in the RAP. The EU is responsible for preparing the RAP and documenting the characterization of waste.

Classification of waste as hazardous or nonhazardous is the first step in selecting an appropriate disposal facility for the waste. Solid wastes disposed of as a result of airport decontamination must be transferred to an approved solid waste landfill or other solid waste disposal facility. Regulations regarding the type of facility appropriate for decontamination wastes and waste-handling procedures are controlled by state regulations governing solid wastes. In California, solid wastes are further subdivided and regulated on the basis of the threat arising from a particular solid waste. Solid wastes are disposed of in several classes of landfills. The more robust classes of landfill accept higher-threat wastes, defined as "designated wastes." All other solid waste can be sent to any classification. In Utah, for example, solid wastes are in one general category, with several types of landfills mainly subdivided in terms of the origin of the waste (e.g., industrial, commercial, or municipal). The owner or operator of a solid waste landfill or other disposal facility may impose additional acceptance and disposal restrictions. It may be necessary to negotiate with a facility concerning special acceptance and disposal requirements. Sampling and monitoring of the waste must take into account the waste acceptance parameters of the receiving solid waste facility to ensure that waste acceptance criteria in the facility's permit are met.

Regulatory authorities in different jurisdictions may classify the same wastes from treatment differently. Because classification of a waste as hazardous can lengthen waste disposal schedules by many months and increase disposal costs several fold, contacting local regulators to clarify waste classification procedures is essential to forecast realistic budgets and schedules. See Annex F for additional guidance on classification of wastes.

3.5.5 Comply with Shipping and Handling Guidelines

3.5.5.1. CWAs

Equipment and other materials from a contaminated airport facility must be shipped and handled safely and appropriately. Department of Transportation (DOT) requirements for packaging, manifesting, and transporting hazardous material are specified in DOT 49 CFR. For materials known or suspected to be contaminated with CWAs, refer to examples of decision criteria in use at the Spring Valley Formerly Used Defense Site in metropolitan Washington, D.C. (Parsons 2007). See also CWA handling guidelines recommended by the National Response Team (NRT 2008; <www.nrt.org>) as well as acceptable approaches for verifying decontamination processes. Civilian authorities are ultimately responsible for considering options and making appropriate site- and sample-specific decisions.

3.5.5.2. Nonhazardous Waste

Regulation of nonhazardous solid wastes is primarily the responsibility of individual states. Solid wastes disposed of as a result of airport decontamination would need to be transferred to an approved solid waste landfill or other solid waste disposal facility. Regulations pertaining to the

type of facility appropriate for decontamination wastes and waste-handling procedures are controlled by state regulations governing solid wastes. Sampling and monitoring of the waste must take into account the waste acceptance parameters of the receiving solid waste facility to ensure that waste acceptance criteria in the facility's permit are met.

3.5.6 The EPA's Decision Support Tool

The EPA's National Homeland Security Research Center (NHSRC) has been developing a decision support tool for the disposal of items and debris from the decontamination of buildings and water systems following a CWA or TIC attack (Lemieux et al. 2006). The tool can quickly estimate quantities and characteristics of residues produced during decontamination, and it provides information useful for selecting an appropriate disposal facility. This tool can assist in evaluating cost tradeoffs between decontamination and disposal, and it can be used either as a planning tool before an incident occurs or during remediation to develop a waste management action plan. The web-based decision support tool called, "EPA's Suite of Disaster Debris Management and Disposal Decision Support Tools," is accessible at: <http://www2.ergweb.com/bdrtool/home.asp>.

Five categories of web-based support tools are available, as follows:

- Building Decontamination Residue (BDR) Disposal Decision Support Tool.
- Decontamination Wastewater Disposal Decision Support Tool.
- Water System Materials Disposal Decision Support Tool.
- Agricultural Biomass Disposal Decision Support Tool.
- Natural Disaster Debris Disposal Decision Support Tool.

The types of information accessible through the support tools include:

- Disposal facility information.
- Building residue characteristics and quantity estimates.
- Water systems material characteristics and equipment.
- Agricultural biomass disposal guidance.
- Natural disaster debris characteristics and guidance.
- Contaminant and decontaminant characteristics.
- Transportation, packaging, and storage information.
- Worker protection information.
- Library of useful resources.

The support tool provides two methods for estimating the amount of waste residue that could be generated during decontamination activities. The first method is called the Back-of-the-Envelope Estimator; the second involves manually building a waste inventory from databases of common items found in various types of facilities, including airports. The Back-of-the-Envelope Estimator provides an order-of-magnitude estimate for the weight and volume of residues that may require disposal. This tool is limited to specific type of facilities (office, shopping mall, hotel, residence,

school, or theater). The user identifies the type of facility involved and enters an approximate square footage of the area affected by an incident. The tool provides weights and volumes of building material, electronic equipment, furniture, food, and other items that may be generated as waste for the type of facility chosen. Finally, the tool has databases for landfills, combustion facilities, and other disposal facilities that are searchable on the basis of a contaminated facility's location. The databases provide contact information as well as information on disposal facility capacity and permitting.

Information provided by the user concerning the chemical of concern, decontamination method, and size of facility affect the identification of categories of waste likely to be generated and an estimate of the amount of waste that could be generated. The decision tool allows a user to evaluate disposal cost according to the amount of waste that could be generated and the chosen disposal methods. An incident summary is generated by the tool.

3.6 Prepare Remediation Action Plan and Related Documents

Developing the RAP is a coordinated effort by the Planning and Operations Sections, including the EU and Decontamination Group. The incident-specific RAP specifies the decontamination method(s) to be used and many other details. The Operations Section Chief reviews, and the UC approves, this plan. The RAP is implemented in a series of daily (or other specified interval) Incident Action Plans (IAPs) as defined in the NIMS. Because of the complex landscape at an airport, it is anticipated that all three types of decontamination technologies discussed in the previous sections may be required. The template in Annex J can facilitate preparation of the plan. Depending on the incident, not all sections in Annex J will be required. If the RAP calls for gas- or vapor-phase decontamination, then the plan should also contain an AAMP to ensure that air releases of the treatment gas are managed. The RAP (containing an AAMP) may be (if a jurisdiction so requires) submitted to local regulatory boards, especially those that regulate air quality. The Site Safety Officer develops the Contingency Plan to address what actions would be taken during potential, uncontrolled releases of treatment gas (or in the event of other contingencies, such as explosion, fire, or severe storm).

Sampling performed to directly support the decontamination process can be documented in the RAP or in a separate, related document. For example, if monitored natural attenuation is employed, a monitoring plan would be required. Similarly, sampling and analysis plans for any monitoring of key process variables specific to the selected decontamination strategy (e.g., temperature and concentration of a gaseous reagent) must be documented.

3.7 Perform Site Preparation

The Operations Section's Decontamination and Sampling Groups perform all site preparations specified in the RAP. Whereas the details of site preparation are incident- and site-specific, if gas-or vapor-phase decontamination technologies were required, site preparation before decontamination might include the following:

- Subdividing spaces with temporary walls.
- Sealing all leaks and openings, and testing for leaks, or arranging for tenting.
- Installing and testing oxidant-generation systems.
- Installing and testing systems for monitoring oxidant concentrations, temperature, and humidity.
- Installing and testing NAUs and air-filter systems.
- Commissioning new equipment.
- Testing low-level gas or vapor.
- Modeling (low-cost) and airflow measurements to determine the approximate amount and direction of air movement.

3.8 Prepare Clearance Environmental Sampling and Analysis Plan

The EU, with input from the TWG, if such a group is in place, develops a Clearance Environmental SAP and justification for the sampling and evaluation scheme that is to be used to confirm the effectiveness of decontamination. Activities described in the Clearance Environmental SAP, which are implemented during the Clearance Phase are discussed in more detail in Section 4.3.

3.9 Perform Decontamination

After the three documents (SAP, RAP, and AAMP) are completed, an internal review by the Operations Section's Decontamination Group is initiated. After the internal review is complete, the UC approves and submits the three documents (SAP, RAP, and AAMP) and applies for any necessary regulatory permits needed for offsite actions (e.g., NPDES permits, offsite storage permits for hazardous waste) and determines the substantive requirements for onsite actions (e.g., hazardous waste treatment and demolition). Note that EPA OSCs are exempt from having to obtain permits for onsite actions conducted under CERCLA and the NCP. Upon receipt of any required permits, the designated decontamination contractor(s) and trained decontamination personnel carry out the decontamination, with oversight by the Operations Section's Decontamination Group.

Decontamination strategies and tactics for a particular incident are worked out by Planning and Operations staff members. During tactics meetings, resource needs are identified for each work assignment. Specific decontamination actions cannot be suggested for an airport in advance of an attack because the details are specific to the chemical of concern, site, and incident. Following decontamination activities, the EU and the Decontamination Group, with input from the TWG, evaluate the results for completeness and to ensure that process criteria have been met. The EU, Decontamination Group, or both, may recommend more decontamination activities, if warranted.

3.10 Pre-Incident Planning

Table 3-5 identifies essential pre-incident planning activities related to site decontamination.

Table 3-5. Summary of decontamination-related actions taken prior to a CWA attack.

Responsible Personnel	Pre-Incident Actions Related to Decontamination
Airport authority management	• Identify equipment to have on hand (general-purpose or dedicated) for decontamination. • Contact vendors to establish priority procurement or loan for replacing critical equipment. • Document HVAC and AHU systems in the facility. • Select staging areas or warehouses for equipment and supplies. • Determine likely decontamination method(s) for various incidents, chemicals of concern, and materials. • Determine barrier and isolation areas for decontamination activities. • Select and retain contractors for the decontamination team. • Determine initial disposition of contaminated materials, staging and storage areas for waste. • Identify locations of drains and other connections that could allow contaminated materials to enter the environment. • Initiate discussions with local waste-disposal facilities, local sanitary-sewer agencies, and wastewater management authorities on capabilities, capacities, and costs. • Discuss waste-disposal issues with state solid-waste-management authority. • Identify whether any regulatory permits are required, and the applicability of any state or Federal exemptions or waivers for onsite and offsite actions. • Stockpile supplies for decontaminating personnel and surfaces, traffic control, and containment, or make arrangements with vendors to supply such items when needed.

3.11 Summary

Table 3-6. Summary of actions during the Decontamination Phase showing the approximate sequence of events.

Responsible Personnel	Action
Planning Section, including Environmental Unit and input from TWG	Develop measurable decontamination performance criteria from characterization results. Develop the decontamination strategy, including assessment of potential environmental impacts of decontamination. Prepare the Remediation Action Plan (RAP), including: • Areas to decontaminate and types of surfaces involved. • Materials and structures to decontaminate in place or remove. • What decontamination technology (e.g., reagent and delivery system) to use. • Appropriate process parameters and analytical techniques. • Waste-disposal decisions, including estimated types and amounts of wastes; selection of staging and waste-storage areas; transportation needs and costs; clearance sampling at disposal sites; and long-term monitoring, if necessary. Include Ambient Air Monitoring Plan (AAMP) in the RAP, if required. Prepare Clearance Sampling and Analysis Plan (SAP), including: • Clearance zones. • Sampling approaches for each zone (judgmental or random sampling, or both).
Operations Section: Decontamination Group	Perform source reduction. Provide input to, and review draft RAP and clearance SAP.
Site Safety Officer	If toxic gas or vapor decontamination is used, develop a Contingency Plan to address uncontrolled releases from explosion, fire, or hurricane. Review and update the HASP.
UC	Approve the RAP and clearance SAP with input from the TWG.
Operations Section: Decontamination Group and Sampling Group	Perform all site preparations specified in the RAP.
Operations Section: Decontamination Group	Conduct decontamination, and monitor process parameters. Conduct limited surface sampling to check effectiveness of decontamination. Evaluate whether decontamination process criteria are met. • For gas or vapor decontamination (e.g., concentration, temperature, contact time). • For liquid decontamination (e.g., initial pH, reagent contact time). Recommend additional decontamination activities, as necessary.

3.12 Section 3 References

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4 Clearance

The purpose of clearance is to decide whether or not to release previously contaminated parts of an airport for Restoration/Reoccupancy Phase activities (see Figure 1-1). The clearance process includes two major components:

- Reviewing information from earlier phases, including
  - The strategy for characterization environmental sampling.
  - Source-reduction activities, if any.
  - Data provided by analyses of samples collected during the Characterization Phase.
  - Data provided by analyses of samples collected during the Decontamination Phase.
- Conducting clearance environmental sampling and analysis after decontamination and comparing the results with clearance goals.

Initial characterization assessments (Section 2.2.9) may have identified areas (e.g., Class 4 zones) that were considered highly unlikely to be contaminated. It is also possible that contamination may *not* have been found in areas initially assessed as being Class 2 or Class 3. Such initial assessments might have led to an accelerated decision process and early reopening of some areas. Alternatively, such areas might have been set aside for later clearance evaluation. Both options would have required that such areas be effectively isolated from contaminated areas to protect them from cross-contamination. Whether or not formal clearance sampling is required in such areas depends on how much confidence was developed during characterization.

Decision-makers must decide whether an airport is to be cleared in phases (i.e., a section at a time), in which case Restoration Phase activities might begin in some areas before clearance has been granted in others, or whether all restoration activities should wait until the entire airport has been cleared. In either case, a positive clearance decision for any section (e.g., a boarding concourse) is made only after a positive clearance decision has been reached for every clearance zone in that section (for example, the upper and lower levels could be separate zones).

Clearance environmental sampling may include surface, air, and bulk sampling. All information and data related to the clearance process are reviewed relative to the selected clearance goals (see Section 2.3). This section assumes that clearance goals were set appropriately, at health-protective levels, for the appropriate populations. Resources necessary for clearance activities are the same as those identified in Table 2-1. Figure 4-1 shows major activities associated with the Clearance Phase.

Clearance, like characterization, should be organized using a zone-by-zone approach. Zones should be defined in a flexible manner that makes sense to those performing the work. For example, if gas or vapor decontamination is performed, each distinct volume is a natural clearance zone. Annex C discusses zones in more detail. Annexes H and I contain templates designed to help with the process.

Clearance

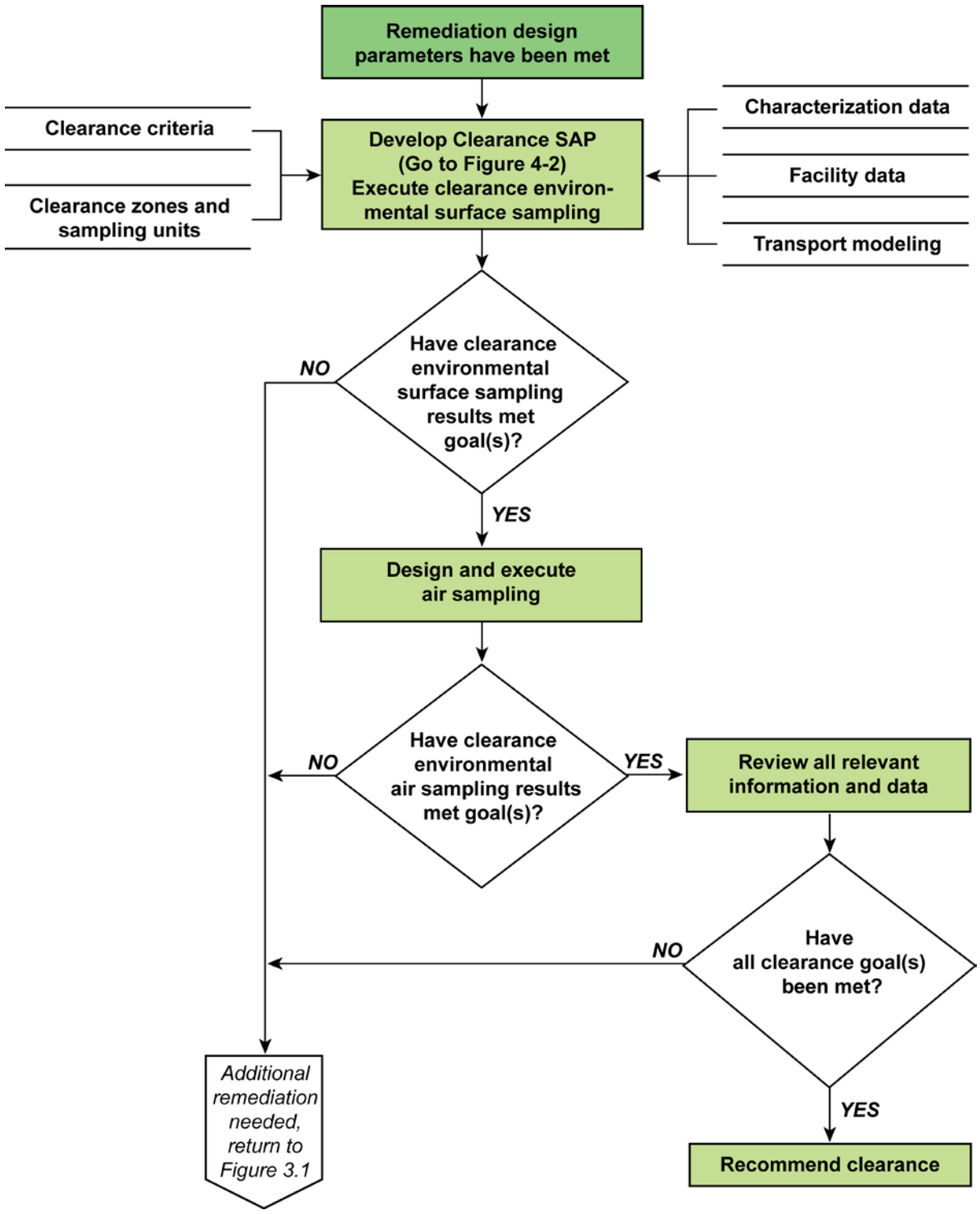

Figure 4-1. Major activities during the Clearance Phase.

4.1 Review Clearance Goals

Before selecting and using a decontamination technique, clearance goal(s) as discussed in Section 2.3 must be established along with an agreed-on process for judging whether the goal(s) have been met. In other words, the two major components related to clearance are:

- Setting clearance goals—clearly stating acceptable numerical levels of residual CWA or TIC in the airport environment after decontamination.
- Choosing clearance decision criteria—establishing how to decide whether the clearance goals have been met.

The goals depend on many factors, including—but not limited to—the type of chemical of concern and its properties, including:

- Toxicity of the chemical(s) of concern and any degradation products (the single degradation product of toxicological concern in the present assessment is the VX hydrolysis product EA 2192).
- Pathways and parameters of potential exposure.
- Cumulative risk associated with multiple pathways of exposure.
- Potentially exposed populations.
- Location(s) of contamination (e.g., at a ticket counter versus in an air cargo building).
- Method of dispersal (e.g., liquid spill versus aerosol delivery versus HVAC delivery.
- Public perception of risk.
- Scientific information on hazardous levels and potential risk.
- Applicable environmental regulations.

Section 2.3 includes more details.

In general, clearance decision criteria that apply to sampling results can be either qualitative or statistical, and either or both can be used. Sampling to support such decision criteria can be either judgmental or random, and either or both can be used.

Qualitative criteria are based on professional judgment. An example qualitative decision rule is: resample all locations where contamination was found during characterization, and require that all such samples yield results that are less than the clearance goal. Statistical decision criteria employ random sampling and result in a numerical confidence statement. An example statistical decision rule would be to require that a statistical analysis of the sampling results lead to a statement such as, “We are 95% confident that less than 1% of the surface area contains concentrations of contamination greater than the clearance goal.”

Both judgmental and random sampling can be done in various ways. Two types of judgmental sampling used in the 2001 anthrax cleanups were “targeted” and “biased,” described further in Section 4.2.2. Random sampling includes purely random sampling (every location is chosen at random) and grid sampling (samples are uniformly spaced, but the starting point for the grid is

selected at random), among others. Additional discussion is in Annexes C and E. In all likelihood, both qualitative and statistical decision criteria will be used.

Clearance goals and decision criteria associated with sampling results need to be specified in terms of measurable environmental parameters. For example, surface or air concentration units can be used for goals; upper bounds, average levels, and presence versus absence of a chemical of concern can be used for decision criteria. See Section 4.2.2 and Annex C.

In Section 4, the terms "positive" and "positive result," when referring to a single sample, mean that the CWA or TIC was detected on the sample. The terms "negative" and "negative result" mean that either the CWA or TIC was not present in the sample or, if present, it was not detected. Negative results occur when the signal from the analytical instrument is not distinguishable from "zero," i.e., is within the range of signals produced by a sample that has no chemical of concern. Such results are also referred to as "below the limit of detection" or as "nondetections." Each positive result (also called a detection) is accompanied by a measured concentration, which is an estimate of the amount of chemical of concern present in the environment at the sample location. When possible, the measured concentration should be accompanied by an estimate of its uncertainty.

4.2 Plan for Clearance Environmental Sampling

The clearance environmental sampling strategy is documented in the post-decontamination or Clearance Environmental Sampling and Analysis Plan (clearance SAP). Essential information includes the selected clearance goals, selected sampling locations (or rules describing how locations will be selected), selected sampling and analysis methods, and the rules by which sampling results will be evaluated to make the clearance decision. Figure 4-2 shows the process of developing a clearance SAP.

4.2.1 Choose Sampling and Analysis Methods

The methods used for sampling and analysis must produce reliable measurements of contamination at concentrations less than the levels specified by the clearance goals. The methods used and data they provide must be sufficient to ensure the health and safety of the public and airport workers and withstand any scientific or legal challenges. Laboratory-based methods in general, and mass-spectrometry-based methods in particular, are the most rigorous and therefore most likely to produce defensible data that will instill public confidence. The requirement to withstand challenges implies that the analytical laboratory's work must be well documented. See Section 2.4.4 for additional discussion of sampling and analysis methods, and note that detection limits must be below clearance goals for clearance sampling.

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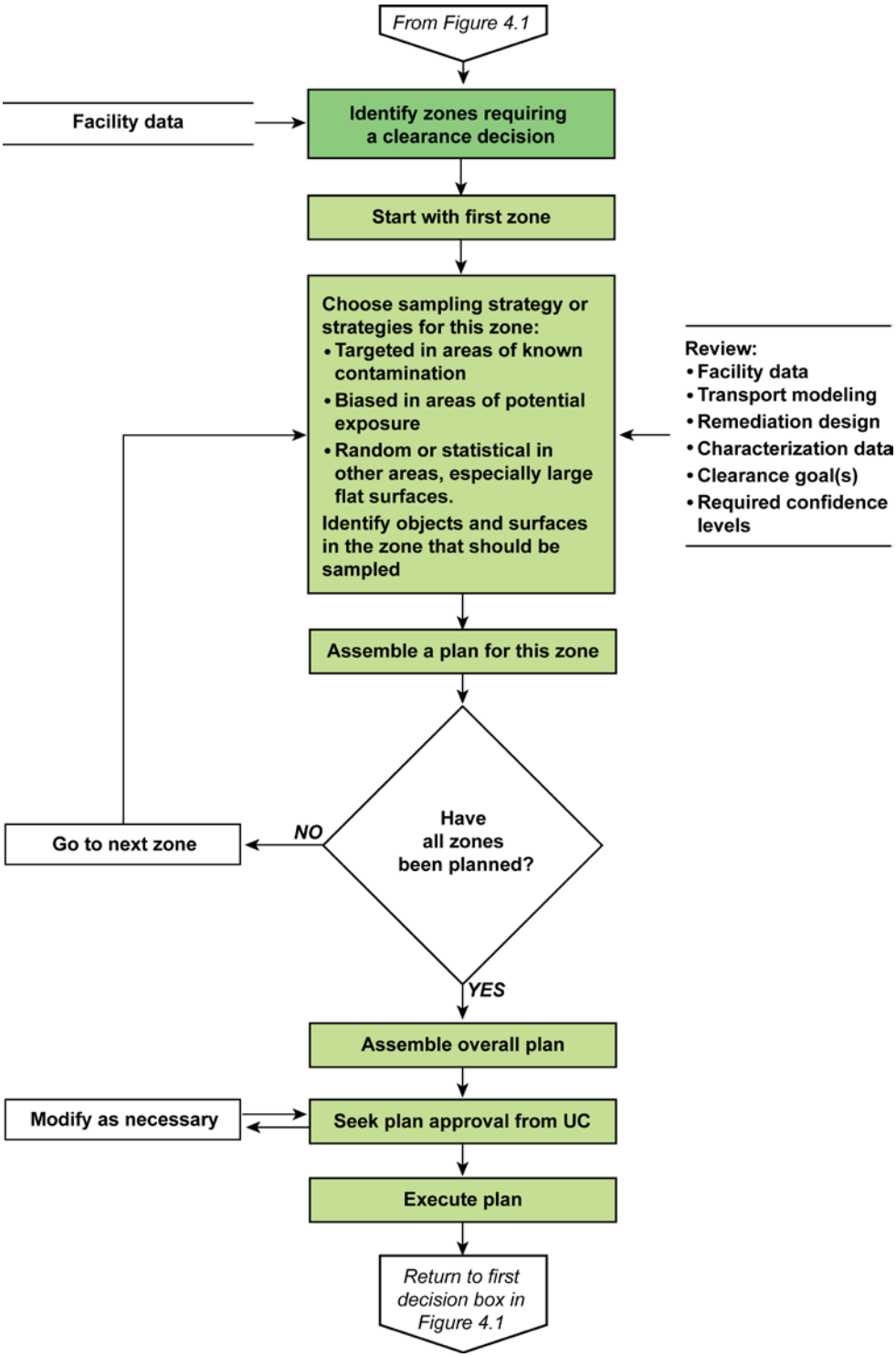

Figure 4-2. Developing a Clearance Environmental Sampling and Analysis Plan (SAP).

Surface and air samples provide data directly comparable to surface contact and inhalational/ocular exposure guidelines, respectively. Therefore both types of samples should be considered. In addition, a CWA or TIC may sorb into some materials. If there is a potential that the chemical of concern may outgas from materials after decontamination, then bulk samples of the materials should be taken. Bulk samples should be considered only if the chemical of concern penetrates into material or into the material pore space. For other materials, there would be no contamination other than surface contamination. See Annex D for more discussion.

The choice of sample type has implications for post-clearance monitoring (the ideas are repeated in Section 4.5):

- If only surface samples are used for clearance, then long-term surface monitoring, and possibly air monitoring, is recommended. Such monitoring is intended to detect "rebound," or the release of a chemical of concern from materials after clearance.

- If surface and bulk samples are used for clearance, and the surface samples are nondetections or less than the clearance goal, but some bulk material contains contamination, then long-term monitoring should be required. In addition, more decontamination may be warranted.

- If surface and bulk samples are used for clearance, and both surface and bulk samples are nondetections (or less than the clearance goal in the case of surface samples), then long-term monitoring is not necessary (although such monitoring may reassure stakeholders).

4.2.2 Surface Sampling for Clearance

It is not possible to sample all of the surfaces that employees or members of the public will eventually contact. Therefore, it is necessary to *infer* that reopening the airport will not present an unacceptable health threat. The confidence placed in that inference depends on the clearance goals and on how the data are used to decide whether the airport environment meets those goals. There are two components to this inference. First, clearance goals must be set at an appropriate health-protective level, and limits of detection must be below clearance goals. This requirement ensures that when a sampling result is a nondetection, one can infer that even if residual contamination is present at that location, exposure to it will not result in an adverse health effect. Discussions in this section assume that such conditions are met at the time of clearance sampling. Second, it is necessary to make inferences about nonsampled locations. Inferences can be statistical, judgmental, or both, but only statistical inference provides a quantitative (and objective) confidence level. Inference about nonsampled locations is the subject of this section.

For example, it is not possible to *prove* by sampling that absolutely no chemical of concern is present on any surface after decontamination, if that is selected as the clearance goal. Even if every square inch of a facility could be sampled, the following limitations apply:

- Sampling methods have less than 100% collection efficiency, meaning that the chemical of concern may be present in the environment, but not enough is collected in the sample to be detectable.

- Extraction methods have less than 100% extraction efficiency, meaning that the chemical of concern may be present in the sample, but the analytical method does not extract enough of it from the sample medium to be detectable.

- Even if both sampling and extraction had 100% efficiency, analytical methods still have detection limits, meaning that the chemical of concern could be present in the environment but not be detectable by the analytical method.

- Some errors in collection, analysis, and documentation of samples, are inevitable.

Thus, even if all clearance sample results are negative, it is not certain that absolutely no chemical of concern remains in the environment. It is necessary to *infer* that the locations or levels of remaining contamination, if any, are sufficiently rare or low, respectively, that they present no unacceptable threat to human health.

If a clearance goal permits detectable levels of a chemical of concern to remain after decontamination, the decision criteria will include comparing positive sample results with a selected clearance goal. The exact manner of comparison will be set by the EU after consultation with the TWG, and is referred to as a clearance decision criterion. Several options are available: the simplest include comparing the maximum analyte concentration with a clearance goal, or comparing the average of measured analyte concentrations with a clearance goal (see Annexes C and E). The appropriate method of comparing environmental levels with clearance goals should be representative of the assumed exposure conditions that are the basis for the clearance goals (see Section 2.3). These kinds of comparison also require inference. For example, if the TWG chooses to compare the average concentration with a clearance goal, the real goal is that the true environmental average concentration (the average of the entire zone of comparison) is below the clearance goal. Because only a subset of possible locations is sampled, the sample average will differ somewhat from the true average. This leads to some uncertainty as to whether the true average concentration is above or below the clearance goal. Statistical methods are used to reduce uncertainty to a degree satisfactory to the UC.

The choice of decision criteria is incident-specific and is likely to depend on risk management decisions, including the degree of risk that decision-makers are willing to accept. The following approach is suggested as a starting point for a statistical decision criterion, applicable at the time of clearance sampling:

> Surface clearance goals are likely to be expressed in terms of an acceptable exposure level, i.e., as a surface concentration at or below which it is acceptable for a member of a potentially exposed population to touch. Because it is not practical to sample every square inch of a surface, it is not possible to guarantee

with 100% confidence that absolutely no part of the surface is above the clearance goal. Therefore, it is not possible to guarantee with 100% confidence that a member of the population will not touch a surface that is above the clearance goal level. Lacking a guarantee, the decision criteria should include a requirement to have high confidence that contact is highly unlikely.

The "high" of high confidence is selected by decision-makers, and could, for example, be 95%. Contact is unlikely if only a very small portion of the surface is above the clearance goal. This will be the case if, for example, less than 1% is above the clearance goal (or equivalently, at least 99% of the surface area is below the goal). Statistically speaking, this suggests the use of an upper tolerance limit (UTL); in this example a 95%,99% UTL. If a 95%,99% UTL calculated from the sample results is less than the clearance goal concentration, than there is 95% confidence that at least 99% of the surface area has concentrations below the clearance goal. This provides high confidence that contact is unlikely.

The number of samples required for such an approach can be reduced if a combined judgmental and random method (Sego et. al. 2010) is used, as is illustrated in the example in Section 4.2.3. Formulae for the UTL method are available in many references, including Mulhausen and Damiano (1998) and are not included here. Note that confidence levels of 95 and 99% are examples only; the incident-specific choice is up to appropriate decision-makers.

The remainder of this section contains a more general discussion of some options for making the inference from samples to an entire zone. The important question that must be answered is: how much sampling is necessary to make the inference with confidence? Different sampling strategies lead to different numbers of samples. Sampling strategies are drawn from either of two major categories: judgmental and statistical. Statistical strategies generally include some form of random sampling and specify a desired level of confidence in decisions based on the sampling. Judgmental sampling presumes that investigators who have some information about the incident can determine that sampling information from specific locations will be useful.

During the *B. anthracis* remediations of 2001 and subsequently, three strategies were used for clearance surface sampling, and they can also be used for clearance sampling following CWA or TIC decontamination. The strategies, as described in the *SA-32 Environmental Clearance Sampling Plan* (2003), are targeted, biased, and random sampling. Targeted and biased sampling are special forms of judgmental sampling, and in the context of this guidance are used only for clearance sampling. The three strategies are defined as follows:

- Targeted sampling consists of "thoroughly sampling objects and/or locations where positive results for *B. anthracis* were previously found." In the SA-32 plan, this type of sampling was called "focused" sampling.

- Biased sampling preferentially targets "objects and/or areas that are adjacent to known contaminated locations, high-traffic areas, and objects and/or areas that are likely to experience high contact by personnel eventually reoccupying the facility." In an airport, the latter includes high-risk, high-use items, such as terminal counters, handrails, baggage-claim carousels, toilet facilities, and difficult-to-decontaminate areas, including air ducts and interior corners.

- Random sampling is "used to provide a certain amount of minimal coverage over areas not necessarily covered by biased or targeted sampling." In the *B. anthracis* cleanups of 2001 and thereafter, random sampling was used for areas where no *B. anthracis* contamination had been found.

The choice of strategy needs to take into account how initial environmental sampling and characterization sampling were performed, where positive samples were found, the frequency and levels of contamination found, where no positives were found, and the types of samples obtained. Annex C has more information on clearance sampling strategies and related issues.

Inference from targeted sampling is based on the following reasoning: If the responsible organization is confident that all areas of significant contamination were found during characterization, and the same areas are re-sampled during clearance and found to be clean, then there is confidence that decontamination was successful. This reasoning requires a belief that, because decontamination was successful in the known areas of significant contamination (i.e., areas selected for targeted sampling), it was also successful in areas with less contamination and areas of significant contamination that might have been missed during characterization. Inference from biased sampling is essentially the same.

Inference from random or statistically designed sampling is based on the ideas of representative and reproducible sampling (Annex C). Random or statistically designed sampling makes the best sense for large surfaces where human contact occurs in a somewhat random or haphazard manner, such as floors, walls, and ceilings; in areas where relatively little is known about the distribution of contamination; or as a backup to targeted and biased sampling. The use of statistically designed sampling for other objects, such as ticket counters, drinking fountains, telephones, or escalators, is more problematic because the objects are relatively few in number, and their complex physical structure makes representative sampling more difficult.

Multiple strategies can be used even in the same clearance zone. For example, targeted sampling would be used on surfaces in the immediate vicinity of an overt release location. Biased sampling would be used in nearby locations having high exposure potential. Random sampling would be used on large surfaces (floors, walls, and windows) at some distance from the release location. Inference from all three approaches is based on the idea that the number and placement of samples provides a high level of confidence that the chemical of concern, if still present anywhere, will be detected somewhere.

Statistically designed sampling can be used with the goal of no detectable CWA or TIC on any clearance sample, and with clearance goals that permit low, but nonzero, levels after decontamination. Statistical methods applicable to the environmental clearance decision can be found in many references, including, Gilbert (1987); Gilbert et al. (1996); Hardin and Gilbert (1993); Mulhausen and Damiano (1998); and EPA (1996, 1997, 2002, 2006a, and 2006b). Annex C contains additional discussion and examples of ways in which random sampling can be statistically designed. Experts in the field of sampling and statistics should be consulted and be a part of the TWG if sampling is used.

The GAO (2005) recommends that statistical methods be used for a sampling design to provide quantitative confidence in the clearance decision. This recommendation was part of a broader one that a clearance decision be based on validated methods. Work is underway to validate potential statistical sampling algorithms for use indoors following a release of CWA or TIC. The validation effort will be important for future decision-makers when evaluating statistical methods for site characterization and clearance.

EPA- and DHS-supported tools to help develop optimal sampling designs for various data-based decision criteria and methods are available [e.g., Visual Sample Plan (VSP), BROOM]. In addition, methods for combined targeted and systematic random sampling approaches are forthcoming. An example is discussed in Section 4.2.3.

4.2.3 Example of Surface Sampling for Clearance

An example of a combined targeted and systematic random sampling approach for surfaces within an LAX-like airport terminal is shown in Figure 4-3. This illustration is for the case when decision-makers require 95% confidence that at least 99% of the surface area is uncontaminated and are willing to make certain assumptions regarding the likelihood that decontamination was successful in the target area, and the greater likelihood that residual contamination, if any, will be found on targeted samples than on random (not targeted) samples. The 30 targeted samples shown in the illustration (light dots) are clustered around the release location, whereas 107 systematic random samples (black dots) are spread out evenly across all floors and walls. The ceiling is omitted from the example, but it could be included or excluded as deemed appropriate. Various zones within the building can be defined, and sampling schemes for each zone can be varied. Several other sampling design approaches are available in VSP that may be applicable during characterization and clearance. If all samples indicated concentrations less than the clearance goal, this type of design would allow investigators to be 95% confident that 99% of the surface area also has concentrations less than the clearance goal.

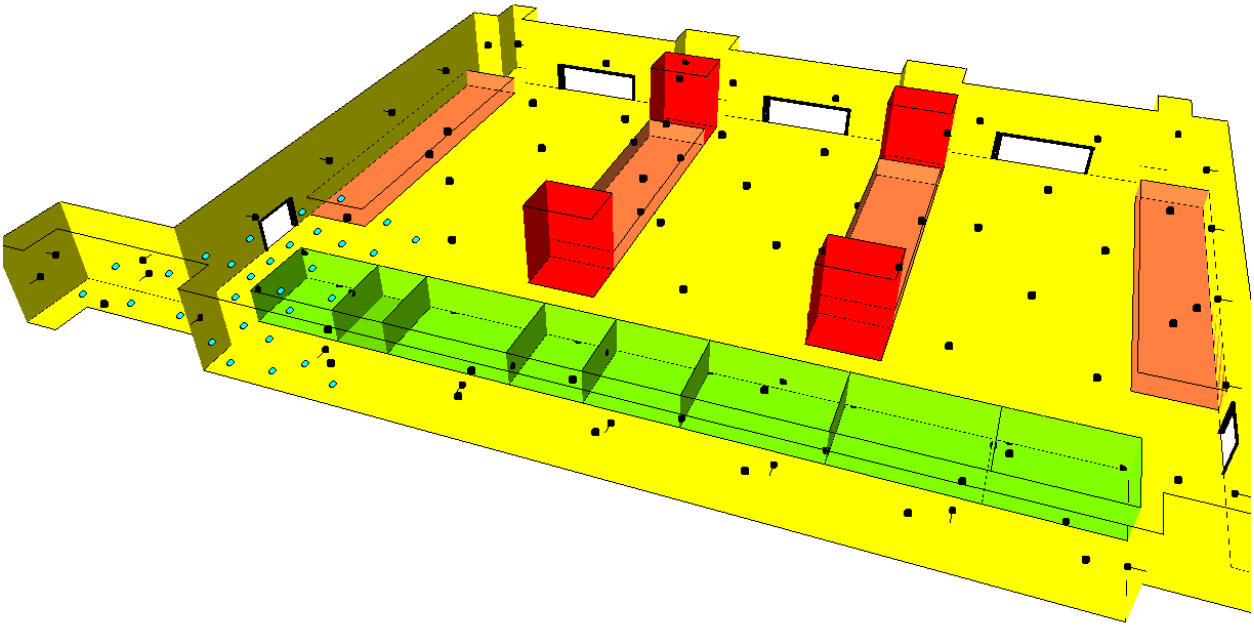

Figure 4-3. Example sampling design created in Visual Sample Plan for an area similar to the departure level of the TBIT. The design combines targeted samples (light dots) and systematic random samples (black dots).

4.2.4 Bulk Sampling for Clearance

Bulk sampling can be used to determine whether a chemical of concern has penetrated or sorbed into a material. Such contamination may or may not represent a health risk, depending on whether there is an exposure pathway and a likelihood of exposure at unacceptable levels. See Annex D for more information on bulk sampling, and Section 4.2.1 for information about how to interpret bulk sample results.

4.2.5 Air Sampling for Clearance

Air sampling methods range from high-volume air samplers whose results are representative of large areas and volumes, to small hand-held chemical agent monitors (CAMs) that rapidly monitor small areas. See Annex D for more details.

High-volume air sampling is an appropriate part of the clearance decision if (1) a clearance goal specifies maximum air concentrations for inhaled air, and (2) sampling is done so that results are representative of inhaled air. Depending on the sampling duration, high-volume samplers can collect samples that are representative of nearly the entire air volume of a space, in which case issues of inference (described in the previous section) do not apply for the period of time sampled. As a foundation for the clearance decision, however, it is necessary to assume that future conditions will be no more hazardous than those during the time sampled. For example, clearance air sampling could be conducted with the ventilation system turned off (see CalEPA 2011, Executive Summary, and Section 4.8). Errors in such an assumption are addressed in Section 4.5.

Small-volume CAM samples are representative of a relatively small air volume for a relatively short time (practically speaking, a single point in time) and for that reason cannot provide a strong foundation for a positive clearance decision. They may, however, be useful for judgmental sampling of potentially problematic locations, for example, near sorbent materials (those that may absorb the chemical of concern). If such materials are present and continue to outgas after decontamination, a CAM sampler is superior to a high-volume sampler at discovering the outgassing and measuring the health hazard close to the material. In this manner, CAM samples do have an important role in the clearance decision. In most cases, however, CAM samplers provide higher detection limits for target analytes than do high-volume samplers. Thus, for analytes that present an inhalation risk, high-volume air sampling will always be a necessary part of the clearance process.

The number of samplers to deploy depends on several factors. They include, at a minimum, sampler throughput, size and shape of the space, and the required detection limit. For example, if the room volume of a concourse is 1.3 million cubic feet, and a large-volume sampler must sample 300,000 cubic feet of air per sampling period to reach the desired detection limit, then each sample represents roughly 25% of the total air volume. Thus four such samplers might be appropriate. Because this is an overly simplified example, an expert in air sampling should be consulted.

4.3 Prepare and Execute Clearance Environmental Sampling and Analysis Plan

Using the concepts shown in Figures 4-1 and 4-2, the EU prepares a clearance SAP, which is approved by the UC. Most environmental sampling plans, including post-decontamination clearance sampling plans, share certain basic elements. They include descriptions of the circumstances of contamination, statements of the authority under which the operation takes place, summaries of applicable environmental laws and regulations, summaries of the kinds of decisions to be made, the rationale behind various decisions, technical information about the sampling and analysis methods, the entity that is to perform sampling data validation, information about the kind of quality controls used, and types of PPE that the sampling teams use. Annex H is a clearance SAP template created to facilitate preparation.

Much of the necessary background information for a clearance SAP will be available from the Characterization Phase, including a set of sampling unit definitions (Annex I), estimates of locations of maximum levels of contamination, possibly a map of contamination, sample naming conventions, a database for analytical results, and other elements.

The clearance SAP must be specific, including information about how many samples to collect, exactly where to take each sample, and the reason why, or how to determine where to take each sample. The plan must include information on what sampling method(s) to use, how to package and transport each sample, how to document each sample, who instructs the necessary personnel and collects the necessary supplies, and so on. Such tasks are largely the responsibility of the contractor who performs the sampling.

After the clearance SAP is completed, it is approved by the Operations Section Chief. The clearance SAP is attached to the IAP for approval by the UC for the next operational period, and clearance sampling commences. The UC staff, especially the EU, must work closely enough with the contractor to ensure that all guidance is followed. Guidance should include, for example, reviewing the method by which the contractor generates random sampling locations where random sampling is used, and working with the contractor's staff to ensure they understand and follow the guidance for statistical sampling.

4.4 Review Clearance Results. and Proceed to Restoration

The EU, with TWG assistance, prepares a report on remediation actions, including details on decontamination and data from clearance sampling. The report includes a data-quality assessment (EPA 2006a) and statistical evaluation of results. The UC reviews and confirms that facility, regulatory, and stakeholder needs are met. The facility authority determines whether to reopen all or parts of the facility, or whether to initiate Restoration Phase activities. If none of those actions can be done, further decontamination may be warranted, and the process is repeated.

4.5 Post-Clearance Environmental Monitoring

To maintain public confidence and regulatory approval, provide assurance, maximize consistency, and ensure public health and safety, some level of post-clearance monitoring may be advisable. The topic of how long the monitoring should continue is discussed in Sections 4.5.2 and 4.5.3. Long-term monitoring should be conducted inside the affected facility, and might be considered outside, but near, the facility. Such monitoring should be documented in a written plan. In addition to describing the monitoring itself, the plan should specify responses to elevated measurements, should they occur. For example, if long-term post-clearance monitoring shows unacceptable concentrations of harmful CWA or TIC, then residual contamination should be located and removed. Other health-protective actions, such as temporary closure of a portion of a terminal, should be considered, and the plan should specify such actions.

Any post-incident sampling program should consider the results of initial characterization sampling, the decontamination procedures used, and clearance sampling results. The team designing any post-incident sampling strategy should include members of the previous sampling design team and the decontamination contractor to ensure that monitoring areas are defined in the context of previous efforts and results. Any uncertainties in estimating the fate and transport of the released TIC or CWA and in verifying decontamination success should be factored into sampling. For example, in areas where inaccessible ductwork may be contaminated, a more robust monitoring effort may be warranted. Results from clearance sampling can help determine whether post-clearance monitoring should be conducted, as follows:

- If only surface samples were used for clearance, then long-term surface monitoring, and possibly air monitoring, are recommended. Such monitoring is intended to detect rebound, or the release of a chemical of concern from materials after clearance.

- If surface and bulk samples were used for clearance, and surface samples were nondetections, but some bulk material contains a chemical of concern, then long-term monitoring is recommended. In addition, more decontamination may be warranted.

- If surface and bulk samples are used for clearance, and both surface and bulk samples were nondetections, then long-term monitoring is not necessary (although such monitoring might be done to reassure the public).

Post-clearance monitoring is most important for releases of the persistent compounds sulfur mustard (HD) and nerve agent VX (McGuire et al. 1993; NRC/COT 2003) because they are much less volatile than the G-series nerve agents or the TICs hydrogen cyanide, phosgene, and cyanogen chloride (see Table F-1 in Annex F). Agent VX was deliberately formulated as a bulk-liquid, "terrain-denial" material and, if not removed by decontamination, is persistent on many surfaces from which it may de-gas for lengthy periods. The de-gas duration depends on environmental conditions, the level of contamination, and the surface material involved. Similar to VX, both GB and sulfur mustard may penetrate into materials and de-gas for lengthy periods.

The principle degradation products of CWAs should also be considered for long-term monitoring. Refer to Table 3-4 for a summary of the principal degradation products and their toxicity. In general, CWA degradation products are less toxic by the ingestion route than parent compounds (Munro et al. 1999), are solids, exhibit low vapor pressure, and are thus of little consequence as a source of vapor inhalation or ocular exposure. For example, the methyl phosphonic acid (MPA) degradation product of nerve agent GB is approximately 1000 times less potent than GB. The single CWA degradation compound of toxicological concern is the VX hydrolysis product known as EA2192 (see Section 2.3.4.1). If VX decontamination conditions favor formation of EA2192, it would be sensible to monitor for this product in locations where liquid VX was released. Environmental monitoring during the post-incident recovery phase requires systematic planning and should use the same protocols and guidelines as those developed for managing industrial releases of TICs of concern, CWA stockpile and disposal facilities, and CWA nonstockpile facilities for the nerve and blister agents.

4.5.1 Action Levels for Post-Clearance Monitoring

Clearance goals will have been developed using a set of assumptions about potential post-clearance exposures. Unless the use of a facility changes in such a way that the assumptions become incorrect, the clearance goals that were deemed protective at the time of clearance should continue to be protective. Therefore, the clearance goals should be suitable as action levels during long-term monitoring.

4.5.2 Long-Term Monitoring Systems

Because the chemical and physical properties (Table F-1) of the more volatile CWAs and TICs indicate that they would dissipate over hours to days, and because decontamination will remove additional residual CWAs and TICs, long-term monitoring after a successful decontamination is not expected to detect the more volatile analytes. Although many different types of samples could be chosen for long-term monitoring (e.g., surface or air), air sampling is the most useful because it provides information in a single measurement about time-integrated analyte concentrations over a large, integrated area. Thus the term, "long-term monitoring." refers here to continuous air samples, and discussion is focused on air-sampling systems. In addition, because the goal of long-term monitoring in the context of this document is to ensure that the public is protected from exposure to CWAs or TICs attributed to the remobilization of residual amounts, only systems that can detect the lowest concentrations of analytes are considered. Although sophisticated monitoring systems are available to provide early warning of a CWA or TIC attack, such systems do not provide sufficiently low detection limits to ensure protection of public health in the context of remediation. For this reason, they are not considered here.

Sampling and analysis systems should be robust and reliable, and relatively simple to operate and maintain while following rigorous QA/QC processes. The systems need to be able to accurately measure and discriminate among chemicals of concern at levels below the selected clearance goal to ensure that the clearance goal continues to be met. Operator training and experience are critical for timely delivery of appropriate information. Table 4-1 shows three types of CWA monitoring systems that meet these criteria and are currently in use at the Tooele Chemical Agent Disposal Facility (TOCDF) in Tooele, UT, where CWA munitions stockpiles are managed and destroyed.

To collect sufficient amounts of CWA or TIC that detectors can measure, preconcentration of the chemical of concern from air on solid sorbent may be needed. This type of sampling, which uses equipment such as ACAMS and DAAMS, allows the collection of integrated air samples ranging from 0.1 to 20 L in volume. Such collection systems can be interfaced to sensitive detectors, such as mass spectrometers or flame photometric detectors, to attain sufficiently low detection limits.

A recent NRC review of agent monitoring capability (NRC/BAST 2005a) indicates that MINICAMS and DAAMS technology, with reasonable modification, is sufficient to monitor for the G agents and blister agent HD. Some detector modification is ongoing at both stockpile and nonstockpile sites. VX monitoring is problematic because of the compound's low volatility and the presence of interferents. The NRC/BAST (2005a) concludes, "it is likely that agents can be detected using DAAMS, it is also likely that interference problems will be much more severe for DAAMS than in the past, especially for VX methods...." Although, to the best of our knowledge, these systems have not been tested in an airport environment, they represent the best available technologies for long-term monitoring following remediation.

Table 4-1. CWA monitoring systems currently in use (TOCDF 2005).

System or Equipment	Technology and Application	Example Manufacturer
Automatic Continuous Air Monitoring System (ACAMS) and MINIature Chemical Agent Monitoring System (MINICAMS®)	Analytes in air collected on solid adsorbent for preconcentration followed gas chromatography Near-real-time, continuous air monitoring at fixed sites	Agilent Technologies OI Analytical, TX (formerly CMS Research, AL)
Depot Area Air Monitoring System (DAAMS)	Analytes in air collected on solid adsorbent for preconcentration followed by onsite or offsite analyses Continuous sampling to quantify or confirm the near-real-time monitors (ACAMS) at fixed sites	Chemical Agent Monitoring Supply Company, TX
Real-Time Analytical Platform (RTAP)	• Mobile and transportable monitoring capability • Characterizes agent release in an emergency • Contains multiple instrumentation (ACAMS, DAAMS, and MINICAMS®) • Onsite verification (approximately 30 min) (CMA 2004a,b)	E-N-G mobile Systems, CA

The systems identified in Table 4-1 are well-characterized, regulatory-agency approved, and in use at CWA munitions and nonstockpile disposal facilities. However, other systems are also suitable. CWA and TIC detection is a rapidly expanding field, and many designs are being developed. Portable systems lend the most utility for post-incident environmental monitoring activity. Because instrument sensitivity and selectivity are evolving, current options are likely to be superseded by future systems.

4.5.3 Duration of Long-Term Monitoring

The duration of long-term environmental monitoring will depend on details of the incident and facility-specific conditions. Once clearance goals are met, any long-term monitoring requirements will be determined by guidance from local public health officials and other stakeholders. The post-incident monitoring duration should be a function of:

- Results of periodically repeated site sampling for the presence or dissipation of released chemicals of concern. Site conditions should initially guide the duration of sampling. Consider monitoring weekly for at least one month to confirm that concentrations remain at acceptable levels or lower.

- Whether the release is from a rapidly dissipated or degraded chemical of concern, or from a persistent one. Release of more persistent chemicals of concern could require longer monitoring durations.

- Source strength and degree of dispersion throughout the facility.

4.6 Decision-Making for Reentry: Case Study of a Volatile TIC

The decision to allow reentry of the public and nonemergency workers to previously contaminated area(s) of an airport facility is based on criteria and decisions made collaboratively by multiple government agencies. A key criterion for reentry is that no significant health effects are likely, as established by air monitoring, source containment or neutralization, analyses of surfaces that may contain residual material, and other considerations that may be facility-specific (e.g., demographic characteristics, public-use patterns, and facility attributes).

Recent experience during and following the Graniteville, South Carolina, chlorine release provides an example of an accepted reentry process following release of a volatile TIC. At 2:39 am on January 6, 2005, 60 to 70 tons of chlorine (Cl_2) vapor were released from an accidentally ruptured rail car. The release led to evacuation of residences and businesses in a mile-wide radius around the accident site. Human fatalities from Cl_2 exposures occurred in the minutes following the railcar impact. Re-entry to areas adjacent to the wreck site occurred only after the site was cleared and began on January 11, 2006. Although specific reentry criteria were not made public, many processes and decisions can be reconstructed from available documents [South Carolina Department of Health and Environmental Control (SCDHEC) 2005].

Principal reentry decisions appear to have focused on establishing that no significant health effects were likely from reentry and re-occupation. The conclusion was reached following the acquisition and analyses of numerous real-time and integrated air monitoring samples from both ambient and indoor air and confirmation that the ruptured Cl_2 tank car sources had been purged, washed, and removed. Additional information regarding public safety took into account data from many hundreds of pH determinations (pH paper wipe samples as well as pH measurement of standing water) of interior surfaces of homes and businesses.

The primary criterion for public reentry to Graniteville residences and businesses was the determination that Cl_2 and HCl (formed by the reaction of Cl_2 with water) were less than the analytical limit of detection (LOD) for real-time monitoring devices deployed throughout the affected area. The LODs for real-time air monitors were well below acute exposure guidelines for Cl_2 and HCL (NIOSH, 2005a and b). That criterion, coupled with the approximately 1000 to 1500 real-time air samples collected over days throughout the critical geographic area, appear to have provided agencies with sufficient evidence that a public health hazard no longer existed.

The LOD for real-time air monitoring for Cl_2 ranged from 0.05 to 1 ppm, depending on detector design and installed sampling apparatus. Borderline detection was considered to be 0.1 ppm Cl_2. The LOD for real-time air monitoring for HCl was 0.5 ppm (SCDHEC 2005). Although the

acceptable pH range used was not specified, pH within the range of 6 to 8 is generally considered neither too acidic (much lower than pH 7) nor too basic (much higher than pH 7), and a wider pH range may be acceptable depending on local conditions.

Data from Mitchell et al. (2005) indicate that public reentry to the evacuated area was phased. Residents were allowed to re-occupy their homes over a six-phase, six-day reentry process, with reoccupation allowed first in areas farthest from the release site. Re-occupation of certain residences closest to the crash site took place over three additional days, with the last reentry occurring 16 days after the chlorine release. On the 19th day post-incident, the state of emergency for Aiken County was rescinded by Governor Mark Sanford.

Key agencies that participated in the response, recovery, and reentry included the CDC Agency for Toxic Substances Disease Registry (ATSDR); EPA Region IV; and the SCDHEC. Records cited in Mitchell (2005) indicate that the EPA deployed 25 real-time air monitoring stations. Records obtained from the DHEC suggest that integrated air monitoring was conducted by the Center for Toxicology and Environmental Health (CTEH), a consulting firm hired by the railway company. The EPA and SCDHEC conducted both air monitoring and surface testing (pH paper analyses) at schools and appear to have been responsible for an analogous effort for all affected residences and businesses (Mitchell et al. 2005). The ATSDR provided technical assistance for determining conditions for public reentry (South Carolina State Emergency Operations Center, 2005).

The experience in Graniteville highlights the size, scope, and technical challenges associated with reentry following an unexpected release of a hazardous chemical. For airport facilities, the following points are relevant:

- Once source removal or neutralization is complete, the key criterion for allowing reentry is attaining the health-based objective of no significant health effects; this is the basis for a pre-established clearance goal.

- Samples may be required from multiple environmental media or by using many collection and analytical techniques.

- Sample collection and analyses may be formidable tasks, potentially requiring the acquisition and analyses of tens to hundreds of samples, or more.

- Interpretation of sample data to support a determination of no significant health effects upon reentry may require substantial time. Even for a well-characterized TIC, such as Cl_2, 16 days elapsed after the chemical release and before all residents were allowed to re-occupy their homes.

4.7 Summary

Table 4-2. Summary of actions during the Clearance Phase.

Personnel	Action
Planning Section: Environmental Unit, with input from the TWG	Review and revise, as necessary, the incident-specific clearance SAP.
UC	Approve the incident-specific clearance SAP if it was revised.
Operations Section: Sampling Group,	Perform clearance sampling.
Planning Section: Environmental Unit, with input from Decontamination Group and the TWG	Evaluate clearance SAP results. Determine if clearance goals are met. Recommend additional decontamination if necessary.
Planning Section: EU with TWG input	Write the final clearance report, and submit it to the UC.
UC	Review the final report, addressing facility, regulatory, and stakeholder needs. Make recommendations on whether facility and items have been effectively remediated.
Facility authority	Determine whether to initiate restoration activities in all or parts of the facility. If not, additional decontamination may be warranted.
Public health officials	Seek guidance from local public health officials and other stakeholders regarding long-term monitoring.

4.8 Section 4 References

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5 Pre-Planning

As is emphasized throughout this document, many preparations can greatly reduce the time required to re-establish airport operations if the activities are conducted before an actual CWA or TIC release. Useful pre-planning actions by airport officials are summarized here by topic. Table 5-1 summarizes the principal pre-planning actions identified in all sections of this *Remediation Guidance* organized by the phase of activity with which an item is most closely associated.

1. Identify members of a Unified Command and other organizations that would be involved in remediating a CWA or TIC release specific to the airport. Focus on the structure of the organizations involved in remediation, and identify their specific roles and responsibilities (refer to Figure 1-4). Formation of a Technical Working Group is recommended. Issues pertaining to local, state, and Federal jurisdictions should be addressed, and stakeholders should be identified. Identify the pros and cons of a Federal versus nonfederal response. Maintain the information in a data supplement. Identify alternative, backup locations for the EOC.

2. Ensure all facility information is readily accessible. Locate all architectural drawings of terminals, boarding areas, and other areas. Locate all mechanical drawings of ventilation and drainage systems, and associated mechanical rooms. All potential entrance and exit points for gases or liquids should be identified (such as sumps, drain pipes, vent shafts, and the like). This information could be summarized in a Data Supplement for quick access and initial planning. It is essential that the information be immediately accessible, legible, and intelligible to remediation personnel. Consider placing the information on a geographical information system (with hardcopy backup) that would be controlled and maintained by airport personnel.

3. Identify containment zones to prevent the spread of CWA or TIC, and isolation zones to prevent the contamination of critical equipment or the release of treatment gas. Assess the facility layout and identify potential sampling, characterization, and decontamination zones. Identify logical containment and isolation zones, and stipulate the means by which the zones are to be established. Isolation can be established at connector halls between major terminal areas or by tenting critical equipment. Fire doors can assist in isolation. Life-safety zones are used for smoke control and are often serviced by dedicated air-handling units (AHUs). Because they are defined by the AHUs of the airport HVAC system, they constitute logical zones for characterization and decontamination. Decontamination zones are defined primarily by physical structures, such as fire doors or corridors that can be easily sealed in the event of a release.

4. Identify sampling and analytical resources. Determine who will collect samples, such as initial environmental samples and subsequent characterization and clearance samples. Meet with the identified laboratory(ies) and discuss sample throughput, reporting of results, and surge capacity. If needed, line up additional analytical laboratories that can be tapped in the event that many samples are to be collected and surge capacity is exceeded.

5. Identify sampling zones and units. Identify logical sampling zones and sampling units for the airport. Decide how the airport can be logically subdivided to facilitate environmental sampling. Sampling zones may be similar to the containment and isolation zones, or they may be defined at a finer scale. It is possible that sampling zones and units may be different, depending on the CWA or TIC released. However, it should be possible to construct sampling zones and units that could be reviewed and modified as necessary in case of an actual incident.

6. Identify the most likely decontamination methods and experienced contractors to be used. Evaluate the strengths and weaknesses of available decontamination methods. Select the most appropriate methods to use for a specific CWA or TIC. In some cases, it may be possible to use or upgrade in-house decontamination equipment. Identify staging areas or warehouses for personnel, equipment, and supplies. Decide on the types and amounts of decontamination supplies needed and whether to purchase them in advance (some materials may have a short shelf life). Select potential contractors to employ as members of the decontamination team.

7. Identify what to decontaminate in situ, remove for offsite treatment, or remove for disposal. In most cases, easily removed and replaced items should be removed, whereas structural components should be decontaminated in place. The decontamination reagent used will affect the decision of what items may be left in place. Whereas treatment in place should reduce the costs of source reduction, some critical equipment and items may be identified for removal and treatment offsite. If existing decontamination methods are not compatible with certain equipment, then identify alternative, backup, or replacement equipment.

8. Determine initial disposition of contaminated materials, and identify staging and storage areas for waste. Decontaminating materials in place will reduce the potential for spreading contamination, but it may also damage certain equipment or materials. Disposition choices should be evaluated in advance of an incident. Estimate waste-storage requirements according to the quantities of materials that might require disposal, and depending on the decontamination technologies of choice. Initiate discussions with local waste-disposal facilities, including municipal waste landfills and construction and demolition debris landfills. Discuss waste-disposal issues with the state's solid-waste-management authority. Discuss wastewater management issues with local wastewater treatment facilities. Identify necessary disposal permits, waivers, and exemptions; disposal facilities, capacities, and transportation routes; and pre-arrange contracts if possible. Staging and storage areas for waste must be selected with an indefinite time requirement so that waste disposal activities do not impact clearance and reoccupancy timelines.

9. Write a new, generic Health and Safety Plan. Write a new HASP or re-evaluate an existing one on the basis of information in this *Remediation Guidance* document.

10. Identify backup facilities to continue commercial air service. In the event that one or more airport terminals is contaminated with a CWA or TIC, identify air cargo areas, hangers, and other infrastructure that can be used for the resumption of commercial air travel in some capacity.

11. Hold planning meetings at scheduled intervals. Airport personnel should meet with prospective UC and TWG members, responders, and stakeholders to continue to develop remediation-related documents, policies, and guidance. Response and recovery plans will change over time as technologies advance and local, state, and Federal policies evolve.

12. Conduct training exercises. Airports should identify the scope of training activities appropriate for responding to CWA or TIC attacks. Activities can range from simple, internal notification drills to full-scale, mass-decontamination exercises that take place over one or more days.

13. Consider implementing other HVAC-related, low-cost items as part of pre-planning. Although the following items are not directly part of remediation, implementing them would reduce the impact of a CWA or TIC attack on an airport and make remediation easier:

- Develop and implement procedures for an HVAC response strategy, specifically, what to do with the HVAC system during the first few minutes after an attack.
- Ensure HVAC dampers respond properly on command and close fully when needed. Seal dampers to prevent leakage and damper bypass.
- Ensure dampers respond to a 100% open/close command within about 30 seconds.
- Install high-efficiency particulate air (HEPA) filters: MERV 13 at a minimum or MERV 16 if possible. Such filters have a collection efficiency of 90 to 95% for most aerosol threats down to 1 micron in diameter, including airborne dust that may adsorb a chemical of concern. Upgrading to higher-efficiency filters can frequently be done with minimal modifications to a filtration system or impact on a system's design performance.
- Seal filter racks with better-fitting gaskets, mastic, or equivalent sealing material to prevent filter bypass.
- Seal all leaks in AHUs and duct systems with mastic or equivalent sealing material to prevent entry of unfiltered air into the distribution system.

Table 5-1. Summary of principal actions to be taken by airport management prior to a CWA or TIC attack. Actions are listed under the phase of activity with which they are most closely associated.

Initial Notification Actions
• Incorporate specific CWA and TIC response plans into the facility's emergency response plan. • Develop a notification protocol for all facility personnel, responders, and agencies (Federal, state, and local) tailored to each stage of a developing incident. (See Annex A.)
Policy, Concept of Operations, and First-Response Actions
• Develop a policy specifying criteria for airport closure or suspension of operations after an attack. • Identify members of a Unified Command, convene the UC, and review this *Remediation Guidance*. • Identify members of a TWG. Members are drawn from the CDC, EPA, DOD, public health, sampling contractors, and analytical laboratories. The TWG should review this *Remediation Guidance*. • Identify alternative locations for an Emergency Operations Center (EOC) and Incident Command Post (ICP), preferably near airport, but offsite in the event that an onsite EOC is contaminated. • Identify the primary, authorized analytical laboratory for sample analysis. Identify backup labs. • Train security personnel, and conduct periodic training exercises with likely command personnel, including TWG members, and other responder and agency representatives.
Characterization-Related Actions
• Identify characterization and decontamination resources listed in Table 2-1. • Identify potential sampling, characterization, and decontamination zones within airport buildings. • Identify sampling units. • Identify areas at the airport that can be used or cleared for staging and storing waste materials. • Create and maintain an up-to-date library of key facility architectural and mechanical drawings including heating, ventilation and air conditioning (HVAC) operating parameters. • Update building vulnerability assessments periodically, and correct any deficiencies. • Create a new or review an existing Health and Safety Plan (HASP).
Decontamination-Related Actions
• Identify in-house equipment that could be used or upgraded for decontamination activities. • Select staging areas or warehouses for equipment and supplies. • Predetermine disposal options for potentially contaminated materials. • Determine likely decontamination method(s) and types of decontamination supplies to store. • Select and retain contractors for the decontamination team. • Identify staging and storage areas for waste, if not already done for characterization actions. • Initiate discussions with local waste-disposal facilities and wastewater treatment facilities. • Discuss waste-disposal issues with state's solid-waste-management authority.
Clearance-Related Actions
• Identify clearance goals, according to explicit health exposure guidelines, early in the process.