United States
Environmental Protection
Agency

EPA/600/R-18/254 | September 2018
www.epa.gov/homeland-security-research

Best Practices to Minimize Laboratory Resources for Waste Characterization During a Wide-Area Release of Chemical Warfare Agents

Office of Research and Development
Homeland Security Research Program

This page left intentionally blank

EPA/600/R-18/254
September 2018

Best Practices to Minimize Laboratory Resources for Waste Characterization During a Wide-Area Release of Chemical Warfare Agents

by

Stuart Willison
Matthew Magnuson
Erin Silvestri
National Homeland Security Research Center
Cincinnati, OH 45268

Paul Lemieux
Timothy Boe
National Homeland Security Research Center
Research Triangle Park, NC

Stephanie Hines
Ryan James
Battelle Memorial Institute
Columbus, OH

Contract No. EP-C-15-002 Task Orders 0003 and 0010

U.S. Environmental Protection Agency Project Officer
Homeland Security Research Program
Cincinnati, OH 45268

Disclaimers

The U.S. Environmental Protection Agency (EPA) through its Office of Research and Development participated in and managed the research described here. This work was performed by Battelle under Contract No. EP-C-15-002 Task Orders 0003 and 0010.

This text is a draft that has not been reviewed for technical accuracy or adherence to EPA policy; do not quote or cite.

The processes described in this document do not rely on and do not affect authority under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), 42 U.S.C. 9601 et seq., and the National Contingency Plan (NCP), 40 Code of Federal Regulations (CFR) Part 300. This document is intended to provide information and suggestions that might be helpful for waste characterization efforts after a chemical incident and should be considered advisory. The best practices in this document are not required elements of any rule. Therefore, this document does not substitute for any statutory provisions or regulations, nor is it a regulation itself, so it does not impose legally binding requirements on EPA, states, or the regulated community. The lessons and recommendations herein might not be applicable to each and every situation.

Questions concerning this document or its application should be addressed to:

Stuart Willison
National Homeland Security Research Center
Office of Research and Development
U.S. Environmental Protection Agency
26 W. Martin Luther King Drive, MS NG16
Cincinnati, OH 45220
513-569-7253

Table of Contents

FIGURES

TABLES

Acronyms and Abbreviations

AEGL	Acute Exposure Guideline Level
ASTM	American Society for Testing Materials, now ASTM International
BOTE	Bio-Response Operational Testing and Evaluation
BPD	Best Practices to Minimize Laboratory Resources for Waste Characterization During a Wide-Area Release of Chemical Warfare Agents Document
BPG	Best Practices Guide as a quick reference tool to the BPD
GA	Tabun, CAS Number 77-81-6
GB	Sarin, CAS Number 107-44-8
GD	Soman, CAS Number 96-64-0
GF	Cyclosarin, CAS Number 329-99-7
CDC	United States Centers for Disease Control and Prevention
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CI	Critical Infrastructure
CK	Cyanogen Chloride, CAS Number 506-77-4
Cl	Chlorine
CMAD	Consequence Management Advisory Division
CMPA	Cyclohexyl Methylphosphonic Acid, CAS Number 1932-60-1
COLIWASA	Composite Liquid Waste Sampler
CVAA	2-chlorovinyl arsenous acid, CAS Number 85090-33-1
CVAOA	2-chlorovinylarsonic acid, CAS Number 64038-44-4
CWA	Chemical Warfare Agent
DIMP	Diisopropyl methylphosphonate, CAS Number 1445-75-6
DoD	U.S. Department of Defense
DOE	U.S. Department of Energy
DQO	Data Quality Objective
DU	Decision Unit
EA-2192	S-(2-diisopropylaminoethyl) methylphosphonothioic acid, CAS Number 73207-98-4
EHDAP	Ethyl Hydrogen Dimethylamidophosphate, CAS Number 2632-86-2
EMPA	Ethyl Methylphosphonic Acid, CAS Number 1832-53-7
EPA	U.S. Environmental Protection Agency
ERLN	Environmental Response Laboratory Network
FR	Federal Register
GC/MS	Gas Chromatography/Mass Spectrometry
H	Undistilled Sulfur Mustard, di-2 chloroethyl sulfide, bis(2-chloroethyl) sulfide, same CAS Number (505-60-2) as HD
HD	Distilled Sulfur Mustard, bis(2-chloroethyl) sulfide, CAS Number 505-60-2
HVAC	Heating, Ventilation, and Air Conditioning
ICS	Incident Command System
IC/UC	Incident Command/Unified Command
IMPA	isopropyl methylphosphonic acid, CAS Number 1832-54-8
ISM	Incremental Sampling Methodology

L	Lewisite, collective abbreviation for L-1 (CAS Number 541-25-3), L-2 (40334-69-8), and L-3 (CAS Number 40334-70-1)
LC/MS	Liquid Chromatography/Mass Spectrometry
MPA	Methylphosphonic Acid, CAS Number 993-13-5
NCP	National Contingency Plan
NPDES	National Pollution Discharge Elimination System
NRF	National Response Framework
NRT	U.S. National Response Team
OSC	On-Scene Coordinator
PATS	Prioritized Area Targeted Sampling
PMPA	Pinacolyl Methylphosphonic Acid, CAS Number 616-52-4
POTW	Publicly Owned Treatment Works
PPE	Personal Protective Equipment
QA	Quality Assurance
QC	Quality Control
QRG	Quick Reference Guide
RAP	Remediation Action Plan
RCRA	Resource Conservation and Recovery Act
SAM	Standardized Analytical Methods
SAP	Sampling and Analysis Plan
SME	Subject Matter Expert
START	Superfund Technical Assessment & Response Team
TCLP	Toxicity Characteristic Leaching Procedure
TDG	thiodiglycol, CAS Number 111-48-8
TSDF	Treatment, Storage, and Disposal Facility
TTX	Table-top Exercise
TWG	Technical Working Group
UASI	Urban Area Security Initiative
UCL	Upper Confidence Limit
VSP	Visual Sample Plan
VX	O-ethyl-S-(2-diisopropylaminoethyl) methylphosphonothioate, CAS Number 50782-69-9
WARRP	Wide-Area Recovery and Resiliency Program
WMP	Waste Management Plan

Executive Summary

The executive summary is intended to be used as a "quick reference" to the Best Practices to Minimize Laboratory Resources for Waste Characterization During a Wide-Area Release of Chemical Warfare Agents (Best Practices Document, (BPD) document. For the convenience of the reader, Appendix G is formatted as a standalone document that is intended to be used as a reference to the main BPD.

> ***Waste characterization is a process that uses knowledge of the waste and/or sampling results to document that the waste meets regulatory requirements and any additional requirements of waste receivers.***

The BPD will assist users in minimizing the number of samples sent for laboratory analysis for waste characterization tasks while still meeting the data needs of waste regulators and receivers. The executive summary is also reproduced as Appendix G of this document and formatted as a Best Practices Guide (BPG) with the intention that it be used as a stand-alone document, serving as a quick reference tool to the BPD, particularly for use during tabletop/simulation/training events. This executive summary and the BPG include the central flow chart for the waste characterization process, along with identification and a brief description that should enable the participant in such events to locate relevant sections of the BPD as quickly as possible. The quick reference is not intended to replace the full BPD in terms of information or strategy.

A wide-area release of a chemical warfare agent may result in the contamination of several square miles of an urban area, potentially affecting hundreds of buildings. The response and recovery activities from this type of incident could generate several tons of solid waste and millions of gallons of liquid waste. Materials that are not going to be reused or recycled from the incident will become waste when they are identified for disposal. All generated waste from the wide-area incident must be appropriately characterized. However, laboratory demand during a wide-area incident will likely be greater than the available capacity due to the need for sampling and analysis during site characterization, assessment of decontamination efficacy, waste characterization, and clinical or medical testing. As a result, laboratory analysis could become a chokepoint and limit overall progress in incident management.

Important concepts to reduce the number of laboratory samples include:

- Waste characterization is a legal requirement for all generated wastes, but sampling might not be necessary if acceptable to regulators and waste receivers;
- Appropriate waste segregation is critical for efficient waste characterization;

- Waste characterization strategies should leverage the use of lines of evidence to the extent possible as a primary means to reduce sample numbers for laboratory analysis;
- Field screening can be combined with lines of evidence or the use of a limited number of confirmatory laboratory samples to reduce the number of laboratory samples analyzed; and
- Waste characterization strategies must be acceptable to regulators and waste receivers, and these entities should be involved throughout the process, especially in the beginning where many decisions are made that drive characterization and decontamination waste streams.

Lines of Evidence are information or data from various sources that can be used to support waste characterization decisions. Lines of Evidence can include technical data on agent fate and transport, persistence in defined environmental conditions, and efficacy of decontamination technologies.

Waste Characterization Process

Figure 1, as detailed in the BPD, provides a description of the overall waste characterization process. For clarity, progression through Figure 1 is intended to be a stepwise process. However, there are multiple factors within the process that may be optimized to reduce the number of laboratory samples and may result in the simultaneous determination of several process decisions or dictate an iterative nature to waste characterization decisions. Site- or incident-specific conditions may also dictate the sequence of decision-making.

Step 1: Segregate waste into homogeneous groups (Section 6.3), Identify waste acceptance criteria and associated data quality objectives (DQOs) for each waste group (Section 6.4), and Identify laboratories with analysis capabilities for desired analyses that will accept material (Section 6.7) Waste materials are segregated to facilitate reduced sampling requirements by grouping materials assumed to have similar characteristics. Waste group characteristics that might be relevant for segregation are described in further detail in the BPD. Individual waste groups might be targeted for different waste management options, with varying waste acceptance criteria and DQOs based on the waste receiver(s), i.e., utilities that will be receiving the waste. Waste acceptance criteria are specific to each waste receiver that will accept the waste. There might also be unique acceptance criteria for locations that hold or stage waste prior to its final management, particularly with hazardous chemical warfare agent (CWA) waste. It will be helpful to identify contractor and waste receiver resources that will be present on-scene during an incident who can provide region-specific knowledge for waste characterization and available waste receivers. The criteria can be concentration-based or performance-based standards (i.e., decontamination technology) and include the volume of waste that will be accepted (Section 6.4). It is important to recognize that degradation products (Table B-1) and non-CWA constituents of the waste should also be considered in the waste characterization process. If laboratory analysis of samples will be performed, laboratories that can perform the analysis and that will accept the waste material must be confirmed (Section 6.7).

Step 2: Determine the waste characterization strategy (Section 6.5). The waste characterization strategy is developed to demonstrate if the waste material meets the identified waste acceptance criteria and DQOs. The strategy might consist of application of lines of evidence, field and/or laboratory sampling, or a combination of the two approaches. Lines of evidence should be considered as a first approach. Software tools are available to assist with the development of sampling strategies (Section 6.5.3.1).

Step 3: Gather Data. Lines of evidence data can be gathered from the published literature, subject matter experts, waste receivers, regulators, and previously gathered site data (Section 6.5.1). In the case of sampling, decisions to gather data are made for the overall sampling strategy (i.e., non-probabilistic, probabilistic, combination), (Sections 6.5.2 and 6.5.3, Table ES-1), sample collection (Section 6.6, Table ES-2), and analysis (Section 6.7).

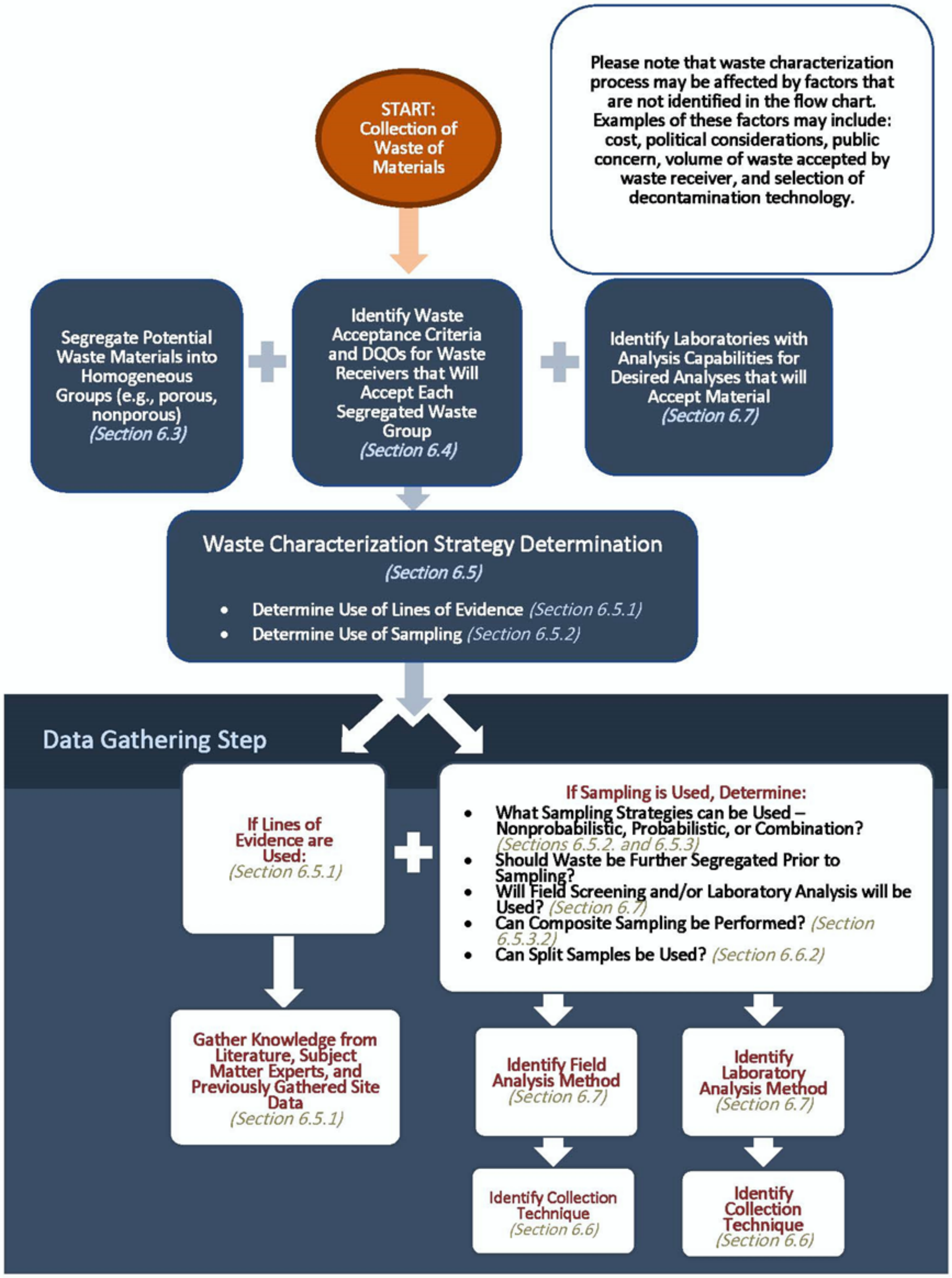


Figure ES-1. Waste characterization process flow chart

1 Introduction

The U.S. Environmental Protection Agency (EPA) is designated as a coordinating agency, under the National Response Framework (NRF), to prepare for, respond to, and recover from a threat to public health, welfare, or the environment caused by actual or potential hazardous materials incidents. Hazardous materials can include chemical, biological, and radiological substances. A wide-area incident may result in large-scale contamination because of its geographical size (e.g., tens to hundreds of square miles) and the potential for additional transport after the release due to urban conditions (e.g., complexity of environment, magnitude of contamination, and spread of contamination). Environmental remediation might be driven by the desire to return contaminated areas to their original use and by compressing the timeline for the associated environmental remediation activities. Urban wide-area contamination might result in items or materials that require characterization before decontamination, after decontamination, and prior to waste management decisions. Waste characterization is a necessary task in making waste management decisions. Waste characterization is a process that uses knowledge of the waste and/or sampling results to document that the waste meets regulatory requirements and any additional requirements of waste receivers. Developing and implementing sampling plans to address wide-area contamination and associated waste characterization is complex. Laboratory resources will be limited during an incident, yet samples will need to be collected and assessed in such a manner that the resulting data are useful for the overall, site-specific recovery process. There will likely be a variety of types of materials within an urban environment, each requiring distinct sampling and analysis procedures during waste characterization, creating a potential bottleneck that could limit the overall recovery effort.

The potential size of an urban wide-area incident will add to the complexity of developing a sampling plan. Sufficient samples will need to be collected without overwhelming the available laboratory capacity and capability. Because chemical warfare agent (CWA) incidents are infrequent and direct practical knowledge is limited, approaches for performing the appropriate sampling techniques are inherently novel with unpredictable technical needs and complexities.

Further increasing the complexity of developing a sampling plan are the multitude of phases and activities surrounding an urban CWA release, each of which will have its own sampling needs. The phases and activities that follow a chemical contamination incident start with the initial notification of an incident/first response, continue with remediation of the site, and end with the clearance decisions and restoration/re-occupancy of the contaminated site. Considerations for appropriate waste management, including waste characterization, should be incorporated into all activities from the earliest stage of the incident. As a result, waste receivers (e.g., treatment, storage, and disposal facility [TSDF] personnel) and regulators should be involved from the start of the incident to provide information on waste characterization requirements. States may have more stringent regulations on CWA-generated waste, which will require further input from waste receivers and regulators. In general, efforts to remediate a site might include characterization of the site, decontamination of the site, and sampling following decontamination to ensure decontamination efforts were successful. Information about treatment, decontamination, and other topics related to sampling are not discussed in detail in this document, but can be found elsewhere (EPA, 2012c; EPA, 2015d; NRT, 2015b).

As waste management is a common feature of all these phases and activities, towards addressing these complex issues, a literature review was conducted that focused on comparing and contrasting multiple approaches to address the challenges in sample planning, sample collection, and analysis for waste samples during an urban wide-area release of chemical warfare agents (CWAs). Three acutely toxic CWAs were targeted in the literature review: nerve agent VX (O-ethyl-S-(2-diisopropylaminoethyl) methylphosphonothioate), blister agent distilled sulfur mustard (HD), and blister agent Lewisite (L). Each agent has properties that may extend its persistence in an urban environment. The literature review was limited to published information from peer-reviewed journals, EPA, and other state and federal agencies. The information obtained from the literature review, as well as with input from response professionals, was used to help identify best practices to assist users in reducing the analytical laboratory sampling load for activities associated with the waste characterization process. The best practices were identified based on waste characterization considerations for the three identified CWAs in an urban wide-area release scenario. However, the material presented might also be appropriate for an all-hazards evaluation of non-CWA waste that because of volume or toxicity presents a similar waste characterization challenge relative to significant limits on available laboratory analysis capacity.

1.1 Purpose of this Best Practices Document

The purpose of this document, the Best Practices to Minimize Laboratory Resources for Waste Characterization During a Wide-Area Release of Chemical Warfare Agents (Best Practices document or BPD), is to present best practices to minimize resources needed for determination of waste characterization strategies, sample collection techniques, and analytical approaches for characterization of waste materials contaminated by an urban wide-area release of CWAs. The best practices discussed in this document might be applicable to consequence management activities that EPA will be involved with and will require waste characterization. This document is intended to be general and all-hazards in nature, applicable to a multitude of settings, and to provide information on techniques and approaches that efficiently optimize sampling and analytical resources associated with the response to a wide-area incident. The material presented has value for pre-incident planning and use during an incident. The processes described in this document do not rely on and do not affect authority under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), the Resource Conservation and Recovery Act (RCRA), the NRF, the National Contingency Plan (NCP), or any other statute.

1.2 Intended Audience

This document is intended for personnel involved in the waste characterization process, specifically: On-Scene Coordinators (OSCs), local, state, tribal, and Regional Response Teams; Superfund Technical Assessment & Response Team (START) contractors; waste regulators, waste receivers including TSDF personnel, and subject matter experts (SMEs) who might be called upon by the Incident Command or Unified Command (IC/UC) or the Technical Working

Group (TWG) that might convene under the IC/UC as part of a wide-area incident. The document might also be useful for the individuals identified above when they are working in a Superfund setting and wish to consider waste characterization practices that minimize the use of laboratory analysis.

2 Scope

The following best practice objectives are included to reduce the number of samples sent to laboratories for analysis: data gathering strategies, analysis approaches and methods, and collection techniques. Other potential approaches may be available, but were not evaluated. While the document discusses three CWAs (nerve agent VX [i.e., O-ethyl-S-(2-diisopropylaminoethyl) methylphosphonothioate], blister agent sulfur mustard [HD], and blister agent Lewisite [L]), other agents of interest may have unique properties that affect the sampling and analysis procedures. This document specifically deals with the waste characterization component of response and recovery. Other components such as site characterization, decontamination, and clearance are beyond the scope of this BPD and could be the subject of follow-on efforts.

To assist users of the document, several appendices have been developed to provide additional resources for waste characterization. Given the diversity of users who may have varying levels of background knowledge for terminology associated with sampling and waste characterization, a glossary is provided in Appendix A for important terms that are used in the BPD. Background information on CWA agents, including potential degradation products and markers, can be found in Appendix B. Appendix C provides a data quality objectives (DQO) case study specific to waste characterization of CWAs. Appendices D and E provide summaries of sampling designs and collection techniques, respectively. Appendix F reports on the findings and recommendations from a table-top exercise (TTX) held to evaluate an earlier draft version of the best practices identified herein and from which final revisions to the best practices were identified. Appendix G provides a Best Practices Guide (BPG) that summarizes important concepts associated with the waste characterization best practices described in this document.

2.1 Quality Assurance

This report was generated using references (secondary data) identified as having relevant content for the purpose of this study. Some of the literature was derived from sources other than US EPA and used for other purposes. Therefore, it might not necessarily be ideal in terms of accuracy, precision, representativeness, completeness, and/or comparability. However, the selected literature was considered to be the best sources of available information. If additional sources of information become available, they should be considered during use of this document. Secondary data were limited to peer-reviewed documents and evaluated based on content relevance for each source. The literature review identified and assessed the secondary data for intended use(s). After the literature searches were conducted and the results subsequently reviewed, the quality of the secondary data was examined against the overall needs and was deemed either appropriate or inappropriate for inclusion in the results. Professional judgment was used to assess each article qualitatively according to the document evaluation categories listed below.

An extensive literature review was performed using several sources of secondary data related to assessing the extent of contamination, verification of decontamination efficacy, and waste disposal characterization of chemical agents embedded on surfaces, solid materials and waters contaminated by an urban wide area release of chemical agent. The key chemical agents that were the focus of this review were sulfur mustard (HD), Lewisite (L), and nerve agent VX along with their various degradation products. The information sources were collected from existing data primarily in peer-reviewed documents, including journal articles; books; and government and industry reports. The literature search included databases, such as, Energy Science & Technology and the National Technical Information Service (NTIS), the Homeland Defense and Security Information Analysis Center (HDIAC) managed by the Defense Technical Information Center (DTIC) [formerly CBRNIAC], Google Scholar™, and active identification of EPA research reports that are in varying stages of completion.

3 Data Gathering Processes for Waste Characterization

Waste will be generated during each phase of the response and recovery process. Therefore, waste management begins from the moment the incident occurs until the very end. All phases need to be considered together for effective incident pre-planning. Waste management activities should be identified within a waste management plan (WMP) and incorporated into the remediation action plan (RAP). The information provided within the document contains valuable resources and material that can be used even if a pre-incident waste management plan has not been developed. This document focuses on the waste characterization efforts during remediation of a contaminated wide area; other aspects of response and recovery will not be discussed in detail. Further information about other phases can be found in additional planning documents (DHS 2011 and EPA, 2005).

3.1 Considerations of Waste Characterization Process

The following best practices are focused on waste characterization prior to treatment and proper management. Figure 1 illustrates the interactions of data gathering strategy, collection, and analysis that the best practices coalesce during waste characterization. The waste characterization process should consider both the site-specific circumstances (e.g., agent, environment) and desired downstream applications of the data to ensure the validity of the data generated from the process. The DQO process should be integrated throughout all waste characterization decisions. While first response activities will have been completed at this point, additional hazards might remain. Therefore, all planning activities should be coordinated with health and safety planners to ensure that the number and types of planned samples are compatible with available sampling resources and the constraints of the health and safety plan.

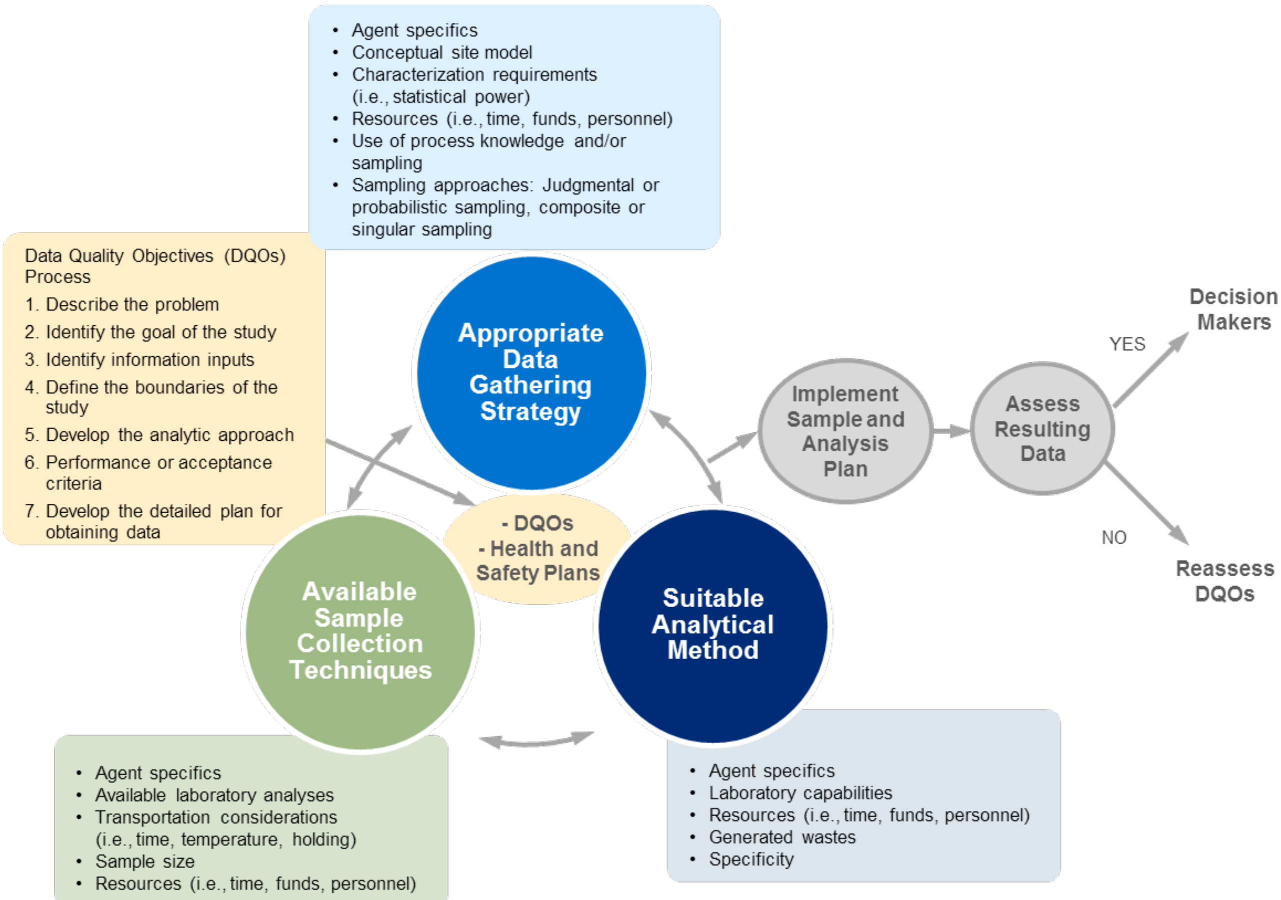


Figure 1. Interaction of data gathering strategy, collection, and analysis.

3.2 Sources and Amounts of Waste: Relationship to Sampling Needs

Waste is generated throughout all phases of the response and recovery process, and the associated waste management activities will likely be an important factor in the duration and cost of the response and remediation (EPA, 2015d; Lemieux et al., 2016). Urban wide-area incidents may generate large quantities and wide varieties of waste such as waste generated from residential homes, businesses, industry, infrastructure, and hospitals (EPA, 2012d). Waste streams might include (EPA, 2012d):

- Personal protective equipment (PPE) such as disposable gloves, suits, and boot covers;
- Decontaminated items from characterization and post-decontamination phases destined for disposal or further management; and
- Decontamination water (rinsate).

Federal and state requirements for waste management identify that all waste should be appropriately characterized as part of proper management practices. For purposes of this document, waste characterization is defined as information, gathered through situationally-appropriate means, about the composition of waste that can be used by decision makers to properly direct waste management.

As illustrated in Figure 1, sampling is a key element of waste characterization. As a result, the waste characterization process has the potential to contribute significantly to the overall sampling demand during a wide-area incident. Waste items will likely be packaged in bags, barrels, or other containers that inhibit access for sampling. Given that an urban wide-area incident might produce millions of tons of waste, sampling every bag or waste container might be logistically impossible. A pre-incident WMP should not only identify the waste management facilities available for use but also identify their individual waste characterization requirements, as individual establishments might have additional requirements beyond what is required in their state-issued permit(s). Given the volume of waste and potential limits on the capacity of individual waste receivers, multiple waste facilities should be identified and relevant WMP data gathered to ensure sufficient options to manage the total volume of waste that may be generated. It is also important to note that after environmental samples have been analyzed by the laboratory and are stored for further management, they will also be treated as regulated waste (EPA, 2010).

4 Operational Assumptions

The best practices identified in this document are not designed to be regulatory or formal guidance. Given that the best practices will be implemented within a larger framework for response and recovery after a wide-area incident, it is acknowledged that additional or varying operational assumptions may better describe an individual wide-area incident.

There are six main operational elements that have been assumed:

(1) Regulatory requirements at the federal, state, and local level must be met in the waste characterization process;
(2) Pre-incident waste management planning has been performed (NOTE: The material within this document may be valuable towards developing a WMP and should be considered);
(3) Laboratory resources and capabilities are known;
(4) Generalized DQOs have been identified;
(5) The chemical contaminant(s) of concern (including potential breakdown products or impurities) have been identified; and
(6) Waste receivers are known.

The first four assumed operational elements are described in more detail below.

4.1 Regulatory Context

All materials that will be disposed of as waste must be characterized to meet the requirements of regulators and waste receivers. Waste characterization must, at a minimum, meet the regulatory requirements associated with the waste and the identified management action. Communication with treatment, storage, and disposal facility (TSDF) personnel is necessary to determine if emergency RCRA permits will apply to assess alternative options for waste disposal. Land disposal of solid and hazardous waste is primarily regulated by federal laws such as the RCRA of 1976 and the Hazardous and Solid Waste Amendments of 1984 (DHS, 2012a; EPA, 2012a). Under RCRA, “solid waste” is broadly defined and includes discarded materials such as solids, liquids, semi-solids, and contained gaseous materials. However, RCRA Subtitle C hazardous waste landfills (CFR Title 40 Part 264§264.314) and RCRA Subtitle D solid waste landfills (CFR Title 40 Part 258 §258.28) have restrictions on the disposal of waste containing "free" liquids that must be accommodated. In addition, surface runoff or other discharges to surface water bodies from decontamination wastewater might fall under the purview of the National Pollution Discharge Elimination System (NPDES) in the Clean Water Act (Campbell et al., 2012). Certain waste treatment technologies (e.g., incineration) are also regulated under the Clean Air Act Amendments of 1990 (e.g., Kilgroe (1996)). The management of liquid waste as wastewater by Publicly Owned Treatment Works (POTW) is related to the Clean Water Act, but is also subject to any additional requirements of state and local managers of the POTWs (Campbell et al., 2012; DHS, 2012a), introducing many complexities, with no universal solutions regarding the role of POTWs in the management of liquid wastes such as decontamination rinsates. Liquids may need to be collected and held in secure storage until a designated disposal facility is identified.

In most states, the authority for these federal laws is delegated (i.e., implemented and enforced) by the states, and thus state and possibly local regulatory agencies determine the waste testing requirements associated with various waste management practices. The states could impose more stringent requirements than the Federal Government. However, it is ultimately the waste management facilities that accept the waste, and these facilities might have waste acceptance criteria of their own in addition to the state requirements (EPA, 2015d; Lemieux et al., 2016).

4.2 Pre-Incident Waste Management Planning

A pre-incident WMP is assumed to be available to support development of an incident-specific waste management plan, so is not described extensively in this section. It is useful, however, to briefly discuss this topic to see how it integrates with the overall goal of this document Figure 2 shows the waste management planning process, including the presence of multiple steps that might occur prior to an incident. Pre-incident planning may help to reduce potential chokepoints in the recovery process that may delay the overall rate of recovery (DHS, 2012a). During the initial stages of an incident, a pre-incident WMP will be developed by a team to address waste management issues. Development of the plan will require coordination and approvals with regional response teams, state officials and agencies for each state expected to receive waste, and waste treatment, and disposal facilities. As part of pre-incident waste management planning, the process and outputs should be communicated to politicians, state and local regulators, and waste receivers. Factual communication, technical translation, and the viability of a proposed solution will provide valuable information for the planning process. These groups will be critically important to implementation of the waste management plan during an incident.

These pre-incident plans should be incorporated into area contingency plans for each region in accordance with the National Contingency Plan (NCP). In instances of a chemical release, the pre-incident WMP would ideally be quickly adapted for the specific incident (i.e., the incident-specific RAP and the associated WMP). Such adaptations are critical for successful responses to wide-area incidents and especially for those involving chemical agents because of the limited experience involved in handling these wastes and the difficulties that might arise in finding facilities willing to accept such waste (EPA, 2015d).

The pre-incident WMP should provide guidance on the options and preferences for waste management as well as potential preferred options for waste management for identified waste streams. In the context of wide-area incidents for biological agents, Lemieux (2016) observed that waste management tasks were simplified when aqueous wastes (i.e., wastewaters) can be managed at a POTW facility and non-aqueous wastes can be managed as solid waste in a RCRA Subtitle D facility. This simplification is also likely true for wide-area incidents involving chemical agents, and as mentioned above, it cannot be taken for granted "if" managing wastes in this manner is possible for a specific site. It is important for response managers, regulatory authorities, and utility managers to meet, and pre-plan if possible, to prevent, assess, and respond to the potential impacts of decontamination wastewater (EPA, 2015d; National Association of Clean Water Agencies, 2005), solid waste, and hazardous waste generated during the response to a wide-area urban chemical agent release. EPA (2016a) provides an excellent example of a pre-planning activity in the form of a collaborative workshop held with the wastewater sector, SMEs, and regulatory representatives. EPA (2016a) reports on the findings of the workshop and includes relevant references that might assist in future pre-planning activities for the management of chemically contaminated wastewater. EPA is developing an online tool to aid communities, states, tribes, and facilities in preparing a pre-incident WMP (2018).

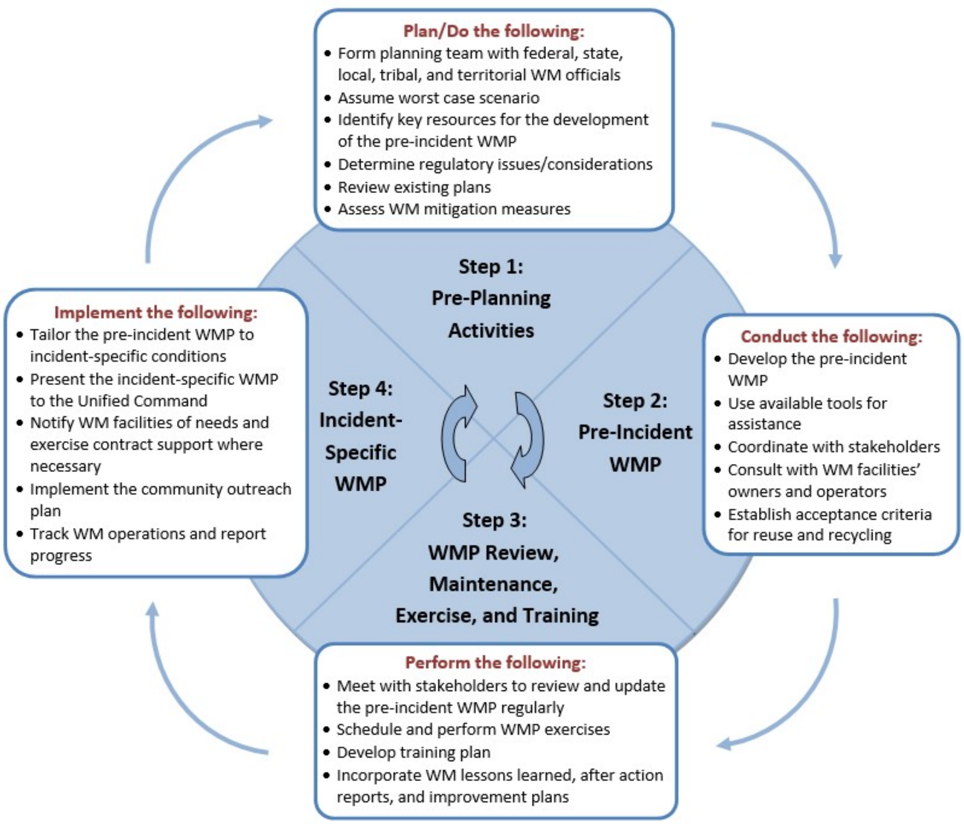


Figure 2. Pre-incident all-hazards waste management planning process. Source: (EPA, 2016b).

Elements of a WMP, based on the process described in Figure 2, can include:

- Waste management requirements (federal, state, and local)
- Waste types and quantities
- Waste facilities and resources needed
- Waste acceptance criteria of waste management facilities
- Waste facility personnel contact information
- Waste characterization requirements
- Waste sampling and analysis plan
- Waste management strategies (e.g., collection, segregation, staging/storage, transportation, treatment and disposal)
- Waste tracking and reporting
- Waste management oversight activities
- Community outreach and communication plan
- Waste management health and safety.

4.3 Known Laboratory Resources and Capabilities

The basic tasks of determining the extent of contamination, determining the efficacy of decontamination, and characterizing waste for proper management are key sampling decisions that place demands on laboratory resources. As a result, pre-incident planning, including the development of sampling plans, should identify known laboratory resources to ensure that such information is readily available during an incident. Planning can also identify gaps in coverage that could be addressed as resources become available. Available laboratory resources with capabilities to analyze CWAs should be identified prior to an incident so that individuals developing sampling plans are aware of analytical capabilities (e.g., specific analyses and equipment, matrices, detection limits) and laboratory quality capabilities (e.g., data quality programs). EPA established the Environmental Response Laboratory Network (ERLN) as a national network of laboratories that can be ramped up as needed to support large scale environmental responses (EPA, 2017). The ERLN provides consistent analytical capabilities, capacities, and quality data in a systematic, coordinated response. The ERLN integrates capabilities of existing public-sector laboratories with accredited private sector laboratories to support environmental responses.

Given the probable large number of samples requiring analysis, knowledge of laboratory capacity and capability would assist distribution of samples to multiple laboratories to facilitate timely analyses. Depending upon individual laboratory capabilities, this knowledge might also assist in covering the diverse types of materials being sampled.

4.4 Generalized DQOs Identified

The DQO process (see inset) is an iterative seven-step process that generates performance criteria for the collection of new data that guide waste management decisions. It is important to recognize that the DQO process might need to be repeated multiple times as the incident unfolds and new information becomes available. Pre-incident planning might involve identifying the data quality process necessary to make decisions using data of defined quality in the response and recovery process following a wide-area incident. While decision-making will be performed in an agent- and incident-specific manner during a wide-area incident, pre-incident knowledge of the generalized DQOs and processes that are in place will facilitate the decision-making process.

DQO Process

1. State the Problem
2. Identify the Goal of the Study
3. Identify Information Inputs
4. Define the Boundaries of the Study
5. Develop the Analytical Approach
6. Specify Performance or Acceptance Criteria
7. Develop the Detailed Sampling and Analysis Plan for Obtaining Data

Note that the Process Should be Repeated as New Data or Data Needs Are Identified

Six crucial inputs are necessary before developing the overall Sampling and Analysis Plan (SAP) in step seven (EPA, 2006). The optimized SAP would outline the desired quality assurance (QA) and quality control (QC) parameters to achieve the overall project goal. The SAP should outline agent activity, agent formulation, toxicological properties, persistence, and other physical properties of the agent at hand.

Knowledge of the types of decisions to be made and the desired data quality will assist in the development of a range of potential sampling strategies for consideration prior to a specific incident. For each activity detailed herein, DQO examples for a Decision Problem and an Estimation Problem have been hypothesized (Appendix C) for a specific scenario. Note that the DQO examples included in Appendix Care hypothetical and should be appropriately modified for an actual incident but show the importance of having adequate DQOs during these types of incidents.

5 Planning Assumptions

Three planning assumptions were identified during the development of this document and are described in in the following subsections.

5.1 Limited Laboratory Capacity Relative to Analysis Needs

Laboratory resources are limited relative to the anticipated demand caused by a wide-area CWA incident. The reasons for the lack of necessary laboratory capacity are twofold. The first reason is that the laboratory capacity to analyze CWA agents is limited to existing ERLN laboratories.

Using HD analysis as an example, there are only 10 ERLN laboratories in the United States where samples can be sent for analysis.

The second reason is the potential for an extremely large number of samples that could be collected and sent for laboratory analysis throughout a wide-area incident. Sampling is used extensively in a wide-area incident for site characterization, decontamination efficacy, waste characterization, and evaluation of clinical/medical samples. As result, there is the potential that sample analyses could become a limiting pathway and greatly reduce progress on the overall response and recovery. Evaluations were not identified that described the potential number of samples associated with response to a wide-area CWA incident. However, one evaluation reported the potential number of samples that may be collected to evaluate extent of contamination in a wide-area release for a biological agent. France et al. (2015) evaluated potential sampling needs for an airport area of approximately 140 square kilometers (km^2) with different rates for sample collection by material type (e.g., every 5,000 square meters [m^2] of open ground, every 500 m^2 on asphalt, and every 100 m^2 on buildings) and estimated that approximately 85,000 samples would need to be collected. Laboratory analysis and timely reporting of results cannot be performed on this scale of sample numbers.

While field analysis techniques represent a potential factor to limit demands on laboratory resources, they might lack sufficient sensitivity to accurately determine the presence or concentration of an agent across the material types in an urban environment (DHS, 2012a). As a result, increased use of field analysis techniques alone is insufficient to fully address the issue of limited laboratory capacity.

5.2 Lack of Universal Sampling Approaches for Wide-Area Incidents

A wide-area release of CWAs has the potential to impact square-kilometer areas of significant size (e.g., tens of square kilometers) depending upon the agent released, the site-specific definition of contamination by the responsible authorities (e.g., loading concentration, presence or absence), weather conditions, and numerous other factors (DHS, 2012b). However, no specific open-source guidance or peer-reviewed publications provide detailed sampling strategies for such an incident. The agent-specific Quick Reference Guides (QRGs) developed by the U.S. National Response Team (NRT) provide general agent information relevant to sampling and site selection, waste management, and sample shipping considerations (https://www.nrt.org/Main/Resources.aspx?ResourceType=Hazards&ResourceSection=2).

A primary challenge in determining sampling strategies is the development of sampling plans that can be scaled for a broad geographic area while not exceeding the finite capacity of laboratory resources. Based on the scale of the area for assessment, there might be resulting tradeoffs that might affect overall data precision, accuracy, or generalizability. Knowledge of traditional sampling approaches used at Superfund or other hazardous material remediation sites might help to inform the identification of potential sampling approaches for consideration. These approaches will likely have to be modified in a wide-area incident to stay within bounds of the current laboratory capacity. As a result, it might be appropriate to consider potential modifications when applying traditional sampling approaches in a wide-area incident. However, data are scarce describing potential advantages and disadvantages for traditional sampling approaches (with or without potential modification) when applied to a wide-area incident.

6 Waste Characterization Process

6.1 General Characteristics of Waste Materials

Prior to characterization of waste for proper management, it must be determined which materials or items will be treated as waste and which materials or items will be decontaminated and reused (EPA, 2015a). The determination of materials as waste or items that will be re-used is likely to be determined on an incident-by-incident basis (EPA, 2015a). However, there are some general types of materials that are more likely to be waste than others. For example, waste materials from a wide-area incident might include, but not be limited to (EPA, 2012d):

- Personal protective equipment such as disposable gloves, suits, and boot covers;
- Decontaminated items destined for treatment and disposal (e.g., carpet, furniture, computers);
- Spent decontamination reagents; and
- Decontamination water (rinsate).

In the hypothetical Denver Wide Area Recovery and Resiliency Program (WARRP) chemical agent scenario (Appendix C), an analysis of the waste generated noted that the greatest contributors of items to be decontaminated and disposed were ceiling tile, carpet, electronics, furniture, paper, and other office supplies (EPA, 2012d).

Items that are more likely to be considered for decontamination and reuse include:

- Structural components of building spaces; and
- High-value or irreplaceable materials (e.g., large computer servers, heavy equipment, artwork, elements of subway cars).

After delineation of the waste and non-waste items in the sampling environment, waste characterization must be performed on all waste items to ensure proper management. The waste characterization process might not require sampling. Other characterization approaches (i.e., lines of evidence) may be used if acceptable to regulators and waste receivers. Materials will be decontaminated, using appropriate approaches, prior to transportation off-site. When the materials are aqueous wastes that may potentially be discharged to a wastewater system, decontamination of such waste may include appropriate treatment prior to discharge. It is important to identify whether owner/operators of the wastewater system have specific treatment requirements for acceptance of the waste prior to initiating treatment (National Association of Clean Water Agencies, 2005). The requirement for approval of the selected treatment by owner/operators may be especially important if the wastewater system is not already contaminated by uncontrolled discharges of contaminated water as may occur for wide-area incidents.

One purpose of waste characterization is to determine if the waste meets the acceptance criteria for a specified treatment or disposal facility or if subsequent decontamination/treatment is required. The presence of multiple surface types in the urban environment may affect the ability to decontaminate all materials to meet re-use criteria and may lead to re-designation of these materials to waste when decontamination cannot be performed (DHS, 2012a). Furthermore, liquid waste designated for disposal may be complicated by the unknown factors determining how chemical agents may behave in wastewater systems.

The significant volume of waste material generated from an urban wide-area incident will require unique data gathering approaches for waste characterization. An urban wide-area incident might produce millions of tons of waste. Sampling every bag or container of waste would be logistically impossible based on the anticipated load placed on field teams to collect data and laboratories for sample analysis. For example, waste analysis of the hypothetical Denver WARRP chemical agent scenario (described more fully in Appendix C) estimated that there could be 15 to 36 million gallons of aqueous waste and approximately 3 to 8 million tons of solid waste generated due to the decontamination of personnel, materials to be reused, and materials that will be disposed (EPA, 2012d).

The analysis of waste characterization samples will be competing with all other collection and analytical resources (e.g., characterization, clearance, clinical) during consequence management. Therefore, it is critical that waste sampling requirements be considered along with all other analytical needs as part of the prioritization of available analysis capacity for various uses (EPA, 2015d). However, it is possible that waste characterization samples identified for laboratory analysis may have a lower priority than other sampling tasks. As a result, care must be taken to minimize the analytical samples needed to perform waste characterization while still meeting the data requirements set forth by facility managers, transporters, and regulators. Ultimately, the goal is to minimize the number of analytical samples sent to the laboratories and ensure that all necessary sampling and analysis needs are met for consequence management.

The following best practices are applicable for waste characterization and apply during all phases of response and recovery after an urban wide-area incident. The purpose of these best practices is to optimize the collection and analysis of data to characterize waste in a manner that meets the data quality needs of regulators and waste receivers. Waste characterization is a legal requirement of federal, state, and local regulators (Lemieux et al., 2016) and is a condition of acceptance of waste by waste receivers (e.g., landfills, incinerators, POTWs). Waste characterization also provides necessary data for proper handling, labeling, transportation, and treatment (Lemieux et al., 2016).

The identified best practices utilize available (EPA, 2015d) guidance on waste characterization and the development of waste analysis plans. The best practices also provide additional information specific to waste characterization of chemical agents and the wide-area incident environment. The best practices incorporate the following three starting assumptions:

Starting Assumptions:

- Extent of the urban wide-area release is confirmed and the release is no longer ongoing
- Contaminating agent has been identified and the extent of contamination is well characterized
- Pre-Incident Waste Management Plan is in place

These best practices could also be used to help prepare pre-incident waste management planning documents, particularly to initiate a dialog with the relevant regulatory authorities so that waste management strategies could appropriately incorporate required analytical laboratory capacity and capabilities. Pre-planning could identify applicable regulations, key decision-makers, and potential waste management facility compliance requirements that are necessary to develop sampling requirements and assess analytical laboratory capabilities (EPA, 2012d). Ideally, many relevant technical decisions needed to perform waste characterization could be addressed via pre-planning for various hypothetical scenarios. The waste characterization best practices were developed for use by sampling professionals, especially those personnel who will be developing the waste characterization sampling plan, as well as incident decision-makers such as those experts serving on technical working groups. When developing a sampling plan for characterizing waste for proper management, it is important to work closely with a wide range of personnel to ensure that the sampling effort results are adequate to characterize the waste including representatives from the following perspectives (EPA, 2003):

- End user of data or decision-maker (e.g., waste receiver and federal, state or local regulators);
- Project Team (Manager or project chemist);
- Health and Safety Officer;
- Sampling Team (Lead);
- Analytical Laboratory (Director or analytical project coordinator);
- Quality Assurance;
- Risk Assessment; and
- Statistics.

6.2 Summary of Waste Characterization Process

Figure 3 reflects the overall waste characterization process. When presented with a collection of waste materials, the first step is to segregate waste into homogeneous groups (e.g., porous, nonporous) to facilitate identification of materials with similar properties to aid in the assessment of residual agent levels. After the waste has been segregated, the waste acceptance criteria and associated DQOs must be determined for each waste group. The waste acceptance criteria include a concentration- or performance-based criterion and the volume of waste that will be accepted. Individual waste groups might be targeted for different waste management options, and individual waste management options might have unique waste acceptance criteria and DQOs. If laboratory sampling is necessary to demonstrate that the waste acceptance criteria have been met, the laboratories with the desired analysis capabilities should be identified, and they should be consulted for confirmation that they can perform the identified analysis at the requested sampling load and that they will accept the waste material for analysis. After the waste acceptance criteria and DQOs are known and laboratories identified if needed, the next step is to determine the waste characterization strategy for each waste group. The waste characterization strategy can consist of the use of lines of evidence, field and/or laboratory sampling, or a combination of the two approaches. The next step is to collect the data. In the case of sampling, decisions must be made on the overall sampling strategy, analytical approach (i.e., laboratory, field analysis, or combination), analytical method, and collection method for the sample. Lines of evidence data can be gathered from the literature, SMEs, waste receivers, regulators, and previously gathered site data.

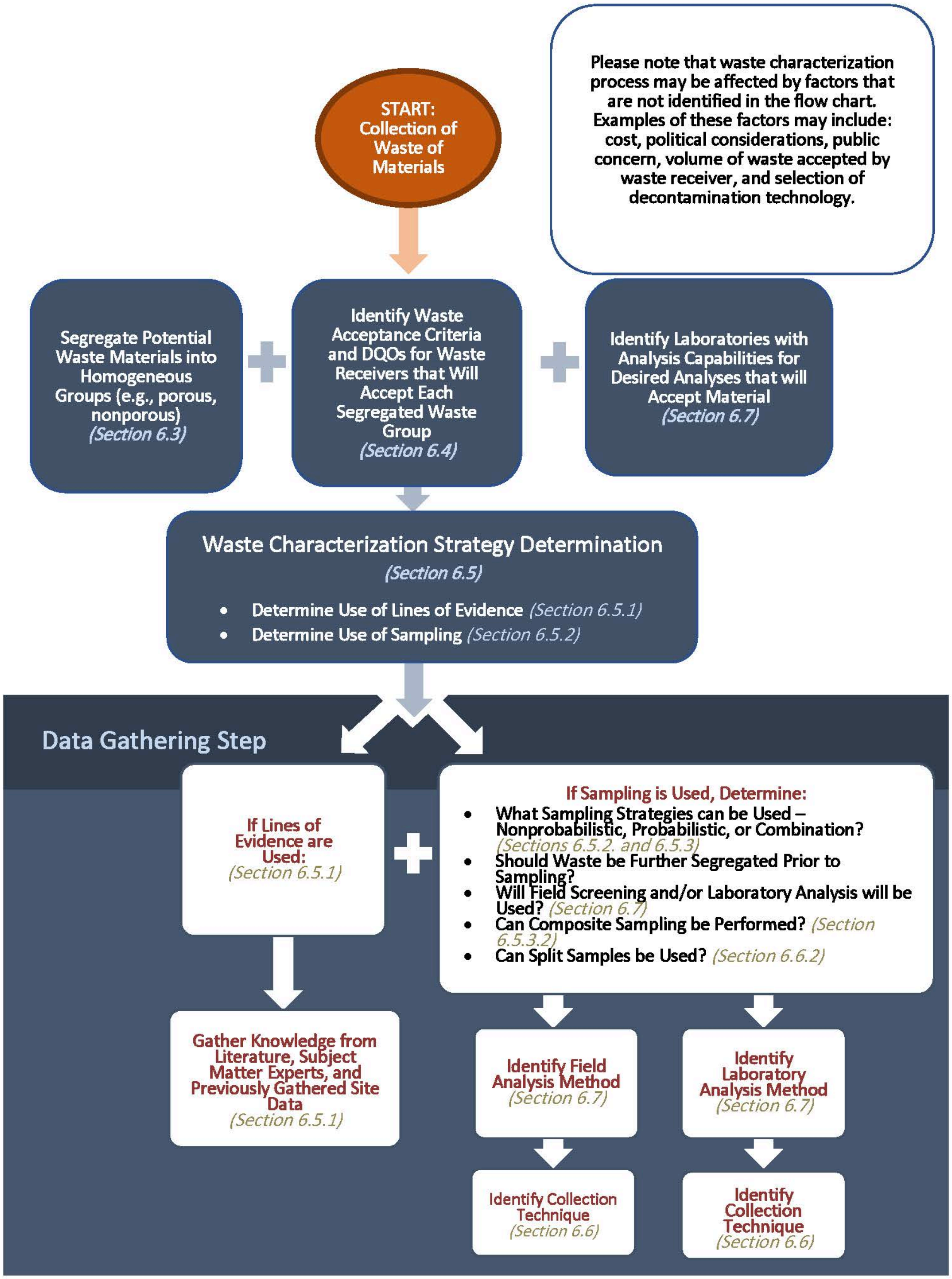


Figure 3. Waste characterization process

For clarity, progression through Figure 3 is intended to be a stepwise process. However, there are multiple factors within the process that may be optimized to reduce the number of laboratory samples and may result in the simultaneous determination of several process decisions or dictate an iterative nature to waste characterization decisions. Agent- or incident-specific conditions may also dictate the sequence and relevant considerations necessary for decision-making. It is important to note that there may be additional outside factors that may affect the ability to perform waste management, but that are not explicitly considered in the waste characterization process. These factors might include, but are not limited to: cost, political consideration (e.g., stigma of waste), public concerns, volume of waste that can accepted by waste receivers, acceptance of waste by potential waste receivers, and selected decontamination technology. Each of the following sections describes the individual elements in the flow chart in greater detail. Similarly, the information presented in each of the sections should be evaluated for its relevance based on agent- or incident-specific conditions.

6.3 Segregation of Waste into Homogeneous Groups

After a collection of waste materials has been identified for characterization, the first step in the waste characterization process may be to segregate waste into homogeneous groups. Segregation of waste materials is necessary for collection of representative samples and might facilitate reduced sampling requirements by waste receivers with prior approval. Materials that are designated for re-use or recycling are not waste. However, these materials might re-enter the waste stream if they cannot be decontaminated or are no longer able to be re-used or recycled.

Relevant areas of consideration to segregate waste include:

- Material characteristics – e.g., porous, nonporous, material susceptibility to contamination during the incident and decontamination technology in use;
- Distribution of material characteristics – e.g., homogeneous or heterogeneous collection of material characteristics to be sampled;
- Agent characteristics – e.g., agent affinity for materials and surfaces, persistence under defined environmental conditions; and
- Environmental conditions – e.g., temperature, relative humidity, time since agent release.

To demonstrate how these considerations can be implemented in an environment likely to be encountered in an urban wide-area incident, a typical office environment contaminated with Agent Yellow will be reviewed using the areas of consideration identified above. A typical office setting environment is a heterogeneous mixture of materials and surface types that exhibit diversity in their likelihood to capture and retain released agent. In the office environment, the presence of porous and nonporous materials may be a common contributor to heterogeneity in waste materials. Porous material may include cubicle dividers, ceiling tiles, vinyl floor tiles, fabric-covered chairs, carpeting, wallboard, or grout between tiles whereas nonporous material may include stainless steel surfaces, desks, porcelain sinks, toilets, or glass. Materials that are porous, permeable, organic or polymeric (e.g., carpet, floor tile) should be considered to preferentially capture, retain, and release agents such as Agent Yellow (Mustard – Lewisite Mixture, HL) (NRT, 2015h) when compared to nonporous materials.

The presence of a heterogeneous mixture of materials in a sampling environment is a signal that either waste segregation should be performed or a restricted set of sampling strategies should be considered. EPA (2002b) reported that heterogeneous waste (such as demolition debris, drums) can be challenging to sample representatively due to the variability in size, shape, and composition. In the context of waste characterization, heterogeneous materials may exhibit differing potential to capture and/or retain agent. The representativeness of the sample is a key contributor to the accuracy of the sampling results to answer the sampling questions of interest (EPA, 2003; EPA, 2015d).

As a result, the chemical concentrations may not be consistent across the mixture of heterogeneous materials, affecting the ability to use sampling strategies and calculate statistical measures that assume a relatively homogeneous waste source. In situations with a heterogeneous mixture of materials, segregation of materials could be performed to group materials with similar characteristics, and then random sampling could then be conducted within the segregated populations of materials (i.e., stratified random sampling). Absent segregation of waste into similar groupings, strategies must be selected that do not rely on identification and collection from an individual population (e.g., simple random, systematic grid or transect, judgmental).

In addition to concerns regarding the chemical agent contamination levels of waste, waste items might be packaged in bags, barrels, or other containers that inhibit access for sampling and could affect collection of representative samples. The specific types of indoor waste materials identified for the biological agent decontamination study might be useful for an indoor chemical agent contamination incident.

6.4 Determine Waste Acceptance Criteria and DQOs

Prior to selection of appropriate data gathering strategies for waste characterization, the waste characterization criteria and associated DQOs must be determined for each waste group and waste receiver(s) identified that will accept the waste. The waste acceptance criteria define the standards that must be met and the volume of waste that will be accepted. The DQOs define the process to generate the data to document that the waste materials meet the waste acceptance criteria. If a pre-incident WMP is not available, the relevant NRT QRG might be consulted as a first step to identify general waste characterization information for an individual agent. For more specific waste characterization and disposition information, consult other sources such the Incident Waste Decision Support Tool [(i-WASTE DST) (2018)] and appropriate authorities within the locality of the incident. It will also be helpful to identify contractor and waste receiver resources that will be present on-scene during an incident who can provide region-specific knowledge for waste characterization and available waste receivers.

Waste acceptance criteria identify the standards that must be met for an individual waste management facility to accept the waste and the volume of waste that will be accepted. Waste acceptance criteria can take the form of a concentration-based criterion or performance-based criterion. Concentration-based criteria, also termed numerical-based criteria, identify chemical-specific concentrations that must be must achieved. Concentration-based criteria are typically associated with the presentation of analytical results and sampling plans to document attainment of the standard. Appendix C provides additional information on the types of comparisons that might be associated with a waste acceptance criterion (e.g., comparison of average waste concentration including upper confidence limit with concentration-based criterion).

The second type of waste acceptance criteria, performance-based criteria, identify the technologies or treatment processes that can be used to treat the waste as a demonstration of meeting identified clearance levels. With the prior approval of regulators and waste receivers, performance-based criteria might take the form of lines of evidence data as detailed in Section 6.5.1. As part of a lines of evidence demonstration, technical documentation is then provided to substantiate the effectiveness of the process and its effective implementation in the wide-area incident during which the waste was generated. The use of performance-based criteria might still be associated with sampling, either field screening or laboratory analysis, to verify anticipated agent concentration levels in the waste. However, the number of samples required is likely to be considerably reduced. The most current available waste management plan (i.e., pre-incident WMP, incident-specific WMP) should be consulted for information on waste acceptance criteria for the wide-area incident. If a pre-incident WMP is used, waste receivers and regulators should also be re-contacted to ensure that the waste acceptance criteria are still valid and to confirm that appropriate data collection strategies are identified.

To ensure that the process to achieve the waste acceptance standards meets the data quality needs identified by decision-makers, EPA (1992b; 2002b) recommends following a systematic planning process such as the DQO Process to define the quality control requirements for sampling, analysis, and data assessment for environmental data collection. The DQO process can be used to help clarify study objectives, define appropriate data types, and specify tolerable levels of decision errors that will form the basis of establishing the quality and quantity of data required (EPA, 2006). As described by EPA (2006), the DQO process is not specific for chemical agents, so consideration must be give on how to apply the DQO process to the contaminant at hand. In this manner, the optimized sampling plan would predetermine the QA and QC parameters desired for achieving the overall project goal.

If lines of evidence are used to reduce or replace sampling, the DQO process will identify indicators of data quality that must be met prior to use of these data in waste characterization. For example, data quality indicators can identify quality requirements for data sources (e.g., peer-reviewed publication, federal agency report) that are deemed to provide acceptable data. If sampling is conducted, an explicit evaluation of the characteristics of the waste materials (e.g., concentration distribution based on waste characteristics) should be performed relative to the statistical requirements of the sampling strategies and associated statistical measurements as part of the DQO process. An example application of the DQO process for waste characterization is given in Appendix C.

6.5 Determine Waste Characterization Strategy

A waste characterization strategy must be developed to determine if the waste material meets the identified waste acceptance criteria and DQOs. Figure 3 identifies the data gathering options available during the waste characterization process. The purpose of the waste characterization is to generate an accurate assessment of the residual contamination levels of an identified waste group. Data can be generated using lines of evidence, chemical analysis, or a mixture of both data gathering approaches. Each approach will be discussed more fully in the following sections.

6.5.1 Lines of Evidence

The first element of consideration when collecting data for waste characterization is lines of evidence. Lines of evidence are defined as information or data from various sources that can be used to support waste characterization decisions and reduce the number of laboratory samples required for analysis. Lines of evidence can include, but are not limited to, technical data on agent fate and transport, persistence in defined environmental conditions, and efficacy of decontamination technologies when properly deployed. Lines of evidence is analogous to the use of acceptable knowledge for hazardous waste characterization that is "obtained from existing published or documented waste analysis data or studies conducted on hazardous waste generated by processes similar to that which generated the waste" (EPA, 2015d). Alternative names for lines of evidence include process knowledge or generator knowledge (EPA, 2015d). Knowledge of waste is an acceptable means of waste characterization for typical hazardous waste streams (e.g., generation from a known industrial process) to determine whether a waste is likely to be a solid or hazardous waste per federal and state regulations (EPA, 2015d) or if wastewater has been sufficiently pre-treated prior to discharge to a POTW or surface water body. As a result, lines of evidence might also have utility in the management of less typical waste streams such as those generated from management of a wide-area incident. However, the use of lines of evidence approaches might be more difficult for a CWA for which the level of knowledge is low relative to the more studied CWAs such as HD or Lewisite. As a result, the effectiveness of lines of evidence in reducing the number of laboratory samples may be limited.

Lines of evidence can dramatically reduce sampling and analytical demands associated with waste characterization. For example, a demonstration of the efficacy of a decontamination approach prior to a release incident could be used to reduce the number of waste characterization samples (EPA, 2014c). However, the regulators and waste receivers must be involved in the development of the lines of evidence demonstration and agree to its use to replace sampling data. The availability of sufficient technical data is key to successful use of lines of evidence claims (EPA, 2015d).

In the context of a wide-area incident, there are no prior published analytical studies that describe the waste generated from such an incident. However, a broad definition of lines of evidence can be employed with prior approval by the regulators and waste receivers. As a result, lines of evidence data can be used to generate a weight of evidence determination that the waste items will meet waste acceptance criteria. Relevant lines of evidence data will vary based on the consequence management stage, management approach (e.g., active or passive decontamination technologies), agent, and environmental conditions. For example, a weight of evidence determination could be used to characterize residual contamination of waste after implementation of a monitored natural attenuation process. The determination would document available persistence data for the agent when associated with similar waste materials and environmental conditions (e.g., temperature, relative humidity, operation of heating, ventilation and air conditioning (HVAC) or other fans) during and after the incident. The identification of conditions necessary for successful deployment of decontamination technologies followed by thorough documentation that these conditions were achieved might meet waste acceptance criteria based on certification that the decontamination process was followed (DHS, 2012c).

General elements that could be relevant to characterize the residual contamination of waste materials generated during a wide-area incident may include:

(1) Loading of chemical agent in or on waste material based on prior sampling results, distance from release, and expected transport of contaminants (e.g., environmental fate and transport, movement via contaminated persons and material),
(2) Fate and transport characteristics of chemical agent (e.g., affinity for porous materials/surfaces, persistence),
(3) Environmental conditions (e.g., characteristics of waste material in contact with chemical agent including porous or nonporous composition, temperature, relative humidity, time since release), and
(4) Expected interaction of the chemical agent, material, and decontamination technology if assessing waste after decontamination (e.g., time after monitored attenuation initiated, loading of decontamination agent if applied, contact time, access of decontamination technology to material in environment).

A second effective means of reducing sampling load is selection of waste management options based on the reduced sampling requirements associated with them. For example, sulfur mustard, which was sometimes disposed of at sea in the early 1900s, has recently resulted in human exposure during clam harvesting by commercial fisherman (Coast Guard, 2010). In June 2010, a commercial fishing vessel inadvertently harvested unexploded ordnance projectiles containing sulfur mustard (Lagan, 2010). The projectiles leaked, requiring decontamination of the fishing vessel and disposal of approximately 500,000 pounds of clams. The clams were shipped in lined containers for incineration. Off-site incineration was selected over landfilling as the disposal option in part because the clams were not required to be sampled and analyzed for sulfur mustard prior to disposal (Coast Guard, 2010). Understanding and applying such processes in sampling plans could reduce many of the waste sampling and analytical demands, which could greatly reduce the time and expense associated with the overall response when there is available incinerator capacity. This type of option may be most useful for selected waste materials that are difficult to sample reliably or have some other characteristics that make management at a solid or hazardous waste landfill infeasible.

6.5.2 Sampling Strategies

Samples must be collected and analyzed when non-sampling options cannot be used as the sole determinant of residual contamination. In this context, the best practices define "sampling strategy" as the study plan or design by which sample locations, numbers, and types are collected for measurement to collectively reach an appropriate conclusion regarding the incident at hand (EPA, 2015d). However, in the context of an urban wide-area release, the amount of waste generated could overwhelm the laboratory analysis capacity with waste characterization efforts alone. Sampling strategies for characterizing waste must incorporate approaches to streamline the sampling process. Applicable sampling strategies to characterize waste for proper management are summarized in an EPA report entitled "Waste Management Benefits, Planning and Mitigation Activities for Homeland Security Incidents" (EPA, 2016b). The sampling strategy for waste will likely be dictated by federal regulations (e.g., RCRA) as implemented by the states, and individual waste management facilities. Many states have delegated authority for waste management and might have more stringent requirements than federal regulations. Since it is most likely that a wide-area incident will require waste management facilities in multiple states and/or regions, a pre-incident WMP should identify available facilities ahead of an incident to ensure that waste management does not impede the response activities (EPA, 2015d).

Table 1 identifies the three most likely sampling strategies for use in waste characterization. Appendix D provides a more detailed table identifying sampling strategies that might be used across all sampling tasks in a wide-area incident, and might have utility for unique waste sampling situations in the wide-area incident.

Waste Characterization Sampling Strategies

- Judgmental
- Simple Random
- Stratified Random

In more typical waste characterization scenarios, a random sampling approach is typically identified as a strategy of choice for obtaining the most "representative sample" from waste piles, which might include powdered, granular, or block materials of various size and structure (EPA, 2002c).[1] However, the complex mixtures of waste materials in an urban wide-area incident and associated surfaces will require segregation to develop waste groups with similar characteristics prior to the ability to generate a representative sample.

Non-probabilistic judgmental sampling, also termed biased sampling, is intended to collect samples with the highest amounts of contamination (EPA, 2002b). Biased sampling might be used when taking multiple samples from heterogeneous waste contained within a discrete item (such as a barrel). The biased sampling conservatively estimates high-end contamination levels and can be useful when there is insufficient sampling capacity for use of other strategies. This strategy can be very efficient and cost-effective if the site is well known (Table 1). The strategy also has advantages for screening to determine the presence or absence of agent.

With simple random sampling, each sample location/item has an equal chance of being sampled (EPA, 2002c). Sample location selection is not haphazard, but is based on equiprobable selection, often relying on the use of randomly generated numbers (EPA, 2002c). Simple random sampling can be used only with uniform or homogeneous populations. Using prior knowledge and professional judgment, stratified random sampling divides heterogeneous wastes into groups that are relatively homogeneous (EPA, 2002c). The homogeneous groups are then randomly sampled. The primary advantage of simple random sampling is that it allows for estimates of uncertainty and statistics to be developed (Table 1). Simple random sampling can also be easy to understand and implement after appropriate segregation has been implemented.

[1] Note that regulatory programs or analytical methodologies may have specific definitions for representative that should take precedence over other definitions of the term, as appropriate.

Table 1. Features of Sampling Designs for Waste Characterization.

Sampling Strategy	*Non-Probabilistic*	*Probabilistic*	
	Judgmental	*Simple Random*	*Stratified Random*
Definition	Selection of samples based on professional judgment alone without randomization. Biased sampling (a type of judgmental sampling) is intended to collect samples with the highest amounts of contamination.	A set of sampling units is independently selected at random from a population.	Prior information is used to determine groups (lots) that are sampled independently.
Application	• Small-scale conditions are under investigation • Screening for presence/absence of a contaminant • Might be used in conjunction with simple random sampling of containerized waste (i.e., samples collected from within the container might be judgmentally sampled to maximize the collection of biological agen, such as collecting samples from porous materials)	• Relatively uniform or homogeneous populations • Selecting a sample aliquot from a composite sample	• Used to produce estimates with pre-specified precision for important subpopulations • Monitoring of trends • Used to gain specific information (i.e., mean) regarding each group Potentially more efficient approach for sampling heterogeneous wastes, if the wastes can be segregated
Required Laboratory Resources	Low: site information used to minimize laboratory resources	Medium: sample number is predetermined	Medium: sample number is predetermined
Wide-Area Pros	• Can be very efficient and cost effective if site is well known • Ideal for presence/ absence screening • Quick implementation to achieve time and funding constraints	• Enables uncertainty and statistical inferences to be calculated • Protects against sampling bias • Easy to understand and implement • Sample size formulas are available for determining sample numbers (EPA, 2002a)	• Provides an estimate of the population to effectively define groups and specify sample sizes • Sample size formulas are available to aid in determining adequate sample numbers (EPA, 2002a)
Wide-Area Cons	• Dependent upon expert knowledge • Cannot reliably evaluate precision • Personal judgment is needed to interpret data • Confidence statements regarding absence of contamination difficult to make	• Random locations might be difficult to specify • Sampling design depends upon the accuracy of the conceptual model • All prior information regarding the site is ignored • Sampling can be costly if there are difficulties in obtaining samples due to location	• Random locations might be difficult to specify • Sampling design depends upon the accuracy of the conceptual model • All prior information regarding the site is ignored • Sampling can be costly if there are difficulties in obtaining samples due to location
Cautions or Additional Critical Information	• Does not ensure that unsampled items are free of contamination • Degradation by-products might be of concern depending upon the parent agent and create a hazardous environment incident after the parent (or tested agent) is no longer present	• Simple random sampling is often used as the last stage of sampling when multiple iterations are conducted – selecting an aliquot from a composite sample • All populations should be relatively uniform • Degradation by-products might be of concern, depending upon the parent agent, and create a hazardous environment incident after the parent (or tested agent) is no longer present	• Each group should be homogeneous within itself • Groups should be defined before determining sample sizes • Degradation by-products might be of concern, depending upon the parent agent, and create a hazardous environment incident after the parent (or tested agent) is no longer present • Potentially more efficient approach for sampling heterogeneous wastes, if it can be segregated
Reference(s)	EPA (2006); EPA (2002a); EPA (1998); EPA (2015c); EPA (2013a)	EPA (2002b); EPA (2002c); ITRC (2012); EPA (2006)	EPA (2002b); EPA (2006)

6.5.3 Sampling Strategy Tools

6.5.3.1 Visual Sample Plan – VSP

The Visual Sampling Plan (VSP) is a software tool that follows the DQO process and aids the user in determining the number and location of samples that will be collected (PNNL, 2014). Data collected per VSP and the associated sampling plan have the statistical confidence needed for decision-making and typically involve a planning team with statistical expertise to guide a statistical approach (PNNL, 2014). The development of VSP, which is public domain software, was sponsored by several U.S. government agencies, including EPA (PNNL, 2014).

VSP includes functions for developing sampling plans with specific sampling goals.

Within VSP, there are several applications (or sampling goals) that are intended to address the rationale for why data are being collected. One sampling goal, "Item Sampling", is especially applicable to waste characterization. This module, which might also be referred to as acceptance or compliance sampling, is applicable for the sampling of discrete items (such as barrels). The intent is to determine a limited number of discrete items that must be sampled from a larger number of distinct items, so that an X % confidence statement can be made about Y % of the population being acceptable. An example of VSP output for item sampling is: "If 51 of the 200 items are selected using random sampling and all 51 are acceptable, then you will be 95% confident that at least 95% of the items in the population are acceptable" (PNNL, 2014). In the instance of characterizing waste for proper management, the acceptability criteria could be, for example, the absence of detectable chemical agent. EPA (2002b) acknowledged that a straightforward approach to determine whether a specific proportion of waste achieves acceptability is to use the simple exceedance rule, which requires zero or a few analysis results to exceed an applicable standard for a set of samples. The statistical expertise of the planning team should be utilized to ensure that the underlying statistical assumptions are met before proceeding with a statistical approach. In addition, the planning team will need to ensure that the sampling strategy includes all site-specific circumstances and established DQOs.

A similar approach to VSP item sampling was proposed by Sexton (1993) for sampling nearly 38,000 drums of solid heterogeneous mixed waste, containing hazardous and radioactive waste. The drums were grouped and processed based, in part, on the procedure that produced the waste. Random samples from approximately 25 drums for lot sizes of 100 or more would be used to draw X %/Y % confidence statements such as X % confident Y % (or fewer) drums containing hazardous waste will be accepted. A lines of evidence approach to characterize waste streams can help optimize waste characterization strategies, if applied appropriately and planned in advance. EPA (2015d) recognizes that there are rare cases where it is dangerous, impractical, or unnecessary to use direct sampling and analysis to characterize waste feed streams. In these instances, the use of lines of evidence approaches to characterize waste should be maximized to document that: (1) the waste can be protectively handled at the specific treatment facility, and (2) the treatment facility is complying with all federal, state, and local regulations (EPA, 2015d).

The advantages of the statistical sampling approaches that generate X %/Y % confidence statements using the simple exceedance rule are that they are relatively easy (assumptions about the underlying data distributions are not required), and they can be used when many of the analytical results are non-detections (EPA, 2002b). Statistical sampling designs for waste characterization involve establishing an assumption of whether a waste is or is not hazardous, designing a data collection program that will test that assumption, evaluating the resulting data, and drawing a conclusion about whether the data are sufficiently strong to support or reject the assumption, given the uncertainties in the data. Selection of an appropriate statistical approach to sampling and data evaluation will depend upon the waste generation and management scenario, the type of test data generated, the ability to apply statistical assumptions to the site-specific conditions associated with the incident, and limitations on laboratory capacity to fulfill statistical requirements. Depending on the desired level of confidence that will be assumed in the statistical sampling design, statistical sampling might identify a specific number of samples to be collected that does not effectively facilitate a reduction in the number of samples sent to laboratories for analysis.

Efforts to segregate the waste to make the waste more homogeneous might allow decision-makers to accept lower levels of confidence, which would likely result in fewer samples needed (e.g., the use of stratified random sampling rather than simple random sampling of waste). As noted by EPA (2002b), if stratified sampling is applied, one of the following types of stratification will likely be used:

- Spatial boundaries/physical area to be sampled (e.g., in an urban wide-area incident, this might be all waste generated from the same floor of a decontaminated building);
- Temporal boundaries/time interval to be sampled (e.g., this might be all materials decontaminated on the same day); and
- Component (items/materials) (e.g., waste items will likely be segregated to improve the homogeneity of the population such as grouping carpet and ceiling tile waste separately).

Stratification by component type is applicable for wastes that are difficult to characterize such as wastes originating from buildings (EPA, 2002b). Use of the item sampling approach in VSP (or similar approaches) to generate X %/Y % confidence statements about a population based on limited sampling might be enhanced or supplemented with judgment (biased) sampling to focus on materials most likely to harbor chemical agent and/or composite sampling to further reduce sampling and analytical efforts.

6.5.3.2 Composite Sampling

Composite sampling is a strategy in which multiple individual or “grab” samples (from different locations or times) are physically combined and mixed into a single sample so that a physical, rather than a mathematical, averaging takes place. Combining samples from multiple locations into one sample might help reduce the resource demands on the analytical and sampling efforts. Additional advantages of composite sampling are:

- Improved precision (i.e., reduction of between-sample variance) of the estimate of the mean concentration of a constituent in a waste or medium.
- Reduced cost of estimating a mean concentration, especially in cases in which analytical costs greatly exceed sampling costs or in which analytical capacity is limited

- Increased sample support and reduced grouping and segregation errors through the use of "local" composite samples, formed from several increments obtained from a localized area
- Finding "hot spots" or determining whether the concentration of a constituent in one or more individual samples used to form the composite exceeds a fixed standard.

Composite sampling is not a statistically based sampling strategy per se. However, composite sampling can be used in conjunction with the strategies listed in Table 1 to maximize the area/items sampled while minimizing analytical costs. For example, if three to four samples are to be collected from each discrete item sampled, a single composite sample (i.e., a single wipe used to sample all three or four surfaces) would still result in only one sample to analyze rather than three or four. There are multiple ways to composite samples. For example, one approach simply uses the same sampling device (e.g., a wipe) to sample multiple locations. Another approach might combine multiple sample extracts into one sample for analysis. Composite samples can improve sampling precision while reducing the number of samples analyzed (EPA, 2002b). Composite sampling might be especially beneficial when the prevalence of contamination is low (EPA, 1995).

EPA (2002b) gave an example where systematic composite sampling was used to make remediation decisions for tetrachlorodibenzo-*p*-dioxin-contaminated soil. EPA (2005) also provided examples of how composite sampling has been used with chemical contamination including the characterization of polyaromatic hydrocarbon soil contamination at a Superfund site, assessing contamination in fish tissue, and ground water monitoring programs.

Potential limitations associated with composite sampling might be:

- When a regulation specifies otherwise;
- When sampling costs are much greater than analytical costs;
- When analytical imprecision outweighs sampling imprecision and population heterogeneity;
- When individual samples are incompatible and may react when mixed;
- When properties of discrete samples such as pH or flash point may change qualitatively upon mixing;
- When analytical holding times are too short to allow for analysis of individual samples if testing of individual samples is required later (e.g., identify a "hot" sample);
- When the sample matrix impedes correct homogenization and/or subsampling;
- When there is a need to evaluate whether the concentrations of different contaminants are correlated in time or space;
- When samples contain volatile chemicals;
- When the integrity of the sample may be compromised by physically combining samples (e.g., samples that contain volatile chemicals) (EPA, 2002b).

The integrity of individual sample values could be affected by chemical precipitation, exsolvation, or volatilization during the pooling and mixing of samples. For example, volatile constituents can be lost upon mixing of samples or interactions can occur among sample constituents. In some cases, compositing of individual sample extracts (e.g., volatile constituents) within a laboratory environment might be a reasonable alternative to mixing individual samples as they are collected.

6.6 Determining Sample Collection Technique

Sample collection techniques have not been standardized for characterizing waste for disposal following an urban wide-area incident (EPA, 2014c). Waste associated with these incidents is often porous in nature and might be wet following decontamination with liquid decontaminants, which tends to decrease the efficiency of many sample collection techniques. The sampling of wastes might further be complicated by limited accessibility issues as waste being stored in bags, barrels, or dumpsters, or the waste might be bundled.

The most likely sample collection approaches for use are documented in Table 2. This table summarizes the collection approaches and their applications, pros and cons, and additional cautions. Selected collection approaches will depend upon the type of waste (e.g., porous or nonporous, wet or dry) and the physical state of the wastes (i.e., liquid or solid). A comprehensive table describing sample collection approaches is provided in Appendix E.

The NRT (https://www.nrt.org) produces and regularly updates QRGs that are specific to various chemical hazards. In a similar manner, the EPA has developed the Environmental Sampling and Analytical Methods Program (ESAM) (https://www.epa.gov/homeland-security-research/environmental-sampling-analytical-methods-esam-program-home) to facilitate a coordinated response to a chemical contamination incident. The program is comprised of documents and information supporting field and laboratory efforts for site characterization, remediation and release, including the Selected Analytical Methods for Environmental Remediation and Recovery (SAM) (https://www.epa.gov/homeland-security-research/sam). The analytical approaches included in SAM are not specified for waste samples (except post-decontamination wastewater), but the protocols are intended more generally for soil/powders, particulates (swab, wipe, and dust socks), liquid/water, and aerosols. Additionally, coordination with qualified laboratory personnel or chemical analysis SMEs is necessary when selecting incident-specific sampling and analysis approaches. While every effort has been made to prepare for a CWA incident, verified or validated sample collection methods might not be available for the chemical agent and sample type of interest (see the SAM document for several sample types such as soil, surfaces, water, etc.). Therefore, protocols might need to be adapted from similar chemicals and/or sample types in the scientific literature. Collection approaches should be evaluated relative to the site-specific circumstances and DQOs. Note that QRGs and SAM documentation do not detail CWA detection methods but rather direct the user to the ERLN. To control DQOs, QA/QC, and data comparability, only laboratories approved by ERLN are authorized to handle and analyze CWAs (https://www.epa.gov/emergency-response/environmental-response-laboratory-network).

Regardless of the sample collection approach or the determined purpose of the sampling effort, sampling kits would ideally be available to aid in the organization and ease of use of the collectors. Each sampling kit should be comprised of the sample container, materials, supplies and appropriate forms needed to collect the field samples, decontaminate the exterior, and field-pack the samples for transport to the specified analytical laboratory. Sampling kits might need to be built for the specific incident as each agent and collection technique might require specific materials (EPA, 2014b). Guidance is available to assist in constructing the appropriate field sampling equipment, supplies, and field documentation that should be included in each sampling kit (EPA, 2014b).

Table 2. Features of Various Sample Collection Approaches for Waste Characterization

	Extractive (Solid Material) Sampling	*Wipe (Surface) Sampling*	*Liquid (Surface) Sampling*	*Liquid (Drum) Sampling – Discrete Depth Samplers*	*Liquid (Drum) Sampling – Profile Samplers*	*Air Sampling*
Description	Extractive sampling refers to whole objective sampling or the cutting/removal of a portion of the material sampled. Might also be referred to as bulk sampling or direct extraction.	Surface sampling techniques using wipes, cotton-balls/wipes, or gauze sponges.	The collection of liquid samples from the surface (or shallow depths) might be obtained with various devices including a bailer, dipper, liquid grab sampler, swing sampler, or solid phase microextraction fibers.	Liquid samples might be obtained from discrete depths with a variety of devices include a syringe sampler, discrete level sampler, lidded sludge/water sampler, or solid phase microextraction fibers.	Liquid samples might be obtained from throughout a vertical column of liquid or sludge with a variety of devices including a composite liquid waste sampler (COLIWASA), drum thief, valved drum sampler, plunger type sampler or solid phase microextraction fibers.	Air sampling devices such as those that might be used to sample the headspace of waste containers for volatile compounds could include solid phase adsorbent media (tubes), solid phase microextraction fibers, or air samplers (e.g., SUMMA® canisters).
Application	• Applicable for the sampling of targeted areas (sink materials) where liquid agent might remain, especially porous surfaces or collection of spilled powder • Applicable for sampling materials that are not amenable to wipe sampling such as materials that are wet, irregularly shaped, and/or porous • Might be applicable for sampling heterogeneous waste; cutting, chipping, or drilling of waste samples (and subsequent grinding/mixing together) can make the samples more homogeneous and amenable to being sampled simply with a spoon or scoop	• Generally used for sampling smooth, nonporous surfaces but might also be used on porous surfaces (EPA, 2012b) • Applicable to relatively small sample areas	• Although designed for groundwater sampling, bailers can be used to collect liquid samples from tanks and surface impoundments; bailers collect samples of 0.5 to 2 liters • The dipper, liquid grab sampler, and swing sampler generally collect 0.5- to 1.0-liter samples from the surface of drums, tanks, and surface impoundments	• The syringe sampler and discrete level sampler can collect 0.2- to 0.5-liter samples from drums, tanks, and surface impoundments • A lidded sludge/water sampler can collect 1.0-liter volumes from tanks and ponds	Profile sampling devices typically collect between 0.1- to 3-liter samples from tanks and drums, as well as surface impoundments	Air sampling, especially of the headspace of waste containers might be helpful in confirming that adequate decontamination of wastes materials has occurred
Wide-Area Pros	Extractive-based sampling minimizes the loses of agent that might arise with	Can be an easy and quick way of assessing surface contamination levels	• The bailer, dipper, liquid grab sampler, and swing sampler are	• A syringe sampler is easy to use and decontaminate; it can also be used to sample	• The COLIWASA, drum thief, and valved drum sampler are inexpensive, easy to	Analysis of samples from some sampling devices can be

	Extractive (Solid Material) Sampling	*Wipe (Surface) Sampling*	*Liquid (Surface) Sampling*	*Liquid (Drum) Sampling – Discrete Depth Samplers*	*Liquid (Drum) Sampling – Profile Samplers*	*Air Sampling*
	collection inefficiencies of other sampling protocols		generally easy to use and inexpensive • Analysis of samples from some sampling devices can be performed in the field for some analytes.	discrete depths, including the bottom • The jar in the lidded sludge/water sampling device serves as the sample container reducing the chance of cross-contamination • Solid phase microextraction fibers can be taken into the field to sample. These samples might be returned to the laboratory for analysis or the fibers can be analyzed in the field using portable GC/MS systems	use, and available as reusable or single-use models • The plunger type sampler is easy to operate, relatively inexpensive, and is available in various lengths • Solid phase microextraction fibers can be taken into the field to sample. These samples might be returned to the laboratory for analysis or the fibers can be analyzed in the field using portable GC/MS systems	performed in the field for some analytes
Wide-Area Cons	• Extractive-based sampling might be difficult for personnel working in personal protective equipment. • Extractive-based sampling techniques are not well defined/established • Extracted samples might require more extraction solvent and more time to process than other surface sampling approaches • Small concentrations of a contaminant might be diluted within a larger bulk sample	• Wipe sampling might not result in high agent recoveries from porous materials such as wood • Wipe sampling procedures can vary based on the agent of interest and the material sampled • Limited in area that can be sampled (100 cm^2)	These sampling devices are not intended to collect samples from specific/deep subsurface depths (unless a point-source bailer is used)	• The maximum depth that can be reached with a syringe sampler is approximately 1.8 meters • The lidded sludge/water sampling device is rather heavy and limited to one jar size	• The COLIWASA, drum thief, and valved drum sampler can be difficult to decontaminate, and it might be difficult to collect samples from the bottom of the container • The drum thief cannot sample depths longer than the drum thief itself	Might be difficult to implement, depending upon the accessibility of the containerized waste to be sampled
Cautions or Additional Critical Information	• Extraction efficiencies and agent recoveries will vary with material and extraction approach	• Agent recovery will vary depending upon the area sampled, material type, wipe	• Liquid samples should be collected with the appropriate	• Liquid samples should be collected with the appropriate neutralizers and stabilizers added	• Liquid samples should be collected with the appropriate	For sampling vapors that are heavier than air (e.g., sulfur mustard and Lewisite), include

	Extractive (Solid Material) Sampling	*Wipe (Surface) Sampling*	*Liquid (Surface) Sampling*	*Liquid (Drum) Sampling – Discrete Depth Samplers*	*Liquid (Drum) Sampling – Profile Samplers*	*Air Sampling*
	• Constituents within some materials might interfere with detection technologies • Extractive-based sampling techniques are not well defined/established • Neutralization might be needed to inhibit any residual decontamination solution that could possibly bias/lower the agent recoveries • Evidence collection sampling might have been conducted in this manner	material, amount and type of wetting solution, wipe pattern, etc. • Recovery might be affected by the presence of dirt and other residues as well as background chemical constituents.	neutralizers and stabilizers added • Larger sample volumes or multiple samples might be required such that filtration can be used to detect low levels of contamination	• Larger sample volumes or multiple samples might be required such that filtration can be used to detect low levels of contamination	neutralizers and stabilizers added • Larger sample volumes or multiple samples might be required so that filtration can be used to detect low levels of contamination	low lying areas where vapors might accumulate
Reference(s)	EPA (2012d); Nassar et al. (1998); NRT (2015a)	EPA (2008); EPA (2014a); Koester and Hoppes (2010); Nassar et al. (1998); NRT (2015a); Qi et al. (2013)	EPA (2002b); NRT (2015a); Popiel and Sankowska (2011)	EPA (2002b); NRT (2015a); Popiel and Sankowska (2011)	EPA (2002b); NRT (2015a); Popiel and Sankowska (2011)	Kimm et al. (2002); NRT (2015a); Popiel and Sankowska (2011); Smith et al. (2011)

* SAM (which guides the ERLN laboratories) focuses on environmental sample types that are most prevalently used to fulfill EPA's homeland security responsibilities following an incident involving chemical agents (e.g., aerosols, surface wipes or swabs, drinking water, and post-decontamination wastewater). Other sample types (e.g., soil and vacuum samples) might have to be analyzed, and for those sample types, specific requests should be sent to the SAM technical contacts.

6.6.1 Decontamination Rinsate Sample Neutralization

Waste that will be placed in a landfill may require decontamination prior to disposal. Neutralization of the decontaminant is a potentially important consideration. Decontaminant in the rinsate or extraction liquid of waste-associated samples could bias the analytical results. This bias could result from analytical interferences or simply by allowing additional reaction time between the decontaminant and the contaminant. To determine contaminant concentration/viability at the time of sampling, decontaminant neutralizers should be added immediately after sample collection to inhibit the decontaminant activity (EPA, 2014c). Prior to characterizing waste, neutralization tests might need to be conducted to determine the amount and type of neutralizer required to inhibit the activity of any residual decontaminant. For example, Qi et al. (2013) used a sodium thiosulfate solution to neutralize the oxidants associated with CWA testing with sodium percarbonate and tetraacetylethylenediamine. Note that the waste acceptance criteria at waste treatment or disposal facilities frequently limits or prohibits standing liquids in the bags or containers of waste. It is critically important that the appropriate regulatory authorities be consulted when planning any on-site waste treatment operations (including additional decontamination and/or neutralization), so that decisions meant to expedite the waste management process do not inadvertently complicate and/or paralyze the waste management (Ierardi, 2013).

6.6.2 Split Samples

The potential use of split samples should be considered to collect samples more efficiently. If appropriate, it should be incorporated in the initial stages of planning for sample collection. A split sample is a sample that is collected from a single location but will be analyzed in two or more analyses. For example, one sample could be collected from decontamination rinsate that would be split for individual organic and inorganic analyses. Care must be taken that an appropriate sample volume is collected to perform each desired analysis and that necessary sample treatment or preparation is appropriately identified for each sample analysis to be performed.

6.7 Determine Analytical Technique and Available Laboratories

Numerous analytical techniques might be used to determine the concentration of a particular target analyte within a collected environmental sample. Target analytes should include CWAs, non-CWA constituent chemicals (i.e., arsenic in Lewisite) but also degradation products and any chemicals that may remain from the decontamination process that may pose a human health, safety, or ecological hazard. Regardless of the contaminants that may or may not remain in the waste, waste characterization requirements might be imposed (e.g., Toxicity Characteristic Leaching Procedure [TCLP]) due to other potentially hazardous components. Therefore, it is important to check with the relevant authorities to determine the waste acceptance criteria and associated regulatory requirements. However, these best practices are focused on minimizing the laboratory requirements when characterizing waste for management following an urban wide-area incident. For target agents where no natural concentrations are found within the typical urban area (e.g., VX or HD), field tests and/or quick-response laboratory analyses that determine presence or absence might be appropriate with prior planning and approval from waste authorities.

After the determination of the appropriate analytical technique for samples that will require laboratory analysis, laboratories should be identified that have the capability to perform the requested analyses. It is important to then confirm with the laboratories that they will accept the waste material and that they can perform the requested analyses within the required DQOs (e.g., method detection limit) for the identified type(s) of waste (e.g., decontamination rinsate, contaminated bulk solids). Specifically, coordination with the laboratories should take place prior to collection of samples to ensure that the laboratory will accept samples with potential contamination by CWAs and that they have the capacity to perform the number of requested analyses.

Analytical methods are not available specifically for waste materials. However, there might be a number of possible analytical approaches that could be used to detect a CWA or its degradation by-products within a generated waste stream. However, the technique used for waste characterization must have a quantitation limit below the waste facility acceptance criteria outlined in the DQOs (EPA, 2013c). Ideally, the selected analytical protocol would be able to detect the agent of interest to the lowest available quantitation detection limit as decontaminated waste will likely have low or negative results. Often, the more sensitive techniques that provide the greatest level of confidence for chemical identification and quantification will require a laboratory with well-trained operators rather than a rapid, field-based protocol, and therefore sample results might not be available immediately (EPA, 2013c). Possible laboratory techniques for low concentration CWA testing include, but are not limited to, gas chromatography coupled with flame photometric detection, mass spectrometry, and tandem mass spectrometry.

EPA's **SAM** document should be consulted to determine whether a validated method exists for the specified agent and sample type under consideration.

QRGs that are specific to various chemical hazards are available from the NRT (https://www.nrt.org). Agent-specific SAM sampling documents that outline rapid screening protocols are available from EPA for Environmental Remediation and Recovery (https://www.epa.gov/homeland-security-research/sam). The most current SAM document and the product website should be consulted to determine whether an EPA-validated method exists for the specified agent and sample type under consideration. In addition, the SAM website has several companion documents related to sample disposal, rapid screening and preliminary identification techniques, and sample collection procedures. The analytical approaches included in SAM are not specified for waste samples (except post-decontamination wastewater), but the protocols are intended more generally for soil/powders, particulates (swab, wipe, and dust socks), liquid/water, and aerosols.

The chemical techniques included within SAM have been assigned tiers to indicate the level of usability for a specific analyte and sample type, although in interpreting these tiers, it will be necessary to match the waste type most closely to the sample type listed in SAM. If a validated method is not available, the best available protocol adapted from the chemical literature might need to be conducted. The analysis of atypical samples/materials (i.e., not described in SAM) will require coordination with the SAM technical contacts and the ERLN. The analysis of atypical samples/materials may increase analytical cost and the analysis time. For all the analytical approaches used, careful documentation of the accuracy and limits of detection and quantitation must be available to meet all predefined QA/QC measures. For many CWAs, most laboratories will not have access to ultra-dilute analytical standards for calibration and QC. Access to the CWA agents is controlled by numerous statutes and regulations. The ERLN is supplied with ultra-dilute chemical warfare agent standards (EPA, 2013b). These ultra-dilute standards contain approximately 5-10 parts per million of select CWAs that serve as authentic standards and aid in analytical protocol development by the ERLN (EPA, 2013b). Contact the ERLN directly at https://www.epa.gov/emergency-response/environmental-response-laboratory-network for information regarding laboratory requirements to possess and use ultra-dilute agent standards.

If analytical challenges/gaps arise with SAM and analytical techniques for quantifying CWAs on waste materials, approaches potentially applied more often in Department of Defense-related settings could be discussed, such as:

- Tenting of waste followed by the monitoring of headspace vapor concentrations with gas chromatography (National Academy of Sciences, 2012).
- Ionization mass spectrometric technologies to directly measure (semi-quantitatively) the chemical composition of material surfaces, including porous surfaces (National Academy of Sciences, 2012).

However, these techniques have not yet been proven for environmental remediation scenarios. Limitations include the inability to directly measure the waste materials during the tenting approach and the potential to increase the spread of contamination during the ionization mass spectrometric approach. Additional testing is needed prior to use in an environmental investigation.

6.7.1 Degradation Products

For post-decontaminated waste associated with CWAs, it is important to analyze for dangerous degradation products, some of which (e.g., EA-2192 – S-(2-diisopropylaminoethyl) methylphosphonothioic acid) could be as hazardous as the parent CWA (e.g., VX) (Munro et al., 1999). Capoun and Krykorkova (2014) and Qi et al. (2013) each conducted separate studies that documented degradation products of multiple CWAs following various decontamination technologies. In each study, the decontamination products found were dependent upon the initial chemical agent(s), the environmental conditions, and the decontamination process used. Munro et al. (1999) identified important degradation products from the standpoint of environmental persistence and toxicity. Because Lewisite is an arsenical, inorganic arsenic will likely remain following decontamination and will need to be considered during all waste management plans (EPA, 2014a). Similarly, a VX decontamination study using a hydrogen peroxide-based solution found that EA-2192 persists for at least one week in rinsate-effluents (Wagner and Xega, 2012). A review of degradation products and markers of contamination for selected CWAs is provided in Table B-1.

Many chemical warfare agent decontamination technologies include strong alkaline chemicals that make it difficult to detect trace levels of degradation products in the decontamination solution (Koskela et al., 2007). Nerve agent degradation products on select surfaces have also been detected via wipe sampling (Willison, 2015). Careful attention should therefore be given to degradation by-products when selecting the appropriate analytical approach for characterizing waste for proper waste management.

7 Conclusions

A wide-area incident that releases a CWA in an urban area will require a significant response effort and involve complex management activities. Wide-area contamination incidents can generate large numbers of samples with the potential to overwhelm existing laboratory analysis capacity. Sample analysis has the potential to become a bottleneck that may impede a timely recovery.

A literature search found few documents that addressed sampling approaches specific to CWA wide-area incidents. No resources were identified that evaluated CWA wide-area sampling approaches relative to their demand on laboratory resources. Thus, best practices identified in this report are reflective of traditional sampling approaches for a wide-area incident (e.g., sampling strategies at a Superfund site). Although the incident- and agent-specific considerations are intended for the selection of sampling approaches during a CWA wide-area incident, the best practices may also be used for a variety of chemical scenarios and pre-planning activities.

Numerous data gaps and uncertainties were identified during the evaluation of potential sampling approaches to minimize laboratory demand during management of a CWA wide-area incident. Significant data gaps included:

- The lack of available data on the impact of sampling strategies and collection techniques that will affect sample analysis numbers and the resulting laboratory demand;
- Applicability of a composite sampling approach during various stages of consequence management;
- Verified and validated sample collection techniques for materials commonly found in the urban environment; and
- How to handle mixtures of contaminants during the characterization process.

Potential research studies that may bridge these data gaps were also identified and include:

- Statistical evaluation of resampling when using compositing systems at various stages of consequence management;
- Statistical evaluation of resampling when identified rates of residual contamination are present;
- Testing of various sample collection techniques for commonly identified materials (e.g., cement, marble); and
- Appropriateness of various field screening techniques.

8 References

All Hazards Waste Management Planning (WMP) Tool; https://wasteplanstg.epa.gov/ (accessed September 2018).

ASTM (2006). *D5438-05 Standard Practice for Collection of Floor Dust for Chemical Analysis*, in *Annual Book of Standards*, American Society for Testing Materials.

Campbell, C.G., R.D. Kirvel, A.H. Love, C.G. Bailey, R. Miles, J. Schweickert, M. Sutton, and E. Raber (2012). Decontamination After a Release of *B. anthracis* Spores *Biosecurity and Bioterrorism: Biodefense Strategy, Practice, and Science.* **10**(1): 108-122.

Capoun, T. and J. Krykorkova (2014). Comparison of Selected Methods for Individual Decontamination of Chemical Warfare Agents. *Toxics.* **2**(2): 307.

CFR Title 40, Part 258 §258.28. Liquid Restrictions. https://www.govinfo.gov/content/pkg/CFR-2012-title40-vol26/xml/CFR-2012-title40-vol26-part258.xml

CFR Title 40, Part 264 §264.314. Special Requirements for Bulk and Containerized Liquids. https://www.govinfo.gov/content/pkg/CFR-2012-title40-vol27/xml/CFR-2012-title40-vol27-part264.xml.

Coast Guard (2010). *After Incident Report New Bedford Clam Contamination Incident.* U.S. Coast Guard, MASS DEP Field Assessment and Support Team (FAST). http://www.mass.gov/eea/docs/dep/cleanup/sites/nb610.pdf.

DHS (2011). *National Disaster Recovery Framework - Strengthening Disaster Recovery for the Nation*. Available from: http://www.fema.gov/pdf/recoveryframework/ndrf.pdf.

DHS (2012a). *Key Planning Factors for Recovery from a Chemical Warfare Agent Incident.* Albuquerqe, NM: U.S. Department of Homeland Security, Science and Technology, Chemical Biological Radiological Nuclear and Explosives (CBRNE) Branch Planning Division. ADA570500; http://www.fema.gov/media-library/assets/documents/31719.

DHS (2012b). *Denver UASI All-Hazards Regional Recovery Framework*, Denver Urban-Area Security Initiative (UASI), State of Colorado and Federal Stakeholders

DHS (2012c). *Key Planning Factors for Recovery from a Biological Terrorism Incident.* U.S. Department of Homeland Security. *https://www.fema.gov/media-library/assets/documents/31721*.

EPA SW-846 Compendium. https://www.epa.gov/hw-sw846/sw-846-compendium.

EPA (1992a). *Statistical Methods for Evaluating the Attainment of Cleanup Standards Volume 3: Reference-Based Standards for Soils and Solid Media.* Washington, DC: U.S. Environmental Protection Agency, Department of Policy Planning and Evaluation. EPA 230-R-94-004.

EPA (1992b). *Characterizing Heterogeneous Wastes: Methods and Recommendations.* Las Vegas, NV: U.S. Environmental Protection Agency, Environmental Systems Monitoring Laboratory. EPA/600/R-92/033.

EPA (1995). *EPA Observational Economy Series Volume 1: Composite Sampling.* Washington DC: U.S. Environmental Protection Agency, Department of Policy Planning and Evaluation. EPA-230-R-95-005.

EPA (1998). *Quality Assurance Guidance for Conducting Brownfields Site Assessments.* Washington, DC: U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. EPA 540-R-98-038.

EPA (2002a). *Guidance on Choosing a Sampling Design for Environmental Data Collection for Use in Developing a Quality Assurance Project Plan.* Washington, DC: U.S. Environmental Protection Agency, Office of Environmental Information. EPA/240/R-02/005.

EPA (2002b). *RCRA Waste Sampling Draft Technical Guidance- Planning, Implementation, and Assessment.* Washington, DC: U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. EPA530-D-02-002.

EPA (2002c). *Environmental Response Team Standard Operating Procedures Waste Pile Sampling.* U.S. Environmental Protection Agency, Environmental Response Team. SOP: 2017; Rev: 0.1; 03/13/02.

EPA (2003). *Guide for Industrial Waste Management.* Washington, DC: U.S. Environmental Protection Agency, https://www3.epa.gov/wastes/nonhaz/industrial/guide/index.htm.

EPA (2005). *Research Report Decontamination, Cleanup, and Associated Issues for Sites Contaminated with Chemical, Biological, or Radiological Materials.* Research Triangle Park, NC: U.S. Environmental Protection Agency, Office of Research and Development, National Homeland Security Research Center. EPA/600/R-05/083.

EPA (2006). *Guidance on Systematic Planning Using the Data Quality Objectives Process.* Washington, DC: U.S. Environmental Protection Agency, Office of Environmental Information. EPA/240/B-06/001.

EPA (2008). *Testing and Quality Assurance Plan for the Evaluation of Wipe Sampling Methods for Collecting Chemical Warfare Agents (CWAs), CWA Degradation Products, and Toxic Industrial Chemicals from Various Surfaces.* U.S. Environmental Protection Agency, Office of Research and Development, National Homeland Security Research Center. EPA/600/R-08/079.

EPA (2010). *Sample Collection Information Document for Pathogens and Biotoxins Companion to Standardized Analytical Methods for Environmental Restoration Following Homeland Security Events (SAM) Revision 5.0.* U.S. Environmental Protection Agency, Office of Research and Development, National Homeland Security Research Center. EPA/600/R-09/074.

EPA (2012a). *Report on the 2011 Workshop on Chemical-Biological-Radiological Disposal in Landfills.* Washington, DC: U.S. Environmental Protection Agency, Office of Research and Development, National Homeland Security Research Center. EPA/600/R-11/218.

EPA (2012b). *Technical Report for Surface Analysis of Nitrogen Mustard Degradation Products by Liquid Chromatography/ Tandem Mass Spectrometry (LC/MS/MS).* Cincinnati, OH: U.S. Environmental Protection Agency, Office of Research and Development, National Homeland Security Research Center. EPA/600/R-12/581.

EPA (2012c). *Containment and Disposal of Large Amounts of Contaminated Water: A Support Guide for Water Utilities.* U.S. Environmental Protection Agency, Office of Water. EPA 817-B-12-002.

EPA (2012d). *WARRP Waste Management Workshop*, U.S. Environmental Protection Agency, Office of Homeland Security: Denver, CO, March 15-16.

EPA (2013a). *Bio-Response Operational Testing and Evaluation (BOTE) Project - Phase 1: Decontamination Assessment.* Washington, DC: U.S. Environmental Protection

Agency, Office of Research and Development, National Homeland Security Research Center. EPA/600/R-13/168.
EPA (2013b). *Stability Study for Ultra-Dilute Chemical Warfare Agent Standards.* Cincinnati, OH: U.S. Environmental Protection Agency, Office of Research and Development, National Homeland Security Research Center. EPA 600/R-13/044.
EPA (2013c). *United States Environmental Protection Agency Comprehensive Chemical Agent Tactical Guidebook - DRAFT*, U.S. Environmental Protection Agency.
EPA (2014a). *Systematic Decontamination of Lewisite: Neutralization and Arsenic Removal.* Research Triangle Park, NC: U.S. Environmental Protection Agency, Office of Research and Development, National Homeland Security Research Center. EPA 600-R-14/119.
EPA (2014b). *Sample Collection Information Document for Chemical and Radiochemical Analytes - Companion to Selected Analytical Methods for Environmental Remediation and Recovery (SAM) - 2012.* Washington, DC: U.S. Environmental Protection Agency, Office of Research and Development, National Homeland Security Research Center. EPA/600/R-14/215.
EPA (2014c). *Expedient Approaches for the Management of Wastes Generated from Biological Decontamination Operations in an Indoor Environment Evaluation of Waste Sampling and Decontamination Procedures.* Washington, DC: U.S. Environmental Protection Agency, Office of Research and Development, National Homeland Security Research Center. EPA 600/R-14/262.
EPA (2015a). *Condensed Chemical Agent Field Guidebook for Consequence Management.* U.S. Environmental Protection Agency, Consequence Management Advisory Division. August 25, 2015.
EPA (2015b). *Federal Register Definition of Solid Waste; Final Rule.* Washington, DC: U.S. Environmental Protection Agency, 40 CFR Parts 260 and 261.
EPA (2015c). *Comprehensive Biological Tactical Guidebook Version 1.0 DRAFT.* U.S. Environmental Protection Agency, Office of Research and Development, Consequence Management Advisory Division.
EPA (2015d). *Waste Analysis at Facilities that Generate, Treat, Store, and Dispose of Hazardous Wastes - Final.* Washington, DC: U.S. Environmental Protection Agency, Solid Waste and Emergency Response. EPA 530-R-12-001.
EPA (2016a). *Collaborative Workshop on Handling, Mangement, and Treatment of High-Consequence Bio-Contaminated Wastewater by Water Resouce Recovery Facilities.* Alexandria, VA: U.S. Environmental Protection Agency, Office of Research and Development, National Homeland Security Research Center. EPA/600/R-16/054.
EPA (2016b). *Waste Management Benefits, Planning and Mitigation Activities for Homeland Security Incidents*. Available from: https://www.epa.gov/homeland-security-waste/waste-management-benefits-planning-and-mitigation-activities-homeland#preincident (accessed June 2016).
EPA (2017). *Environmental Response Laboratory Network (ERLN)*. Available from: https://cfpub.epa.gov/si/si_public_file_download.cfm?p_download_id=528746.
France, B., W. Bell, E. Chang, and T. Scholten (2015). Composite Sampling Approaches for *Bacillus anthracis* Surrogate Extracted from Soil. *PLoS ONE.* **10**(12): e0145799.
Hardwick, J. and Q.F. Stout (2016). *Adaptive Sampling Designs*. Available from: http://web.eecs.umich.edu/~qstout/AdaptSample.html.

Ierardi, M.E. (2013). *Begin with the End in Mind: An All-Hazards Systems Approach to Waste Management Planning for Homeland Security Incidents*, in *Handbook of Emergency Response: A Human Factors and Systems Engineering Approach*, A.B. Badiru and L. Racz, Editors. CRC Press. 563-594. Available from: http://www.crcnetbase.com/doi/abs/10.1201/b15372-28.
Incident Waste Support Decision Tool (iWASTE). Available from: https://www.epa.gov/homeland-security-waste/tools-and-resources-homeland-security-incidents. (accessed September 2018).
ITRC (2012). *Incremental Sampling Methodology. ISM-1.* Washington, D.C.: Interstate Technology & Regulatory Council, Incremental Sampling Methodology Team. www.itrcweb.org.
Kilgroe, J.D. (1996). Control of Dioxin, Furan, and Mercury Emissions from Municipal Waste Combustors*. Journal of Hazardous Materials.* **47**(1–3): 163-194.
Kimm, G.L., G.L. Hook, and P.A. Smith (2002). Application of Headspace Solid-Phase Microextraction and Gas Chromatography–Mass Spectrometry for Detection of the Chemical Warfare Agent Bis(2-chloroethyl) Sulfide in Soil*. Journal of Chromatography A.* **971**(1–2): 185-191.
Koester, C.J. and W.G. Hoppes (2010). *VX Sampling.* Livermore, CA: U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344, Lawrence Livermore National Laboratory. LLNL-TL-424141.
Koskela, H., M.-L. Rapinoja, M.-L. Kuitunen, and P. Vanninen (2007). Determination of Trace Amounts of Chemical Warfare Agent Degradation Products in Decontamination Solutions with NMR Spectroscopy. *Analytical Chemistry.* **79**(23): 9098-9106.
Kroening, K.K., R.N. Easter, D.D. Richardson, S.A. Willison, and J.A. Caruso (2011). *Analysis of Chemical Warfare Degradation Products*. First Edition. United Kingdom: John Wiley & Sons, Ltd.
Lagan, C. (2010). *CG Responds to Mustard Gas Exposure*. Coast Guard Compass, Available from: http://coastguard.dodlive.mil/2010/06/cg-responds-to-mustard-gas-exposure/.
Lemieux, P., J. Wood, J. Drake, S. Minamyer, E. Silvestri, C. Yund, T. Nichols, M. Ierardi, and B. Amidan (2016). Analysis of Waste Management Issues Arising from a Field Study Evaluating Decontamination of a Biological Agent from a Building*. Journal of the Air & Waste Management Association.* **66**(1): 17-27.
Munro, N.B., S.S. Talmage, G.D. Griffin, L.C. Waters, A.P. Watson, J.F. King, and V. Hauschild (1999). The Sources, Fate, and Toxicity of Chemical Warfare Agent Degradation Products*. Environmental Health Perspectives.* **107**(12): 933-74.
Nassar, A.-E.F., S.V. Lucas, W.R. Jones, and L.D. Hoffland (1998). Separation of Chemical Warfare Agent Degradation Products by the Reversal of Electroosmotic Flow in Capillary Electrophoresis*. Analytical Chemistry.* **70**(6): 1085-1091.
National Academy of Sciences (2012). *Assessment of Agent Monitoring Strategies for the Blue Grass and Pueblo Chemical Agent Destruction Pilot Plants*, The National Academies Press: Washington, DC.
National Association of Clean Water Agencies (2005). *Protecting Wastewater Infrastructure Assets... Planning for Decontamination Wastewater: A Guide for Utilities*. National Association of Clean Water Agencies. Available from: www.nacwa.org (accessed June 2016).

NRT (2015a). *NRT Quick Reference Guide: Mustard-Lewisite Mixture (HL).* U.S. National Response Team. www.nrt.org.
NRT (2015b). *Quick Reference Guides and Other Links*. Available from: www.NRT.org (accessed August 2016).
NRT (2015c). *NRT Quick Reference Guide: Sulfur Mustard (HD).* U.S. National Response Team. www.nrt.org.
NRT (2015d). *NRT Quick Reference Guide: Tabun (GA).* U.S. National Response Team. www.nrt.org.
NRT (2015e). *NRT Quick Refernce Guide: Soman (GD).* U.S. National Response Team. www.nrt.org.
NRT (2015f). *NRT Quick Reference Guide: Lewisite (L).* U.S. National Response Team. www.nrt.org.
NRT (2015g). *NRT Quick Reference Guide: Cyclosarin (GF).* U.S. National Response Team. www.nrt.org.
NRT (2015h). *NRT Quick Reference Guide: VX.* U.S. National Response Team. www.nrt.org.
NRT (2015i). *NRT Quick Reference Guide: Sarin (GB).* U.S. National Response Team. www.nrt.org.
PNNL (2010). *Acceptance Sampling Using Judgemental and Randomly Selected Samples.* Oak Ridge, TN: U.S. Department of Energy, Pacific Northwest National Laboratory. PNNL-19315; http://www.pnl.gov/main/publications/external/technical_reports/PNNL-19315.pdf.
PNNL (2014). *Visual Sample Plan Version 7.0 User's Guide.* Richland, WA: U.S. Department of Energy, Pacific Northwest National Laboratory. PNNL-23211; http://vsp.pnnl.gov/documentation.stm.
Popiel, S. and M. Sankowska (2011). Determination of Chemical Warfare Agents and Related Compounds in Environmental Samples by Solid-Phase Microextraction with Gas Chromatography. *Journal of Chromatography A.* **1218**(47): 8457-8479.
Qi, L., G. Zuo, Z. Cheng, L. Wang, and C. Zhou (2013). Treatment of Chemical Warfare Agents by Combined Sodium Percarbonate with Tetraacetylethylenediamine Solution. *Chemical Engineering Journal.* **229**: 197-205.
Sexton, R.A. (1993). *An Approach for Sampling Solid Heterogeneous Wastes at the Hanford Site Waste Receiving and Processing and Solid Waste Projects. Prepared for the U.S. Department of Energy Office of Environmental Restoration and Waste Management by Westinghouse Hanford Company*, Presented at Second International Mixed Waste Symposium, Baltimore, Maryland.
Smith, J.N., R.J. Noll, and R.G. Cooks (2011). Facility Monitoring of Chemical Warfare Agent Simulants in Air using an Automated, Field-Deployable, Miniature Mass Spectrometer. *Rapid Communications in Mass Spectrometry.* **25**(10): 1437-1444.
Wagner, G.W. and R. Xega (2012). Mitigation of VX Effluents in Thorough Decontamination Operations. *Industrial & Engineering Chemistry Research.* **51**(49): 16146-16150.
Willison, S.A. (2015). Investigation of the Persistence of Nerve Agent Degradation Analytes on Surfaces through Wipe Sampling and Detection with Ultrahigh Performance Liquid Chromatography-Tandem Mass Spectrometry. *Analytical Chemistry.* **87**(2): 1034-1041.

Appendix A. Glossary

Agency – A division of government with a specific function, or a non-governmental organization (e.g., private contractor, business, etc.) that offers a specific kind of assistance. In the incident command system (ICS), agencies are defined as jurisdictional (having a statutory role in incident mitigation) or assisting and/or cooperating (providing resources and/or assistance).

Agent Yellow – a mixture of the CWAs sulfur mustard (HD) and Lewisite (L) that was evaluated as part of the Wide-Area Recovery and Resiliency Program (WARRP) chemical attack scenario in Denver

All-Hazards – The spectrum of all types of hazards, including accidents, technological incidents, natural disasters, terrorist attacks, warfare, and chemical, biological (e.g., pandemic influenza), radiological, nuclear, or explosive incidents.

Bias – Sampling, analytical or statistical inaccuracies that result in an incorrect estimate of a true concentration estimate (EPA, 2002b).

Clearance – The process of determining that a cleanup goal has been met for a specific contaminant in or on a specific site or item. Generally, occurs after decontamination and before re-occupancy.

Cleanup Goal – For the purposes of this document, a level that has been determined by decision-makers determining that decontamination was effective and/or a specific contamination no longer poses a concern.

Code of Federal Regulations (CFR) – The codification of the Federal regulations published in the Federal Register by the executive departments and agencies of the Federal government. Each volume of the CFR is updated once each calendar year and is issued on a quarterly basis. See http://www.gpo.gov.

Critical Infrastructure (CI) – Systems and assets, whether physical or virtual, so vital that the incapacity or destruction of such might have a debilitating impact on the security, economy, public health or safety, environment, or any combination of these matters, across any Federal, state, regional, territorial, or local jurisdiction (DHS, 2011).

Decision Unit (DU) – Subdivisions of a larger population of waste or media about which decisions can be made (EPA, 2002b).

Decontamination– Processes used to reduce, remove, inactivate, or neutralize chemical or biological contamination. Decontamination might include physical, chemical, or other processes to meet a cleanup goal.

Data Quality Objectives (DQOs) Process – A series of logical steps that guides managers or staff to plan for the resource-effective acquisition of environmental data to ensure that the quality of the data are sufficient for the intended use (EPA, 2006).

Emergency – Any incident, whether natural or man-made, that requires responsive action within hours to protect life or property. As defined in the Stafford Act, any occasion or instance for which, in the determination of the President, Federal assistance is needed to supplement state and local efforts and capabilities to save lives and to protect property and public health and safety, or to lessen or avert the threat of a catastrophe in any part of the United States (42 U.S.C. 5122).

Federal On-Scene Coordinator (OSC) – The Federal official responsible for coordinating and directing Federal responses under subpart D, or the government official designated by the lead agency to coordinate and direct removal actions under subpart E, of the National Contingency Plan (NCP) (per 40 CFR 300.5). The specific duties of the OSC are provided in 40 CFR 300.120. The Federal OSC is predesignated by the U.S. Environmental Protection Agency (EPA), U.S. Coast Guard, U.S. Department of Energy (DOE), or U.S. Department of Defense (DoD) depending upon the location and/or source of the release and might be designated by other Federal agencies under certain circumstances.

Federal Register (FR) – The official weekday publication for rules, proposed rules, and notices of Federal agencies and organizations, as well as executive orders and other presidential documents. See http://www.gpo.gov/fdsys/browse/collection.action?collectionCode=FR.

Hazardous Waste – Waste that, because of its quantity, concentration, physical, or chemical characteristics, might: (1) cause or contribute to increased mortality or illness or (2) pose a potential hazard to human health or the environment when improperly treated, stored, transported, or disposed of, or otherwise managed (EPA, 2015b). Hazardous wastes are a subset of solid wastes. See **Solid Waste** for the definition of a solid waste for the purposes of this document.

Incident – An occurrence, caused by either human action or natural phenomena, that might cause harm and might require action. Incidents can include major disasters, emergencies, terrorist attacks, terrorist threats, wild and urban fires, floods, hazardous material 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.

Initial Response – Actions taken immediately following notification of a contamination incident or release. In addition to search and rescue, scene control, and law enforcement activities, initial response might include initial site containment, environmental sampling and analysis, and public health activities such as treatment of potentially exposed persons.

Key Resources – As defined in the Homeland Security Act, publicly or privately controlled resources essential to the minimal operations of the economy and government.

Laboratory – A permanent/semi-permanent facility with capabilities for processing and assessing environmental samples with predetermined detection limits.

Lines of Evidence – Information or data from various sources that can be used to support waste characterization decisions. Lines of evidence can include technical data on agent fate and transport, persistence under defined environmental conditions, and efficacy of decontamination technologies.

Method – For the purposes of this document, a method is a multi-laboratory, verified procedure that outlines sample collection through laboratory processing including relevant details such as holding times, holding temperatures, quality assurance, quality control, etc.

Mobile Laboratory – A laboratory space that can be transported onto an incident site. The unit may have the rapid processing capabilities for select chemical agents. However, the detection limit may be higher than laboratory protocols.

National Contingency Plan (NCP) – Also called the National Oil and Hazardous Substances Pollution Contingency Plan, this plan (40 CFR Part 300) generally provides a blueprint for carrying out response actions under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and section 311 of the Clean Water Act. The NCP is designed to provide for efficient, coordinated, and effective response to discharges of oil and releases of hazardous substances, pollutants, and contaminants. The NCP describes the organizational structure and procedures for preparing for and responding to discharges of oil and releases of hazardous substances, pollutants, and contaminants.

Population – All waste, or media, of interest located within a target study area (EPA, 2002b).

Recovery – Those capabilities necessary to assist communities affected by an incident to recover effectively, including, but not limited to, rebuilding infrastructure systems; providing adequate interim and long-term housing for survivors; restoring health, social, and community services; promoting economic development; and restoring natural and cultural resources (DHS, 2011).

Recycling - The process of converting waste items into reusable materials.

Remediation – For the purposes of this document, the actions taken and techniques used to implement cleanup of hazardous waste, all solid and hazardous wastes, and all media (including groundwater, surface water, soils, and sediments) and debris that are managed for implementing cleanup. The cleanup process described in this document does not rely on and does not affect authority under CERCLA, 42 U.S.C. 9601 et seq., and the NCP, 40 CFR Part 300.

Resource Conservation and Recovery Act (RCRA) – A 1976 Federal law (42 U.S.C. §6901 et seq.) that gives the U.S. Environmental Protection Agency (EPA) the authority to control hazardous waste from the "cradle to grave." This authority includes the generation, transportation, treatment, storage, and disposal of hazardous waste. RCRA also set forth a framework for the management of nonhazardous solid wastes. The 1986 amendments to RCRA enabled EPA to address environmental problems that could result from underground tanks storing petroleum and other hazardous substances.

Response – Those capabilities necessary to save lives, protect property and the environment, and meet basic human needs after an incident has occurred (DHS, 2011).

Sample – A portion of material collected from a larger quantity for estimating the properties and/or composition of the larger quantity (EPA, 2002b).

Site Characterization – For the purposes of this document, site characterization refers to all available information regarding the incident site- maps, building layouts, weather patterns, population distributions, traffic patterns, agent distribution, etc.

Solid Waste – For the purposes of this document, any garbage, refuse, sludge, and other discarded material resulting from industrial, commercial, mining, agricultural, or community activities. Solid waste includes materials that are destined for final, permanent treatment and placement in disposal units, as well as certain materials that are destined for recycling (EPA, 2015b). It is important to note that under RCRA, "solid waste" is broadly defined and includes discarded materials such as solids, liquids, semi-solids, and contained gaseous materials.

Source Reduction – For the purposes of this document, source reduction refers to removal of contaminated items for off-site treatment and reuse or off-site disposal.

Treatment, Storage, and Disposal Facility (TSDF) – A facility where hazardous wastes are stored, treated, and/or placed in or on land or water (EPA, 2015d).

Treatment Technology – For the purposes of this document, any unit operation or series of unit operations that alters the composition of a hazardous substance or pollutant or contaminant through chemical, biological, or physical means to reduce toxicity, mobility, or volume of the contaminated materials being treated. Treatment technologies are an alternative to land disposal of hazardous wastes without treatment. (See 55 FR 8819, March 8, 1990.) The definition of treatment technology as defined in the NCP can be found at 40 CFR 300.5.

Validation – For the purposes of this document, the term is to be used as described by the EPA Policy Directive FEM-2010-01 "Ensuring the Validity of Agency Methods Validated and Peer Review Guidelines: Methods of Analysis Developed for Emergency Response Situations" (EPA, 2010). More specifically, "…validation is the confirmation by examination and provision of objective evidence that the particular requirements for a specific intended use are fulfilled" (EPA, 2010).

Verification – For the purposes of this document, a synonym for "confirmation" (e.g., decontamination verification or verification that key process variables were controlled).

Waste – For the purposes of this document, waste is defined as any material that is intended for disposal and will not be re-used or recycled. This is a general definition of waste and the applicable legal definition of waste should also be considered when identifying, characterizing, storing, or otherwise managing presumed waste materials.

Waste Characterization – A process that uses knowledge of the waste and/or sampling results to document that the waste meets regulatory requirements and any additional requirements of waste receivers.

Waste Disposal – The placement of waste materials in permanently contained areas (e.g., a landfill, where wastes are disposed of in carefully constructed units designed to protect groundwater and surface water resources).

Waste Management – For the purposes of this document, the administration of activities that include, but are not limited to, source reduction, waste minimization, waste segregation, decontamination, recycling, transport, staging, storage, treatment, and disposal.

Waste Minimization - Actions that reduce the amount of waste generated and/or reduce the amount of waste that is considered hazardous.

Waste Segregation - Sorting and separating waste into more homogeneous waste streams.

Waste Staging – The interim/temporary storage of waste (e.g., waste collected from various buildings may be taken to a staging area prior to being transported to a solid waste disposal facility).

Waste Storage – The holding of wastes until they are treated or disposed. Hazardous waste must be stored in containers, tanks, containment buildings, drip pads, waste piles, or surface impoundments that comply with RCRA regulations.

Waste Transport – For the purposes of this document, waste transport refers to the transportation of waste (e.g., by truck or railroad).

Waste Treatment – Processes such as neutralization or incineration that change the physical, chemical, or biological character of a waste, making it safer for transport, storage, or disposal.

Wide-area – For the purposes of this document, an incident with the potential to generate numerous environmental samples associated with site characterization, clearance determination, and waste management taxing man-power, analytical, and financial resources. A wide-area incident might arise due to the large geographic area affected and/or intensity of the incident relative to critical infrastructure requiring especially robust sampling requirements.

Appendix B. Background on Chemical Warfare Agents

Chemical warfare agents (CWAs) are acutely toxic and capable of causing serious and lethal health effects at very low exposure doses (Table B-1). The CWAs are categorized based on their toxicological actions: vesicants (also called blister agents), nerve agents, blood agents, and incapacitating agents. Vesicant agents are the sulfur mustard agents: the undistilled form of sulfur mustard (H), the distilled form of sulfur mustard (HD), Lewisite (an organic arsenical agent), and Agent Yellow, a combination of HD and Lewisite. The toxicological effects of vesicant agents are blistering and tissue damage of the skin, eyes, and respiratory tract (Munro et al., 1999; NRT, 2015f; NRT, 2015a; NRT, 2015c). Nerve agents, derived from organophosphate chemical compounds, are GA (tabun), GB (sarin), GD (soman), and VX (Munro et al., 1999). Blood agents include cyanogen chloride (CK) (Munro et al., 1999). The toxicological effects of nerve agents might vary depending upon the route of exposure and dose, but can include difficulty in breathing, nausea, vomiting, convulsions, loss of consciousness, coma, and death (NRT, 2015i; NRT, 2015d; NRT, 2015h; NRT, 2015e).

The CWAs can cause both immediate acute effects at the initial site of direct contact with tissues and delayed systemic effects after exposure. For example, sulfur mustard can cause toxicity to the skin, eyes, and respiratory tract within hours to a day of initial direct contact as well as chronic effects, including cancer (Munro et al., 1999). Degradation products of CWAs can be as toxic as the parent compounds themselves, so care must be taken to manage these hazards along with the CWAs during a wide-area incident (Munro et al., 1999).

The CWAs are unique in that they can exhibit lethal toxicity at very low exposure concentrations, with exposure routes of concern in an urban environment most often inhalation, ingestion, or dermal contact. An acute exposure guideline level (AEGL) for a one time 10-minute exposure to an airborne concentration of sarin (GB) is 0.38 milligrams per cubic meter (mg/m^3); this value represents a threshold for severe human health effects and increasing potential for lethality (AEGL Effect Level 3) (NRT, 2015i). Because CWAs are highly toxic at low exposure concentrations, the development of sampling plans to delineate very low levels of contamination can pose a challenge due to variable persistence in the release environment. The development of sampling plans to delineate very low levels of contamination might require modification from the sampling plans typically used at traditional remedial sites. The presence of undetected hotspots (i.e., conditions of elevated concentrations relative to the surrounding area) could lead to unacceptable exposures and/or provide an ongoing source for exposure in the population. Novel exposure pathways might direct sampling of materials that would not be typically addressed in traditional sampling approaches. For example, the off-gassing of low concentrations of CWA from porous materials to which the CWA has sorbed could become the primary route of human health exposure as the duration of an incident extends.

The CWAs are known to exhibit diversity in fate and transport characteristics (DHS, 2012a), even within the same toxicological category (Table B-1). From a sampling perspective, knowledge of these fate and transport characteristics can inform determination of sample location, environmental media to be sampled, or potentially impacted indoor or outdoor materials to target for sample collection. Judgmental sampling uses expert judgment of known chemical behavior to target areas most likely to retain persistent CWAs, as well as areas with the greatest potential for ongoing, frequent human contact. For example, liquid VX is relatively persistent, with a possible range of persistence lasting from hours to months depending upon environmental conditions (NRT, 2015h). In contrast, liquid sarin exhibits the greatest volatility among the nerve agents, and therefore exhibits very low persistence (NRT, 2015i). However, volatility is also predictive of sorption and penetration behavior of the released agent in porous or permeable materials (DHS, 2012a). Targets for sampling might also be selected based on the identification of materials that might function as sinks through prolonged persistence relative to other environmental matrices that might represent an attractive target for sampling (NRT, 2015i).

Depending upon the environmental conditions present at the time of the incident, CWAs may break down into a variety of detectable breakdown products. The rate of formation, structure of formation, and overall persistence is dependent upon environmental conditions (e.g., pH, temperature, relative humidity). In some situations, the breakdown products may serve as a "marker" for determining the extent of contamination. The "marker" agents are intended to act as an indicator of presence, and not as means of identifying which agent is present as some marker compounds can come from multiple parent CWAs.

Table B-1. Review of Chemical Warfare Agents, Persistence, and Breakdown Products

Chemical Abbreviation Common Name; Chemical Formula	*AEGL 3 1 hour (mg/m³)*	*General Persistence*	*Common Environmental Breakdown Products*	*Potential Marker Compounds for Extent of Contamination Determination**	*References*
			Nerve Agents		
GA Tabun; $C_5H_{11}N_2O_2P$	0.0028	Moderately low persistence	Cyanide compounds including: ethylphosphoryl cyanidate, dimethylamine, ethyl N,N-dimethylamidophosphoric acid, hydrogen cyanide, dimethylphosphoramidate, and phosphoric acid	Cyanide compounds; EHDAP	NRT (2015d) Kroening et al. (2011)
GB Sarin; $C_4H_{10}FO_2P$	0.13	Very low persistence	Relatively non-toxic methylphosphonic acid (MPA), isopropyl methylphosphonic acid (IMPA), diisopropyl methylphosphonic acid (DIMP), and fluoride ion	Fluoride ion, MPA, IMPA, DIMP	NRT (2015i) Kroening et al. (2011)
GD Soman; $C_7H_{16}FO_2P$	0.013	Low persistence	Relatively non-toxic MPA, pinacolylmethylphosphonic acid (PMPA), and fluoride ion, which might exist as hydrofluoric acid	PMPA, fluoride ion, MPA	NRT (2015e) Kroening et al. (2011)
GF Cyclosarin; $C_7H_{14}FO_2P$	0.013	Moderately low persistence	Relatively non-toxic fluoride ion, cyclohexylmethylphosphonic acid (CMPA), cyclohexanol, MPA, and combustible hydrofluoric acid	Fluoride ion, MPA; CMPA	NRT (2015g) Kroening et al. (2011)
VX O-Ethyl S-(2-diisopropylaminoethyl) methylphosphonothiolate; $C_{11}H_{26}NO_2PS$	0.010	Persistent	Relatively non-toxic MPA and ethyl methylphosphonic acid (EMPA), and S-(2-diisopropylaminoethyl) methylphosphonothioic acid (EA-2192), which is considered almost as toxic as VX by some routes of exposure	EA-2192, MPA, EMPA	NRT (2015h) Kroening et al. (2011)
			Vesicant Agents		
HD Distilled Sulfur Mustard; $C_4H_8SCl_2$	2.1	Semi-persistent	Relatively nontoxic thiodiglycol (TDG) and hydrochloric acid, and potentially toxic sulfones	TDG	NRT (2015c)
L Lewisite; $C_2H_2AsCl_3$	0.74	Low to moderately persistent; however, vesicant and toxic breakdown products are persistent for decades	Highly toxic arsenic (III) compounds such as arsenites, Lewisite oxide, and 2-chlorovinyl arsenous acid (CVAA), which have vesicant properties. Decontamination by-products include: arsenic (V) compounds, which are less toxic but might be hazardous	Lewisite oxide, CVAA, 2-chlorovinylarsonic acid (CVAOA), total arsenic	NRT (2015f)
HL Agent Yellow; Mustard-Lewisite Mixture	HD: 2.1 L: 0.74	Semi-persistent; could persist in water as globules for decades	Relatively nontoxic TDG and highly toxic arsenic (III) compounds, such as arsenites, Lewisite oxide, and CVAA, which have vesicant properties	TDG, CVAA, CVAOA, total arsenic	NRT (2015a)

**For some agents, environmental conditions (e.g., pH, temperature, relative humidity) determine the individual markers that may be formed, their rate of formation, and persistence.*
CVAA – 2-chlorovinyl arsenous acid; CVAOA – 2-chlorovinylarsonic acid; EMPA - ethyl methylphosphonic acid; EA-2192 - *S-(2-diisopropylaminoethyl) methylphosphonothioic acid;*
MPA – methylphosphonic acid; IMPA - isopropyl methylphosphonic acid; PMPA – pinacolylmethylphosphonic acid; TDG – thiodiglycol; DIMP – diisopropyl methylphosphonic acid;
CMPA – cyclohexylmethylphosphonic acid; EHDAP – ethyl hydrogen dimethylamidophosphate sodium salt

Appendix C. DQO Process Case Study for Characterizing Waste for Proper Management Using the Hypothetical Denver WARRP Scenario

The Denver Urban Area Security Initiative (UASI) developed a hypothetical chemical incident for Agent Yellow (DHS, 2012b). This pre-established Denver Wide-Area Recovery and Resiliency Program (WARRP) scenario will be used as a basis for generating hypothetical examples throughout this appendix (hereinafter: Denver WARRP chemical scenario). Details regarding this scenario are shown in Figure C-1.

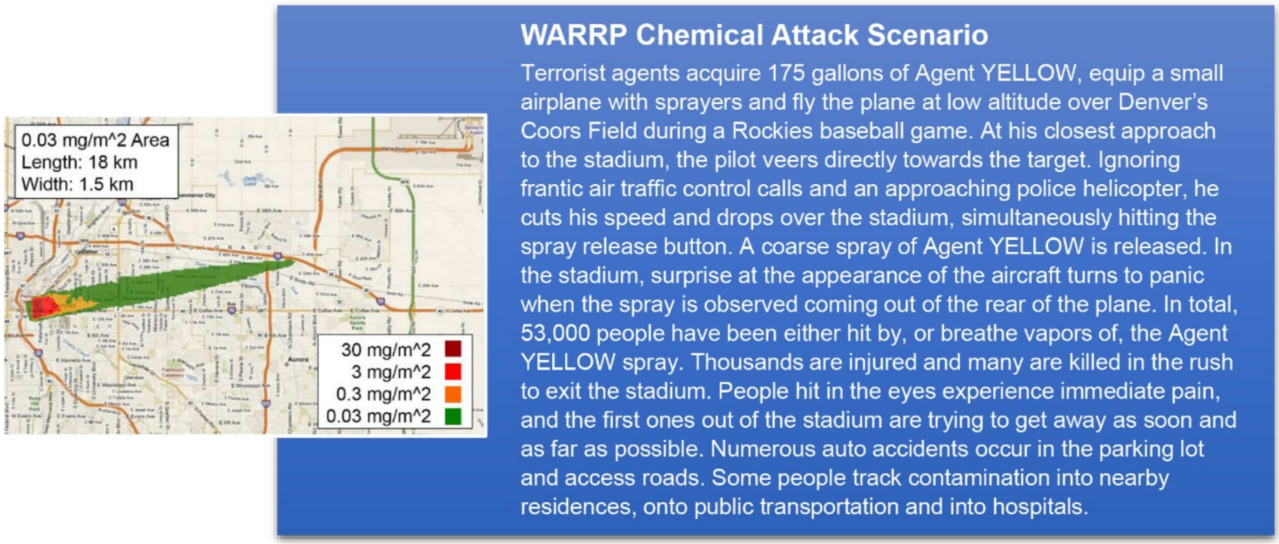


Figure C- 1. Chemical attack scenario. Source: DHS (2012b).

The hypothetical Denver WARRP chemical scenario describes hundreds of facilities that would be contaminated over a five-mile area surrounding the open-air baseball stadium and the downtown Denver infrastructure (DHS, 2012b). Off-gassing of Agent Yellow and the transportation of individuals and materials from or through the contaminated area could increase the extent of contamination and subsequent generation of waste. EPA (2012d) estimated that this incident could generate 15 million to 36 million gallons of aqueous waste and 3 million to 8 million tons of solid waste; these estimates excluded the waste associated with outdoor remediation. Estimates were based on waste generation from hospital and sampling personal protective equipment (PPE), personnel decontamination operations, and building decontamination. Most aqueous waste was estimated to be generated from personnel decontamination operations, and most solid waste was estimated to consist of ceiling tile, carpet, electronics, furniture, and paper (EPA, 2012d).

The WARRP Denver scenario will be used as a basis for demonstrating a hypothetical example of a decision problem data quality objective (DQO) process and an estimation problem DQO process for characterizing waste for proper management following the wide-area release of Agent Yellow over Denver's Coors Field during a baseball game (DHS, 2012b). Pre-Incident WMPs should be compiled prior to any incident to aid all planning efforts after an incident.

The DQO process is an iterative seven-step process that generates performance criteria for the collection of new data. Six crucial inputs are necessary before developing the overall sampling and analysis plan (SAP) in step seven (EPA, 2006). The DQOs identified for an incident will define the indicators of acceptable sampling and analysis data that can be used to answer the question being assessed. The DQO process supports two intended uses of the data: decision-making and estimation (EPA, 2006). Decision-making uses the DQO process to decide between alternative conditions, while estimation evaluates the magnitude of an environmental parameter (EPA, 2006). More detailed direction for utilizing the DQO process can be found within U.S. Environmental Protection Agency (EPA) documentation (EPA, 2006).

To provide a working scenario for the hypothetical DQO process and estimation problems, a conceptual site model was developed based on the conditions expected to be present during Denver WARRP scenario.

- **Agent:** Agent Yellow, a mixture of the CWAs HD and Lewisite, is a liquid blistering agent with a garlic-like odor. Agent Yellow is persistent for several hours in the environment depending upon the temperature and type of surface (DHS, 2012a). Overall, Agent Yellow has low volatility, low water solubility, and may sorb strongly to materials (DHS, 2012a). Additionally, Lewisite contains arsenic, which will not be addressed by Agent Yellow decontamination technologies that rely on chemical oxidation and could require separate remediation strategies (DHS, 2012a).

- **Degradation by-products:** Under certain environmental conditions, HD breaks down in the environment to relatively non-toxic thiodiglycol (TDG), while Lewisite breaks down into highly toxic arsenic (III) compounds, including Lewisite oxide and 2-chlorovinyl arsenous acid (CVAA), can cause blistering like Lewisite (NRT, 2015a).

- **Release Scenario:** Agent Yellow is released from a small agricultural aircraft over a populated baseball stadium in Denver, Colorado. The Agent Yellow deposition plume covers an area over five miles, which includes the open-air baseball stadium, the surrounding area, and infrastructure of downtown Denver (DHS, 2012a). Hundreds of facilities and areas are contaminated.

- **Potential Transport Mechanisms:** After the initial wind dispersal, Agent Yellow dispersal might continue by off-gassing after deposition and transport from contaminated victims who have been moved for medical attention and cross contamination from other material goods transported through the contaminated area (DHS, 2012a).

- **Potentially Affected Waste Materials:** Excluding considerations for outdoor remediation, this scenario was estimated to generate a substantial amount of waste: liquid waste (15 million to 36 million gallons) and other solid waste (3 million to 8 million tons) (EPA, 2012d). Waste estimation included hospital and sampling PPE, personnel decontamination waste, and building decontamination or demolition. Most aqueous waste was estimated to come from personnel decontamination operations, and most solid waste was estimated to consist of ceiling tile, carpet, electronics, furniture, and paper (EPA, 2012d). Depending upon the chemical agent in question, concrete and brick might also constitute a significant fraction of the waste.

- **Waste Management Options:** The National Response Team (NRT) Quick Reference Guide should be consulted as a first step to identify waste management options. A waste can become hazardous waste under Resource Conservation and Recovery Act (RCRA) when it is identified as a listed waste, exhibits specified characteristics, or is generated from discarded commercial chemical product or off-specification chemical product, container residues, or spilled residues. Chemical warfare agents are not categorically regulated under federal RCRA requirements.

  In the context of the WARRP scenario, the Agent Yellow waste components are identified as listed hazardous waste by the state of Colorado. As a result, waste management officials from Colorado would require mustard agent waste materials to be handled as hazardous waste (DHS, 2012). These wastes will be regulated by RCRA requirements and Clean Water Act requirements if discharges to a Publicly Owned Treatment Works (POTW) or surface water body occur (DHS, 2012a). Waste could be incinerated in hazardous waste combustors or disposed of in RCRA Subtitle C (hazardous waste) or possibly Subtitle D (non-hazardous waste) landfills (EPA, 2012d). The waste produced would preferably qualify for disposal as municipal solid waste, but waste sampling would likely be needed to confirm acceptability as some states/locations might have more stringent requirements than the Federal government (EPA, 2012d; EPA, 2015d). Since it is likely that a wide-area incident will require waste management facilities in multiple states and/or regions, it becomes critical to have these facilities identified before an incident.

Decision Problem DQO Example

1. **State the Problem**
    a. **Describing the problem.** A timely process is needed to efficiently manage the sampling and analytical level of effort required to determine how waste incurred during the incident should properly be managed.
    b. **Establishing the planning team**. The planning team includes representatives from the incident command, EPA remediation oversite, the sampling team, federal and state waste management programs, the owners/operators of potential waste management facilities, health and safety personnel, analytical laboratory, statistical expert, quality assurance representative, and risk assessment.
    c. **Describing the conceptual model of the potential hazard.** For this example, up to 8 million tons of solid waste will be generated from this incident. Waste management officials from Colorado require Agent Yellow-related waste materials to be handled as hazardous waste. This hypothetical case study assumes that "Pre-Incident Waste Management Plans" were prepared prior to the incident with potential Subtitle C landfills and hazardous waste incinerators. It is also assumed that waste acceptance criteria are more restrictive for the Subtitle C landfills than the hazardous waste incinerators, but the Subtitle C landfills are less expensive than the hazardous waste incinerators.

   d. **Identifying available resources, constraints, and deadlines:** Sampling team and analytical capabilities are being stretched by the demands associated with other sampling activities (e.g., defining the extent of contamination, verifying the decontamination efficacy).

2. **Identify the Goal of the Study**
   a. **Specifying the primary question**. Is waste associated with the Denver WARRP scenario adequately decontaminated (as pre-determined in the "Pre-Incident Waste Management Plan") to be accepted by the Subtitle C landfills?
   b. **Determining alternative actions. Possible alternative actions include:**
      - Dispose of waste in Subtitle C landfill
      - Treat the associated waste using an on-site decontamination operation and re-assess
      - Treatment of the waste in a hazardous waste incinerator.
   c. **Specifying the decision statement.** Determine whether each lot of decontaminated waste can be disposed of in the Subtitle C landfills.

3. **Identify Information Inputs**
   a. **Identify the type of information that is needed to resolve the decision statement**. This is a new data collection effort, with analyses being performed on waste samples collected as part of the Denver WARRP scenario. The planning team has decided to collect wipe samples for the sulfur mustard component of Agent Yellow from the decontaminated waste items.
   b. **Identifying the source of information**. Data will be collected from lots of similar waste containers (e.g., those of the same types of materials and/or those waste materials originating from the same location and/or undergoing the same decontamination incident).
   c. **Identifying how the Action Level will be determined**. The Action Level will be determined per direction from the owners/operators of the Subtitle C landfills and the Colorado solid waste regulator.
   d. **Identifying appropriate sampling and analysis approaches**. For this hypothetical example only: wipe samples of containerized waste will be sampled for sulfur mustard (an analytical technique for Agent Yellow is not available). Table 2 should be used to identify an appropriate sampling method if this approach is not suitable. The surface concentrations of sulfur mustard will be measured, as directed in the latest on-line version of EPA's Selected Analytical Methods for Environmental Remediation and Recovery (SAM). However, specific methods for CWAs are available only via the Environmental Response Laboratory Network (ERLN).

4. **Define the Boundaries of the Study**
   a. **Specifying the target population**. The target populations consist of all possible samples of waste that comprise the total volume of a given lot of waste containers. Samples collected from this target population will consist of wipe samples.
   b. **Specifying spatial and temporal boundaries and other practical constraints**. The lot of physical containers holding the waste will serve as the spatial boundary

of the waste to be sampled. Each lot will be comprised of several waste containers. Lots will be established by the possible approaches:

- Spatially and temporally, for example, waste originating from the same area (e.g., the same building or same city block) that underwent the same application of decontamination technology (e.g., liquid bleach application from the same vendor) at the same time (e.g., all waste generated during that day of decontamination).
- Lots of waste might further be created by considering the types of waste and performing waste segregation (e.g., decontaminated carpet might comprise a lot and ceiling tile might comprise another lot).

The sampling of each lot will be conducted within the same time frame (e.g., all lot samples will be collected on the same day).

c. **Specifying the scale of inference for decision-making**. A decision unit corresponds to a specific lot of waste containers. The boundaries of the study (as well as other aspects of characterizing waste for proper management) should be determined as part of the "Pre-Incident Waste Management Plan". The assumptions used in this hypothetical case study should ideally be studied before an actual incident to provide lines of evidence (i.e., acceptable knowledge) in accordance with federal (RCRA) and state regulations to assist decision makers should the incident occur. Waiting until an actual incident will prove costly and delay the remediation. If data are needed to inform decision makers, an investigation should be conducted prior to the incident and documented with the "Pre-Incident Waste Management Plan" so that the incident can be an execution of the lines of evidence already documented Table 2 should be used to identify an appropriate sampling method if this approach is not suitable.

5. Develop the Analytical Approach

a. **Specifying the Action Level**. For this hypothetical example only: An agreement with the owners/operators of the Subtitle C landfills and the Colorado solid waste regulator, waste will not be accepted by the Subtitle D landfills if any of the waste container wipe samples have a sulfur mustard concentration >0.1 $\mu g/cm^2$ (the upper calibration range for sulfur mustard from wipe samples). Note: the >0.1 $\mu g/cm^2$ concentration is ONLY for illustration purposes. The actual value would be determined on a site-specific basis.
Please note that this assumption is simplified. Agent Yellow is a mixture of sulfur mustard and Lewisite, and Lewisite contains arsenic. Arsenic will remain even if the sulfur mustard and Lewisite are appropriately degraded. Action levels might also be needed for air/headspace, extraction-based samples of decontaminated items, and water/decontamination solution, and action levels will likely be needed for sulfur mustard, Lewisite, and degradation products including arsenic for these media.

b. **Specifying the theoretical decision rule**. The theoretical decision rule is as follows: If any concentrations of sulfur mustard >0.1 $\mu g/cm^2$ are detected in the wipes of the sampled containers from a waste lot, then the waste in that lot will not be disposed of in the Subtitle C landfills without further decontamination and reassessment or the waste might dictate that the waste be sent to hazardous waste incinerators. Otherwise, the lot of waste will be considered acceptable for disposal in the Subtitle C landfills. Note: the >0.1 µg/cm^2 concentration is ONLY for illustration purposes. The actual value would be determined on a site-specific basis.

6. **Specify Performance or Acceptance Criteria: Specify Probability Limits for False Rejection and False Acceptance Decision Errors**
   a. **Setting baseline and alternative conditions**. The planning team determined that any decision on the disposal of waste in Subtitle C landfills must be made with the safeguard of the public health being of paramount importance. Following the ERLN protocol for measuring the concentration of sulfur mustard in wipe samples, the collected data from a given lot of waste must result in detections ≤0.1 µg/cm^2. The associated baseline condition has been established as "the waste is not acceptable for the Subtitle C landfills" (i.e., a sulfur mustard concentration >0.1 µg/cm^2 was detected), while the alternative condition is "the waste is acceptable for the Subtitle C landfills" (i.e., all measured sulfur mustard concentrations were ≤0.1 µg/cm^2). The statistical hypotheses are then:
   H_o: a sulfur mustard concentration >0.1 µg/cm^2 was detected in the waste lot
   H_a: a sulfur mustard concentration >0.1 µg/cm^2 was not detected in the waste lot
   Note: the >0.1 µg/cm^2 concentration is ONLY for illustration purposes. The actual value would be determined on a site-specific basis.
   Unless there is conclusive information from the collected data to reject the null hypothesis (i.e., H_o, the baseline condition) for the alternative hypothesis (i.e., H_a, the alternative condition), we therefore assume that the baseline condition is true.
   b. **Determining the impact of decision errors**. A "false acceptance decision error" corresponds to deciding that the waste contains sulfur mustard at >0.1 µg/cm^2 (i.e., H_o is not rejected) when (in reality) the waste is not (i.e., H_o is false). In contrast, a "false rejection decision error" corresponds to deciding that the waste is not hazardous (i.e., H_o is rejected in favor of H_a) when (in reality) it is hazardous (H_o is true). The planning team identified the following consequences for each decision error:
      - The primary consequence of making a false acceptance decision error is the considerable expense (in both time and cost) required to treat the associated waste again for potential disposal in a Subtitle C landfill or the increased expense of taking the waste to a hazardous waste incinerator.
      - The consequences of making a false rejection decision error is waste would be sent to a Subtitle C landfill containing Agent Yellow at concentrations possibly endangering human health. Additionally, making a false rejection decision error could compromise public confidence in the remediation.

   As the risk to human health outweighs the consequences of having to pay more for waste disposal and associated delays, the planning team has concluded that making a false rejection decision error would lead to more severe consequences than making a false acceptance decision error.
   c. **Specifying the confidence statement about the waste lot based on limited samples**. Because all waste containers will not be sampled, the goal will be to take limited samples and based on those samples, make statements (with an

associated confidence statement) about unsampled areas. The planning team's desire is to be 95% confident that 95% of the waste containers are sufficiently decontaminated (i.e., sulfur mustard concentrations >0.1 µg/cm^2 were not detected in any of the associated lot samples).

7. **Develop the Plan for Obtaining Data**
   a. **Selecting a sampling design**. The planning team's statistician determined that for each lot of containerized wastes (e.g., barrels), random samples will be collected from a sufficient number of barrels so that if no sulfur mustard is detected at concentrations >0.1 µg/cm^2, the planning team can be 95% confident that 95% of the waste containers are not contaminated with sulfur mustard concentrations >0.1 µg/cm^2. The number of waste containers to be sampled for each lot will be determined statistically (e.g., using the Visual Sample Plan [VSP] software) based on the required confidence statement and the total number of waste containers. For each waste container sampled, one wipe sample will be collected from an item within the drum.
   b. Specifying key assumptions supporting the selected design. The sampling design assumes that the containerized waste has undergone complete immersion in a liquid decontaminant and the liquid was then drained/removed.

Estimation Problem DQO Example

1. **State the Problem**
   a. **Describing the problem**. A timely process is needed to efficiently manage the sampling and analytical level of efforts required to determine how waste incurred during the incident should properly be managed.
   b. **Establishing the planning team**. The planning team includes representatives from the incident command, EPA remediation oversite, the sampling team, federal and state waste management programs, the owners/operators of potential Subtitle C landfills and hazardous waste incinerators, health and safety personnel, analytical laboratory, statistical expert, quality assurance representative, and risk assessment.
   c. **Describing the conceptual model of the potential hazard.** For this example, up to 8 million tons of solid waste will be generated from this incident. Waste management officials from Colorado require Agent Yellow-related waste materials to be handled as hazardous waste. This hypothetical case study assumes that "Pre-Incident Waste Management Plans" were prepared prior to the incident with potential Subtitle C landfills and hazardous waste incinerators. It is also assumed that waste acceptance criteria are more restrictive for the Subtitle C landfills than the hazardous waste incinerators, but the Subtitle C landfills are less expensive than the hazardous waste incinerators.
   e. **Identifying available resources, constraints, and deadlines:** Sampling team and analytical capabilities are being stretched by the demands associated with other sampling activities (e.g., defining the extent of contamination, verifying the decontamination efficacy).

2. **Identify the Goal of the Study**

a. **Specifying the primary question**. Is waste associated with the Denver WARRP scenario adequately decontaminated (as pre-determined in the "Pre-Incident Waste Management Plan") to be accepted by the Subtitle C landfills?
b. **Specifying the estimation statement.** The principal estimation measure will be an average concentration of sulfur mustard sampled from randomized lots of containerized wastes. Upper confidence limits (UCLs) calculated on this measurement are needed to reflect uncertainty. The UCL provides additional assurance that the magnitude of the chemical contaminant levels is properly attained. The process used to estimate these parameters should account for the underlying distribution of measurements and the handling of non-detected measures.

   Please note that this is a simplified assumption. Agent Yellow is a mixture of sulfur mustard and Lewisite, and Lewisite contains arsenic. The estimation statement for the study could also include estimates for Lewisite, arsenic, or other degradation products/markers.

3. **Identify Information Inputs**
   a. **Identify the type of information that is needed to resolve the decision statement**. This data collection effort is new, with analyses being performed on waste samples collected as part of the Denver WARRP scenario. The planning team has decided to collect wipe samples for the sulfur mustard component of Agent Yellow from the decontaminated waste items.
   b. **Identifying the source of information**. Data will be collected from lots of similar waste containers (e.g., those of the same types of materials and/or those waste materials originating from the same location and/or undergoing the same decontamination incident).
   c. **Identifying how the Action Level will be determined**. The Action Level will be determined per direction from the owners/operators of the Subtitle C landfills and the Colorado solid waste regulator.
   d. **Identifying appropriate sampling and analysis approaches**. For this hypothetical example only: wipe samples of containerized waste will be collected for sulfur mustard (an analytical technique for Agent Yellow is not available). The surface concentrations of sulfur mustard will be measured, as directed in the latest on-line version of EPA's SAM. However, specific methods for CWAs are available only via the ERLN.

4. **Define the Boundaries of the Study**
   a. **Specifying the target population**. The target populations consist of all possible samples of waste that comprise the total volume of a given lot of waste containers. Samples collected from this target population will consist of wipe samples.
   b. **Specifying spatial and temporal boundaries and other practical constraints**. The lot of physical containers holding the waste will serve as the spatial boundary of the waste to be sampled. Each lot will be comprised of several waste containers. Lots will be established by the possible approaches:

- Spatially and temporally, for example, waste originating from the same area (e.g., the same building or same city block) that underwent the same application of decontamination technology (e.g., liquid bleach application from the same vendor) at the same time (e.g., all waste generated during that day of decontamination).
- Lots of waste might further be created by considering the types of waste and performing waste segregation (e.g., decontaminated carpet might comprise a lot and ceiling tile might comprise another lot).

The sampling of each lot will be conducted within the same time frame (e.g., all lot samples will be collected on the same day).

c. **Specifying the scale of inference for decision-making**. A decision unit corresponds to a specific lot of waste containers. The boundaries of the study (as well as other aspects of characterizing waste for proper management) should be determined as part of the "Pre-Incident Waste Management Plan". The assumptions used in this hypothetical case study should ideally be studied before an actual incident to provide lines of evidence (i.e., acceptable knowledge) in accordance with federal (RCRA) and state regulations to assist decision makers should the incident occur. Waiting until an actual incident will prove costly and delay the remediation. If data are needed to inform decision makers, an investigation should be conducted prior to the incident and documented within the "Pre-Incident Waste Management Plan" so that the incident can be an execution of the lines of evidence already documented.

5. Develop the Analytical Approach

Determining the key study parameter and a specification of the estimator. The planning team determined that for sulfur mustard, the parameter that will be estimated is the average surface concentration of sulfur mustard ($\mu g/cm^2$) from waste items within the containerized waste.

6. Specify Performance or Acceptance Criteria: Specify Performance Metrics and Acceptable Levels of Uncertainty

a. **Specifying how uncertainty will be accounted for in the estimate**. The upper confidence limit (UCL) represents a density level that falls above the true level (unobservable) with a given degree of confidence (with the confidence level specified as a percentage). Use of the UCL in this context places the burden of proof on demonstrating that the sulfur mustard surface concentration is neither moderate nor high. By calculating the UCL on the average, uncertainty associated with the estimate can be accounted for in estimating the sulfur mustard surface concentration.

b. **Specifying the confidence level associated with the UCL**. The planning team selected 75% as the confidence level associated with the UCL on the average. These values will be used to identify lots of containerized waste to be at or above specific concentrations.

c. **Specifying performance or acceptance criteria**. The planning team determined that a sufficient number of samples should be collected to allow for the 75% UCL to be no more than 20% higher than the average concentration.

7. **Develop the Plan for Obtaining Data**
   a. **Selecting a sampling design**. The planning team's statistician determined that for each lot of containerized wastes (e.g., barrels) random samples will be collected from a sufficient number of barrels to meet the performance/acceptance criteria described in Step 6. The number of waste containers to be sampled for each lot will be determined statistically (e.g., using the VSP software) based on the required confidence level and the total number of waste containers. For each waste container sampled, three wipe samples will be collected from waste items within the drum.
   b. **Specifying key assumptions supporting the selected design**. The sampling design assumes that the containerized waste has undergone complete immersion in a liquid decontaminant and then drained/removed.

Appendix D. Features of Various Sampling Designs

Sampling Strategy	Non-Probabilistic *Judgmental*	Probabilistic *Simple Random*	*Stratified Random*	*Systematic: Grid or Transect*	*Ranked Set*	*Adaptive or Response/Adaptive*	Hybrid *Combined Targeted and Random Sampling*	Composite
Definition	Selection of sample locations based on professional judgment targeting locations most likely to be contaminated.	A set of sampling units is independently selected at random from an area to protect against bias.	Prior information is used to determine groups (strata) that are sampled independently.	Collecting samples at locations in a specified pre-determined grid pattern or transecting paths to ensure target area is fully and uniformly represented in the collected samples.	Combines simple random sampling with the professional knowledge and judgment of the field investigator to rank the selected locations that are subsequently selected for more accurate measurement.	Sampling design where additional samples are collected based upon initial sample results. Particularly useful when a characteristic of interest is sparsely distributed, but highly aggregated.	Combines results from judgment and probabilistic samples to cover most likely and less likely areas of contamination.	A composite sampling and processing protocol that reduces data variability and provides an estimate of mean contaminant concentrations in a composite sample collected from a defined area. Can be collected through either a judgment or probabilistic sampling scheme or a combination thereof.
Application	• Small-scale conditions are under investigation • Screening for presence/absence of a contaminant • Might be used in conjunction with simple random sampling of containerized samples (i.e., samples collected from within the container might be judgmentally sampled to maximize the collection of the chemical agent such as collecting samples from porous materials)	• Relatively uniform or homogeneous populations • Selecting a sample aliquot from a composite sample	• Used to produce estimates with pre-specified precision for important subpopulations • Monitoring of trends • Used to gain specific information (i.e., mean) regarding each group	• Practical and convenient implementation for field sampling with more complete coverage of an area than random sampling • Appropriate if no prior information is known about a location, if a distribution pattern is suspected, or if looking for a "hot spot" • Site characterization or evaluating cleanup standards within contaminated soils	• Ideal when laboratory measurement costs are high relative to field screening (hand-held or professional judgment) • A cost-effective approach for estimating the mean for a specified precision • A Bayesian model has been developed for use in areas where contamination is deemed unlikely either when determining the extent of contamination or following decontamination	• Ideal for lines of contamination or hot spot investigations • Simultaneous determination of mean concentrations and extent of contamination - particularly when a field screening technique is available	All negative judgment results can be combined with probabilistic samples to determine extent of contamination lines or decontamination assessment	• Estimating a mean concentration • Efficiently estimating the proportion of a population with a contaminant without needing to know which units have the contaminant (i.e., how many waste containers are contaminated, but not which ones)
Required Laboratory Resources	Low: site information used to minimize laboratory resources	Medium: sample number is predetermined	Medium: sample number is predetermined	Medium: sample number is predetermined using a gridded scale, with the grid scale determining the intensity of sampling	Low: site information used to minimize laboratory resources	Unknown/High: no site information is used to limit the number of samples that might be required	Low: site information used to minimize laboratory resources	Low: site information used to minimize laboratory resources

Sampling Strategy	Non-Probabilistic *Judgmental*	Probabilistic *Simple Random*	*Stratified Random*	*Systematic: Grid or Transect*	*Ranked Set*	*Adaptive or Response/Adaptive*	Hybrid *Combined Targeted and Random Sampling*	Composite
Wide-Area Pros	• Can be very efficient and cost effective if site is well known • Ideal for presence/ absence screening • Quick implementation to achieve time and funding constraints	• Provides the ability to calculate uncertainty limits and statistical inferences • Protects against sampling bias • Easy to understand and implement • Sample size formulas are available to aid in determining adequate sample numbers (EPA, 2002a)	• Provides an estimate of overall population parameters equal to or better than simple random sampling • Sample size formulas are available to aid in determining adequate sample numbers (EPA, 2002a)	• Provides uniform, known, complete spatial/temporal coverage of an area • Design and field implementation is intuitive • Little to no prior information of the site might decrease sample numbers (EPA, 2002a)	• Increases the chance that the collected samples will yield representative measurements • Can be more cost-efficient than simple random sampling because fewer samples need to be collected and measured	• Simultaneously estimates mean concentrations and extent of contamination • Sampling resources are concentrated to the areas of greatest interest	• Leverages all available information • Allows calculation of statistical confidence statements • Combines the advantages of probabilistic and judgmental sampling approaches	• Significant reduction in analysis costs potentially equal to better representation • Some sources of sampling error are addressed by increasing sample representativeness
Wide-Area Cons	• Dependent upon expert knowledge • Cannot reliably evaluate precision • Personal judgment is needed to interpret data • Confidence statements concerning the absence of contamination are difficult to make	• Random locations might be difficult to identify • Sampling design depends upon the accuracy of the conceptual model • All prior information regarding the site is ignored • Sampling can be costly if there are difficulties in obtaining samples due to location	• Random locations might be difficult to identify • Sampling design depends upon the accuracy of the conceptual model • All prior information regarding the site is ignored • Sampling can be costly if there are difficulties in obtaining samples due to location	• Sample locations are fixed and might not work in an urban environment • If the scale of the grid sampling pattern is larger than the pattern for the agent of interest, the target agent might be missed entirely • Not using any available prior knowledge regarding the site might decrease sample efficiency	• Dependent upon expert knowledge • More complex implementation	• Iterative nature of the design might increase the overall time requirements The final overall sample size is an unknown quantity	• Dependent upon expert knowledge • Negative perception of inferring confidence when compared to statistically based designs	• Compositing cannot be applied to all sample types or detection technologies • Does not provide information on the spatial distribution of contaminants within a given sampling unit • Error might be introduced during the compositing process, i.e., weighing or homogenizing heterogeneous sample Confidence Limits (CLs)

Sampling Strategy	Non-Probabilistic *Judgmental*	Probabilistic *Simple Random*	*Stratified Random*	*Systematic: Grid or Transect*	*Ranked Set*	*Adaptive or Response/Adaptive*	Hybrid *Combined Targeted and Random Sampling*	Composite
Cautions or Additional Critical Information	• Does not ensure that unsampled items are free of contamination • Degradation by-products might be of concern depending upon the parent agent and create a hazardous environment incident after the parent (or tested agent) is no longer present	• Simple random sampling is often used as the last stage of sampling when multiple iterations are conducted – selecting an aliquot from a composite sample • All populations should be relatively uniform • Degradation by-products might be of concern depending upon the parent agent and create a hazardous environment incident after the parent (or tested agent) is no longer present	• Each group should be homogeneous within itself • Groups should be defined before determining sample sizes • Potentially more efficient approach for sampling heterogeneous wastes, if the wastes can be segregated • Degradation by-products might be of concern depending upon the parent agent and create a hazardous environment incident after the parent (or tested agent) is no longer present	• A random starting location must be identified from which all other sampling locations are based • Degradation by-products might be of concern depending upon the parent agent and create a hazardous environment incident after the parent (or tested agent) is no longer present	• Statistical SME input is recommended • Degradation by-products might be of concern depending upon the parent agent and create a hazardous environment incident after the parent (or tested agent) is no longer present	• Field screening or rapid laboratory protocols are ideal • Degradation by-products might be of concern depending upon the parent agent and create a hazardous environment incident after the parent (or tested agent) is no longer present	• Especially useful for determining when an area is not contaminated • Degradation by-products might be of concern depending upon the parent agent and create a hazardous environment incident after the parent (or tested agent) is no longer present	• Area of interest is divided into decision units from which multiple samples are collected and combined, processed, and subsampled before analytical detection • Generally, a minimum of 20–30 [equally sized] discrete samples are needed for an adequate characterization of a defined decision unit area with Incremental Sampling Methodology (ISM) • Degradation by-products might be of concern depending upon the parent agent, and create a hazardous environment incident after the parent (or tested agent) is no longer present
Previous Use(s)	• Brownfield land assessments (EPA, 1998); Capitol Hill Anthrax Response (EPA, 2015c); Bio-response Operational Testing and Evaluation (BOTE) (EPA, 2013a) • Proposed by Sexton (1993) to sample within randomly selected drums. Three to four samples were proposed from each drum (soft items were to be sampled via extractive-based approaches and hard items were to be sampled via wiping). The waste items most likely to contain hazardous materials were to be sampled	Recommended by Sexton (1993) for drum sampling.	Proposed by Sexton (1993) for random drum sampling within "lots" of drums with similar characteristics	Attainment of cleanup standards (EPA, 1992a)				
Reference(s)	EPA (2006); EPA (1998); EPA (2015c); EPA (2013a); Sexton (1993)	EPA (2002b); EPA (2006); ITRC (2012); Sexton (1993); EPA (2002c)	EPA (2002b); EPA (2006); Sexton (1993)	EPA (2006); EPA (1998); EPA (1992a)	EPA (2006)	EPA (2006); Hardwick and Stout (2016); EPA (2015b)	EPA (2015c); PNNL (2010)	EPA (2006); ITRC (2012)

Appendix E. Features of Various Sample Collection Techniques

	Extractive (Solid Material) Bulk Sampling	*Soil Sampling*	*Wipe (Surface) Sampling*	*Vacuum (Surface) Sampling*	*Liquid (Surface) Sampling*	*Liquid (Drum) Sampling – Discrete Depth Samplers*	*Liquid (Drum) Sampling – Profile Samplers*	*Air Sampling*
Description	Extractive sampling refers to the cutting/removal of a portion of the material sampled. Might also be referred to as bulk sampling or direct extraction.	Soil samples might be collected from the surface or from lower depths depending upon the conditions. Might also be referred to as bulk sampling.	Surface sampling techniques using wipes, cotton-balls/wipes, filter paper wipes, or gauze sponges.	Surface collection of dust and or particulates.	The collection of liquid samples from the surface (or shallow depths) might be obtained with various devices including a bailer, dipper, liquid grab sampler, swing sampler, or solid phase microextraction fibers.	Liquid samples might be obtained from discrete depths with a variety of devices include a syringe sampler, discrete level sampler, lidded sludge/water sampler, or solid phase microextraction fibers.	Liquid samples might be obtained from throughout a vertical column of liquid or sludge with a variety of devices include a composite liquid waste sampler (COLIWASA), drum thief, valved drum sampler, plunger type sampler or solid phase microextraction fibers.	Air sampling devices could include high-volume air samplers, solid phase adsorbent media (tubes), solid phase microextraction fibers, or other air samplers (e.g., SUMMA® canisters).
Application	• Applicable for the sampling of targeted areas (sink materials) where liquid agent might remain, especially porous surfaces • Applicable for sampling materials that are not amenable to wipe sampling such as materials that are wet, irregularly shaped, and/or porous • Might be applicable for sampling heterogeneous waste; cutting, chipping, or drilling of waste samples (and subsequent grinding/mixing together) can make the samples more homogeneous and amenable to being sampled simply with a spoon or scoop	Soils might be sampled to assess surface contamination or contaminant permeation	• Generally used for sampling smooth, nonporous surfaces, but might also be used on porous surfaces (EPA, 2012b) • Applicable to relatively small sample areas	• Suitable for porous or nonporous surfaces • Might allow for larger surface areas to be assessed in a single sample than wipe sampling techniques	• Although designed for groundwater sampling, bailers can be used to collect liquid samples from tanks and surface impoundments; bailers collect samples of 0.5 to 2 liters • The dipper, liquid grab sampler, and swing sampler generally collect 0.5- to 1.0-liter samples from the surface of drums, tanks, and surface impoundments	• The syringe sampler and discrete level sampler can collect 0.2- to 0.5-liter samples from drums, tanks, and surface impoundments • A lidded sludge/water sampler can collect 1.0-liter volumes from tanks and ponds	These sampling devices typically collect between 0.1- to 3-liter samples from tanks and drums, as well as surface impoundments	Air sampling might be helpful in confirming the presence of an agent over a wide area

	Extractive (Solid Material) Bulk Sampling	*Soil Sampling*	*Wipe (Surface) Sampling*	*Vacuum (Surface) Sampling*	*Liquid (Surface) Sampling*	*Liquid (Drum) Sampling – Discrete Depth Samplers*	*Liquid (Drum) Sampling – Profile Samplers*	*Air Sampling*
Wide-Area Pros	Extractive-based sampling minimizes the losses of agent than might arise with collection inefficiencies of other sampling protocols	Grab samples are simple and can be easily composited across a wide area	Can be an easy and quick way of assessing surface contamination levels	Large surface areas can be sampled relatively quickly, even for personnel working in PPE	• The bailer, dipper, liquid grab sampler, and swing sampler are generally easy to use and inexpensive • Analysis of some sampling devices can be performed in the field for some analytes.	• A syringe sampler is easy to use and decontaminate; it can also be used to sample discrete depths, including the bottom • The jar in the lidded sludge/water sampling device serves as the sample container reducing the chance of cross-contamination • Solid phase microextraction fibers can be taken into the field to sample. These samples might be returned to the laboratory for analysis or the fibers can be analyzed in the field using portable GC/MS systems	• The COLIWASA, drum thief, and valved drum sampler are inexpensive, easy to use, and available as reusable or single-use models • The plunger type sampler is easy to operate, relatively inexpensive, and is available in various lengths • Solid phase microextraction fibers can be taken into the field to sample. These samples might be returned to the laboratory for analysis or the fibers can be analyzed in the field using portable GC/MS systems	Analysis of some sampling devices can be performed in the field for some analytes

	Extractive (Solid Material) Bulk Sampling	*Soil Sampling*	*Wipe (Surface) Sampling*	*Vacuum (Surface) Sampling*	*Liquid (Surface) Sampling*	*Liquid (Drum) Sampling – Discrete Depth Samplers*	*Liquid (Drum) Sampling – Profile Samplers*	*Air Sampling*
Wide-Area Cons	• Extractive-based sampling might be difficult for personnel working in PPE • Extractive-based sampling techniques are not well-defined/established • Extracted samples might require more extraction solvent and more time to process than other surface sampling approaches • Small concentrations of a contaminant might be diluted within a larger bulk sample	• Soil protocols that require extraction might require more extraction solvent and time to process than other surface sampling approaches • Extractive-based sampling techniques are not well-defined/established and might be difficult for personnel working in PPE • Small concentrations of a contaminant might be diluted within a larger bulk sample	• Wipe sampling might not result in high agent recoveries from porous materials such as wood • Wipe sampling procedures can vary based on the wipe material, agent of interest, and the material sampled • Limited in sample area (100 cm^2)	• Low levels of agent might be diluted within a large sample • Might not be applicable for wet surfaces (surfaces remaining wet after being soaked in liquid decontaminant)	These sampling devices are not intended to collect samples from specific/deep subsurface depths (unless a point-source bailer is used)	• The maximum depth that can be reached with a syringe sampler is approximately 1.8 meters • The lidded sludge/water sampling devise is rather heavy and limited to one jar size	• The COLIWASA, drum thief, and valved drum sampler can be difficult to decontaminate, and it might be difficult to collect samples from the bottom of the container • The drum thief cannot sample depths longer than the drum thief itself	Might be difficult to implement depending upon the accessibility of the sample area
Cautions or Additional Critical Information	• Extraction efficiencies and agent recoveries will vary with material and extraction approach • Constituents within some materials might interfere with detection technologies • Extractive-based sampling techniques are not well-defined/established • Neutralization might be needed to inhibit any residual decontamination solution that could possibly bias/lower the agent recoveries • Evidence collection sampling might have been conducted in this manner	• Extraction efficiencies and agent recoveries will vary with material and extraction approach • Constituents within some soils might interfere with detection technologies • Extractive-based sampling techniques are not well defined/established • Neutralization might be needed to inhibit any residual decontamination solution that could possibly bias/lower the agent recoveries • Small concentrations of a contaminant might be diluted within a larger bulk sample	• Agent recovery will vary depending upon the area sampled, material type, wipe material, amount and type of wetting solution, wipe pattern, etc. • Recovery might be affected by the presence of dirt and other residues as well as background chemical constituents	• Extraction efficiencies and agent recoveries will vary with material and extraction approach • Recovery might be affected by the presence of dirt and other residues as well as background chemical constituents	• Liquid samples should be collected with the appropriate neutralizers and stabilizers added • Larger sample volumes or multiple samples might be required so that filtration can be used to detect low levels of contamination	• Liquid samples should be collected with the appropriate neutralizers and stabilizers added • Larger sample volumes or multiple samples might be required so that filtration can be used to detect low levels of contamination	• Liquid samples should be collected with the appropriate neutralizers and stabilizers added • Larger sample volumes or multiple samples might be required so that filtration can be used to detect low levels of contamination	For sampling vapors that are heavier than air (e.g., sulfur mustard and Lewisite), include low lying areas where vapors might accumulate

	Extractive (Solid Material) Bulk Sampling	*Soil Sampling*	*Wipe (Surface) Sampling*	*Vacuum (Surface) Sampling*	*Liquid (Surface) Sampling*	*Liquid (Drum) Sampling – Discrete Depth Samplers*	*Liquid (Drum) Sampling – Profile Samplers*	*Air Sampling*
Previous Use(s)	Nassar et al. (1998) collected bulk vegetation samples from a military area exposed to nerve agent and subsequently remediated. Nassar et al. (1998) collected bulk vegetation samples from a military area exposed to nerve agent and subsequently remediated.	• Kimm et al. (2002) studied the application of headspace solid-phase microextraction of sulfur mustard from soil and subsequent GC/MS analysis • Solid phase microextraction fibers can sample CWAs in air, headspaces above solutions, water, or soil (Popiel and Sankowska, 2011)	• EPA (2014a) used wetted gauze sponges in a Lewisite decontamination study using glass and wood coupons • Nassar et al. (1998) used cotton wipes to sample painted surfaces from a military area exposed to nerve agent and subsequently remediated		Solid phase microextraction fibers can sample CWAs in air, headspaces above solutions, water, or soil (Popiel and Sankowska, 2011)	Solid phase microextraction fibers can sample CWAs in air, headspaces above solutions, water, or soil (Popiel and Sankowska, 2011)	Solid phase microextraction fibers can sample CWAs in air, headspaces above solutions, water, or soil (Popiel and Sankowska, 2011)	• Kimm et al. (2002) studied the application of headspace solid-phase microextraction of sulfur mustard from soil and subsequent GC/MS analysis • Smith et al. (2011could detect and quantify gaseous samples of CWA simulants with a fully automated, field-deployable, miniature MS equipped with a glow discharge electron ionization source and a cylindrical ion trap mass analyzer • Solid phase microextraction fibers can sample CWAs in air, headspaces above solutions, water, or soil (Popiel and Sankowska, 2011)
Reference(s)	EPA (2012d); Nassar et al. (1998); NRT (2015a)	EPA (2002b); Nassar et al. (1998); NRT (2015a); EPA (2002b); Kimm et al. (2002); Popiel and Sankowska (2011)	EPA (2008); EPA (2014a); Koester and Hoppes (2010); Nassar et al. (1998); NRT (2015a); Qi et al. (2013)	ASTM (2006)	EPA (2002b); NRT (2015a); Popiel and Sankowska (2011)	EPA (2002b); NRT (2015a); Popiel and Sankowska (2011)	EPA (2002b); NRT (2015a); Popiel and Sankowska (2011)	Kimm et al. (2002); NRT (2015a); Popiel and Sankowska (2011); Smith et al. (2011)

* Standardized Analytical Methods (SAM) (which guides the Emergency Response Laboratory Network [ERLN] laboratories) focuses on environmental sample types that are most prevalently used to fulfill EPA's homeland security responsibilities following an incident involving chemical agents (e.g., aerosols, surface wipes or swabs, drinking water, and post-decontamination wastewater). Other sample types (e.g., soil and vacuum samples) may have to be analyzed, and for those sample types, specific requests should be sent to the SAM technical contacts.

Appendix F. Findings and Recommendations from the Table-Top Exercise and Computer Simulation Assessments

Introduction

To evaluate the waste characterization process and the proposed best practices for waste characterization, a table-top exercise (TTX) was held on October 19, 2017 at the EPA facility in Edison, New Jersey. This report documents the exercise process and reports on the recommendations and findings from the players and attendees that were reported during the TTX.

Table-Top Exercise

The purpose of the exercise was two-fold: (1) obtain feedback on the "Best Practices to Minimize Laboratory Resources for Waste Characterization During a Wide-Area Release of Chemical Warfare Agents (October 9, 2017)" (BPD), a draft version of the Best Practices Guide (BPG), and the associated waste characterization process, and (2) evaluate the use of a simulated three-dimensional sampling environment computer simulation as a tool to review the BPD and waste characterization process. For the exercise, a scenario was developed, and waste characterization tasks were identified for players to perform. The overall scenario was designed to be generally consistent with the Denver WARRP scenario for chemical warfare agents. In the scenario, Agent Yellow (a mixture of Lewisite and distilled sulfur mustard [HD]) was released in the air over an urban environment.

Players in the exercise were identified from two main target groups at EPA, subject matter experts who would be able to provide technical feedback on elements of the BPD or individuals who might be expected to use the document as part of their duties during a wide-area CWA incident. Examples of individuals from EPA who were included based on the expectation that they might develop or implement waste characterization strategies during a wide-area incident include On-Scene Coordinators (OSCs) or Consequence Management Advisory Division (CMAD) staff. A list of players and attendees is provided in Attachment F1 to this appendix. Exercise materials, including the agenda, PowerPoint slide presentation, scenarios and associated player tasks, an identification of reference materials, and the player evaluation form are included in Attachments F2 through F10.

The TTX was performed in two parts: a traditional format and a computer simulation format. The sequence of exercise formats in the table-top was designed to increase in complexity from a set of drums containing waste materials to a simulated three-dimensional environment with a mixture of different waste and non-waste materials. For the traditional format, players were split into groups and given a waste characterization task to complete and report back on their selected approach. A simple scenario was provided where players were asked to make waste characterization decisions for a set of drums containing decontamination rinsate, decontaminated PPE, and office materials that had been decontaminated. Sampling results were provided for the areas where sampling was performed by the personnel who went through the decontamination process where the decontamination rinsate was generated.

For the computer simulation, players were to perform the assigned waste characterization task in three computer-generated locations (Figure F-1). The locations were: furnished office, warehouse, and outdoor area with decontamination material present. The computer simulation software provided a unique opportunity for interaction with a realistic, three-dimensional environment to perform waste characterization tasks. Interactive videos were also generated and served as an interaction tool for the user and the software. The contents of the locations were carefully selected to include materials for which waste characterization would be performed during an urban wide-area incident. Materials included office equipment, indoor materials (e.g., carpet, ceiling tile), mixture of low- and potentially high-value materials, porous and nonporous materials, materials that would be hazardous waste without presence of CWA-contaminated materials, and waste products generated from the decontamination of personnel. To encourage players to incorporate composite sampling, materials were selected for inclusion in the warehouse and outdoor setting that presented good opportunities for the appropriate use of composite sampling (e.g., rock salt, decontamination rinsate drums). The use of the simulation also provided a unique opportunity to capture the sampling behavior of players. Each collected sample was documented for player review during the performance of their sampling plan as well as for review after the exercise to evaluate sampling decisions made by players (Figure F-2a and b).

(a)

(b)

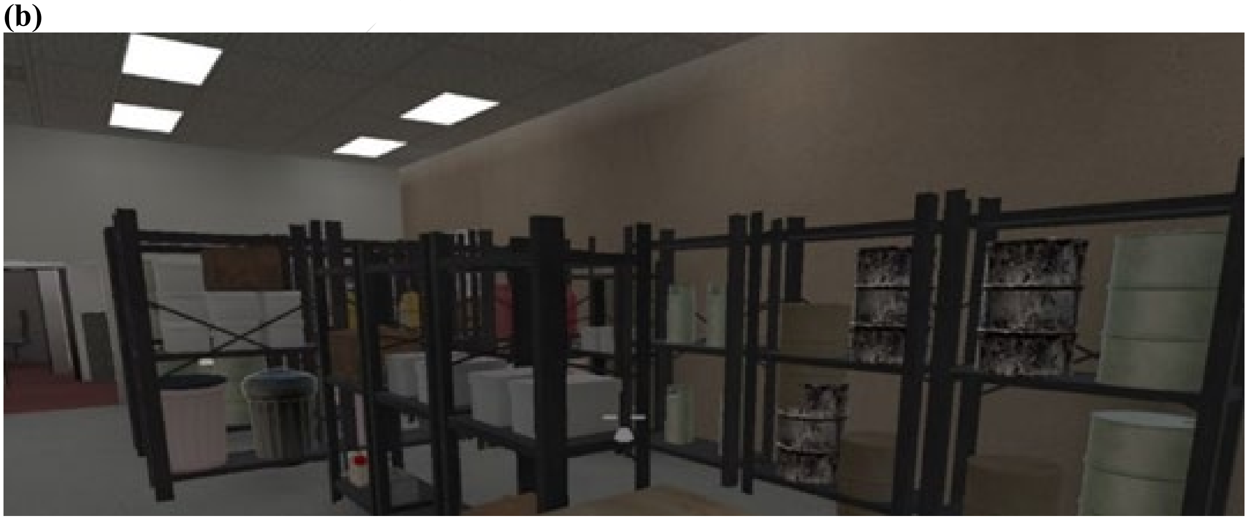
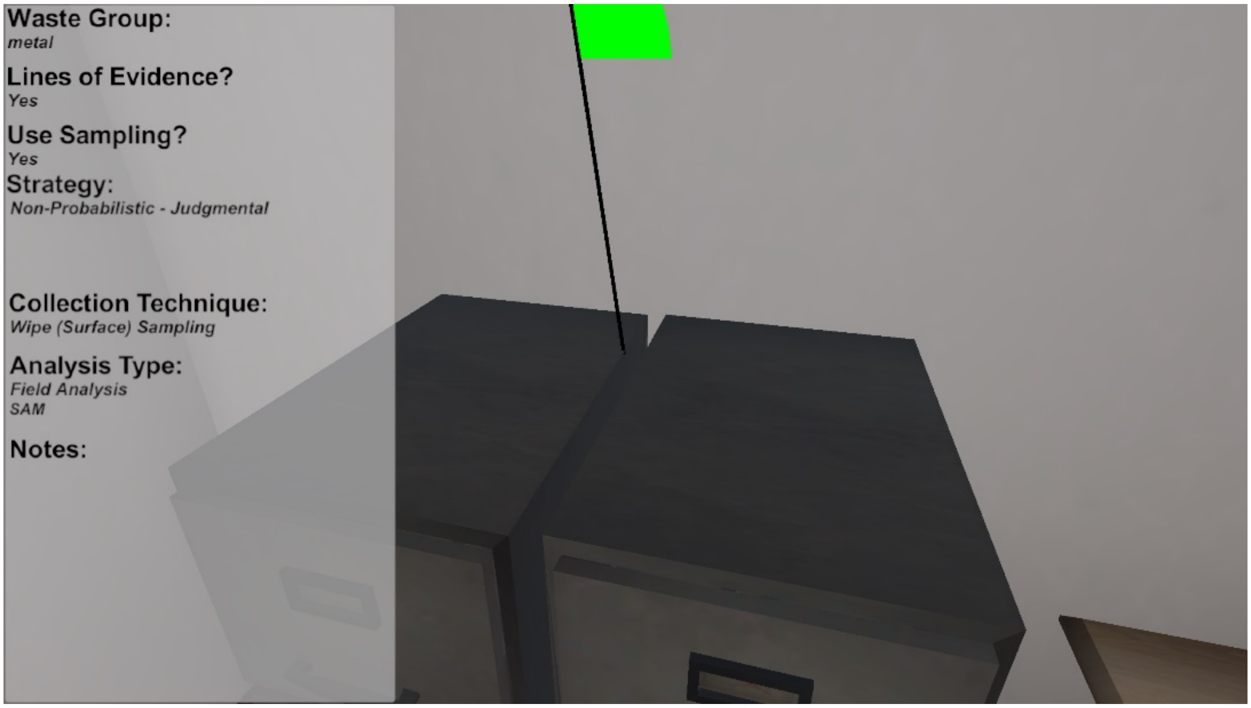


Figure F-1. Screenshot of computer simulation (a) office and (b) warehouse locations.

(a)



(b)

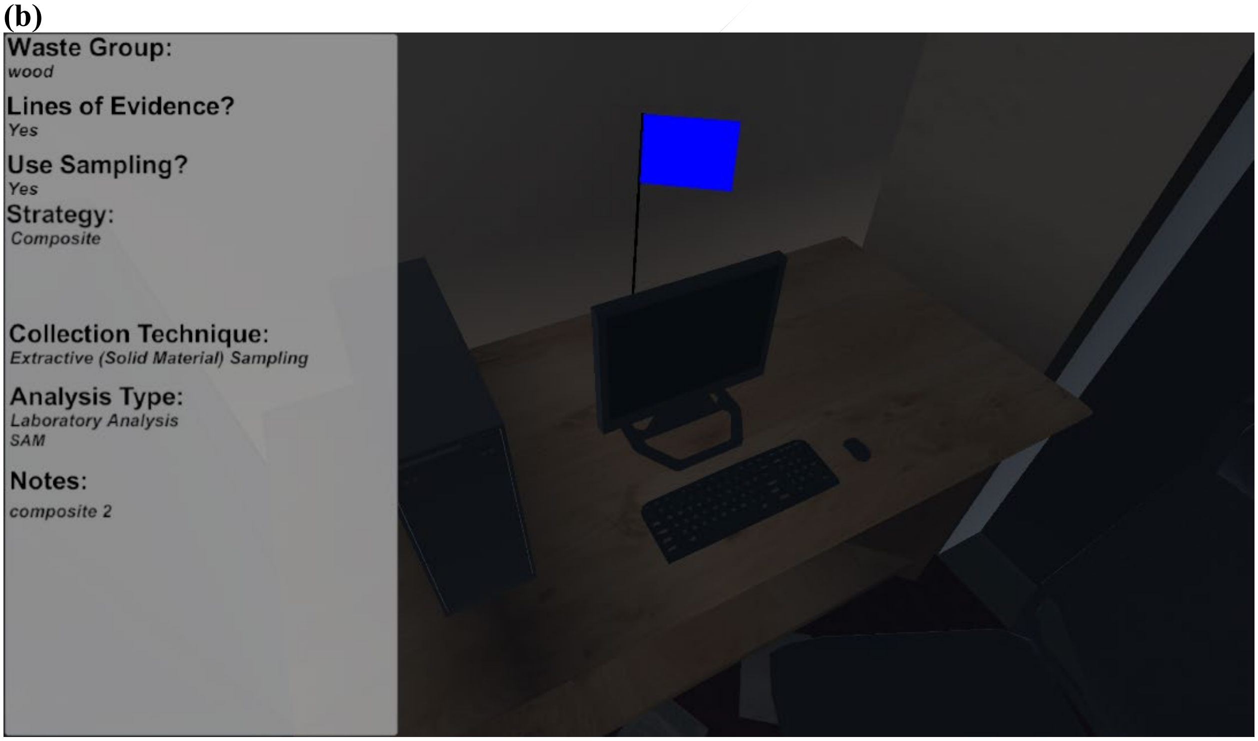


Figure F-2. Computer simulation sample capture for two waste group samples during exercise.

For each waste characterization task, players were encouraged to use the waste characterization process flow chart provided in the draft BPD and BPG. A Waste Characterization Worksheet (Attachment F.6) was also provided to assist users in the implementation of the waste characterization process. Additionally, the computer simulation software queried users regarding sampling choices using the same terminology and question sequencing as the waste characterization process presented in the BPD and BPG.

Figure F-3 illustrates the summary available for each sampling group that can be exported to Excel software to facilitate further analysis of these data. The capture of sampling data allows for the assessment of the identified waste groups that were determined to have homogenous characteristics, and the waste characterization strategy (i.e., lines of evidence, sampling).

Group Name	Image Name	Line of Evidence	Use Sampling	Strategy	Collection Technique	Analysis Type	Analysis Method
carpet	IndoorOffice_carpet_0	Yes	Yes	Non-Probabilistic - Judgmental	Extractive (Solid Material) Sampling	Laboratory Analysis	SAM
wood	IndoorOffice_wood_0	Yes	Yes	Non-Probabilistic - Judgmental	Extractive (Solid Material) Sampling	Laboratory Analysis	SAM
metal	IndoorOffice_metal_0	Yes	Yes	Non-Probabilistic - Judgmental	Wipe (Surface) Sampling	Field Analysis	SAM

Figure F-3. Computer simulation sample capture in Excel format.

Findings and Recommendations from Exercise

The players provided valuable feedback that will be used to improve the waste characterization process and associated documents. Feedback was provided verbally during hot wash discussions after the traditional TTX and computer simulation. A written player evaluation form was given to players for completion (Attachment F10). Players were not asked to achieve consensus on feedback elements or recommendations. As a result, the summary of feedback and recommendations is reflective of individual opinions with varying levels of concurrence from the group. For ease in reviewing, the material is categorized into the following: waste characterization process, material and content in the BPD and BPG, simulation software, suggestions for next reviewers, and format and content of the exercise. Note that some of the feedback and recommendations refer to the materials in this document that are contained in Appendices F and G. Therefore, the reader should evaluate these appendices in context with the summary below.

(1) Waste Characterization Process

(a) The waste characterization flow chart and process should identify that earlier upstream decisions could affect how waste characterization might be performed.

The waste characterization process might be affected by upstream decisions made in the response and recovery process. Examples of these decisions should be identified in the BPD and it should be noted that they might limit the ability to fully implement the proposed waste characterization strategy. Examples of upstream decisions that may affect waste characterization identified during the exercise are provided below. *The BPD and BPG were updated to identify the upstream decisions and the addition of waste volume to the waste acceptance criteria.*

- **The waste receiver that stores or manages the waste might dictate which decontamination technologies can be used (e.g., landfill that will not take waste unless specific type of treatment used)**. If waste characterization is not evaluated until the end of the decontamination and clearance processes, the use of the proposed waste characterization process might be significantly limited. Waste management planning, specifically including waste characterization considerations, should be an explicit element of earlier planning activities (e.g., Remedial Action Plans).
- **Process needs to identify that waste receivers will have limits to the volume of waste that they will accept**. The potential for waste receivers to identify a limit on the volume of waste that they will accept is an additional element to balance in the optimization of laboratory samples for analysis. It is possible that the total number of samples for laboratory analysis could be reduced through evaluation of the sampling requirements associated with waste acceptance criteria in combination with the volume of waste that can be managed by each individual receiver. The volume of waste that can be accepted by each waste receiver should be identified as an explicit element of the waste acceptance criteria.

(b) **Education/communication and acceptance by politicians, state and local regulators, and potential waste receivers will be critically important to implementation of the process.** The lines of evidence concept in the waste characterization process must be demonstrated to have acceptance by regulators and waste receivers. Players noted the concern that absent input from regulators and waste receivers regarding the acceptability of lines of evidence, there may be concerns about use of the proposed process during an incident. Ideally, communication with these stakeholders should begin prior to an incident and continue throughout the incident. Target areas for education should specifically include the lines of evidence approach. It was also noted that the waste might be placed in staging areas for an extended period while the waste receivers and regulators determine whether they will accept the waste. *The BPD was revised to identify the importance of early involvement by politicians, state and local regulators, and potential waste receivers. The potential for long-term storage or staging of the waste was also identified.*

(c) **The ability to effectively use the waste characterization process to reduce the laboratory analysis resources might be limited by CWAs for which there are scarce data or limited familiarity with expected agent behavior.** In contrast to level of knowledge associated with Agent Yellow constituents (i.e., HD, Lewisite), CWAs for which less is known might require more laboratory analysis of samples due to the lack of technical data that could be used to inform lines of evidence determinations. *This concept was added to the BPD.*

(d) **The waste characterization process should be presented as an all-hazards approach.** A player noted that an all-hazards approach for the waste characterization process could be evaluated to maximize its use. Overall strategies associated with waste characterization can be appropriately applied to all-hazards scenarios (e.g., biological agent, chemical agent, natural disasters) regardless of the agent, release environment, and other specifics of a wide-area incident. The tactics or specific decision-making considerations including lines of evidence could then be developed by waste and/or agent type (e.g., biological agents, chemical agents, storm debris) in document appendices. The comment suggested that the focus should be on a process that can be applied universally and not the development of an individual plan for each specific agent or group.

The document authors recommend that the BPD document continue to emphasize its development for CWAs, but note its potential utility for all-hazards application. *The BPD was revised to note that the process could be implemented as an all-hazards approach in the general sense that it could be evaluated for implementation across chemical incidents, whether the release involved CWAs in a wide-area incident or other catastrophic release of industrial chemicals that exhibited high acute toxicity or contaminated a significant volume of materials.*

(e) **The BPD must better communicate the importance of using the lines of evidence approach to perform waste characterization to most effectively reduce the number of samples analyzed at laboratories.** The players commented that the waste acceptance criteria have been determined for a set of CWAs in states that were associated with chemical demilitarization activities through the Department of Defense. However, these specific waste streams are well characterized and lack the sheer volume of waste materials likely to be generated during a wide-area incident.

The BPD needs to communicate clearly that waste characterization processes must meet all regulatory requirements, but the laboratory resources are not available to utilize sampling as it is typically conducted in waste characterization. The BPD should also continue to emphasize that the final determinations on whether a waste receiver will accept the proposed waste acceptance criteria are jointly decided by the waste receiver and regulator. However, it is still possible that these entities might choose to require extensive sampling as part of their waste acceptance criteria. *The BPD has been revised to more clearly emphasize the lines of evidence as a critical tool in the waste characterization process.*

(2) Material/Content in BPD and BPG

(a) **Identify the elements outside the scope of the waste characterization process in the BPD and BPG that will impact waste characterization decision-making.** The elements outside the process include a variety of potential considerations (e.g., politics, stigma, public concerns, cost, selection of decontamination technology). These elements were recommended to be explicitly identified in the document and their importance to the overall waste management process noted. The comment that cost should be included within the waste characterization process was also provided.

The BPD was revised to include an identification of the considerations that were deemed to be outside the waste characterization process. However, the decision to exclude cost as an explicit consideration within the BPD was maintained. The primary reason for this is the complexity of introducing cost within the process and the difficulty of identifying data to aid in implementing the process.

(b) **Tables 1 and 2 should be added to the BPG.** *The requested change was made to the BPG. The change was also made in the Executive Summary of the BPD.*

(c) **The BPD should incorporate additional content on the sample collection volumes to facilitate the use of split samples.** Given the limited number of samples that were allowed in the TTX and likely during an actual incident, the BPD should note the potential challenges of sufficient sample volume for splitting of samples for multiple analyses (e.g., inorganic and organic to capture arsenic from Lewisite and HD or degradation products in Agent Yellow scenario). *A new section has been added to the BPD to provide additional detail on split samples..*

(d) **The DQO appendix in the BPD is useful to assist in the waste characterization process.** The focused examples that are used to walk through the DQO should be helpful to users because of the difficulty in the development of this information. Concerns were noted that DQOs may not be necessary, while others identified the importance of DQOs as the basis to determine the necessary type and quality of data for waste characterization decisions. As an example, the DQOs will describe the type and quality of data necessary to make the lines of evidence "assumptions." *No change was made in response to this comment.*

(e) **Consider identifying waste characterization resources that will be associated with the response to a wide-area incident.** The BPD and BPG should identify contractor and waste receiver resources who will provide region-specific knowledge necessary for waste management during a wide-area incident. The resources will include contractors with a defined role in the remedial process (e.g., START) and representatives from facilities that will be the waste receivers (e.g., on-site treatment, storage, and disposal facilities [TSDF] representatives). A TSDF is a facility where hazardous wastes are stored, treated, and/or placed in or on land or water (EPA, 2015d). Waste receivers, including owner/operators of TSDFs, have region-specific knowledge of waste characterization, the TSDFs that might accept the waste, and associated waste acceptance criteria. These resources will be available throughout the duration of a wide-area incident to provide assistance and maintain current information on TSDF facilities. *This concept was added to the BPD and the BPG.*

Add more content to emphasize evaluation of degradation compounds in BPD. Given the importance of degradation compounds, more information should be included in the BPD for users that highlights their importance and provides additional background information. The draft BPD includes degradation compound information, but may not be easily found by players. *The Executive Summary of the BPD and the BPG were revised to note the availability of a summary table that included data on degradation compounds (Table B-1) and additional cross-references to the text were added to the BPD.*

(f) **Clarify in the BPD that non-Environmental Response Laboratory Network (ERLN) laboratories might not accept samples if there is the potential for CWA-contamination to be present.** In the context of sampling for arsenic from Lewisite breakdown or residual after decontamination, it was noted that laboratories that are not members of the ERLN group might not accept samples for analysis for non-CWA constituents due to the concern for potential CWA contamination. *The BPD was updated to note that the laboratories should be consulted prior to collection of samples to confirm that they will accept samples with potential CWA contamination and have capacity to perform the desired analyses.*

(g) **BPD may need to have greater emphasis that waste characterization is necessary prior to disposal of all materials from the incident.** It was noted several times during the meeting that sampling might not be warranted when the cost of material or sampling (e.g., labor, analysis) was greater than the cost of disposal (e.g., disposal of ceiling tile instead of sampling). While the statement regarding the cost of sampling relative to disposal may be true, waste characterization regulatory requirements must be met prior to disposal of all waste materials. It is possible that lines of evidence (e.g., decontamination efficacy) are implicitly being considered to assume that waste meets waste acceptance criteria for solid waste. It may be helpful if the BPD more clearly identifies the requirement for waste characterization and reaffirms that the process does not require sampling if proposed waste acceptance criteria are satisfactory to both regulators and waste receivers. An example or case study that illustrates this concept may help to clarify this point for the BPD user. The clam shell study described in the BPD is noted as a case study that incorporates this concept. *The BPD and BPG were revised to include earlier and more frequent mention that waste characterization is required for all wastes, but that sampling might not be required if acceptable to regulators and waste receivers.*

(h) ***The BPD provides a valuable summary of multiple documents.*** It was identified that the BPD should be very helpful because it combines materials from a several sources and provides a good resource for use. *No changes were made in response to this comment.*

(3) Simulation Software

The simulation software was outside the scope of the BPD and BPG, but was included as an evaluation tool for the waste characterization process. The exercise format was also used to evaluate potential uses of the simulation software for training or incident response. *No changes were made in the BPD and BPG in response to these comments. However, the comments were compiled for future consideration.*

(a) **The simulation software has utility for the training of OSCs and contractors who are involved in sampling planning and collection.** The simulation software will have utility for OSCs during initial sampling training to develop an understanding of sample strategies and sampling methods. There is also the potential for application in just-in-time training to highlight known sampling issues in a specific situation or to refresh knowledge. Because contractors are expected to do most of the actual sampling, there is value in including contractors as another group that could benefit from use of the software in training.

(b) Refinements for simulation software for training. The simulation software could be improved by the creation of more sampling locations. Identified sampling locations, also termed scenarios in the discussion, include transit hubs, subways, and stadiums. It may also be helpful to incorporate statistical sampling and the Visual Sampling Plan (VSP) directly within the simulation. The ability of the simulation software to generate a two-dimensional map of sampling locations that could be reviewed during or after the sampling session was identified as desirable. Players noted that it was cumbersome not to be able to "remove" or "change" a sample in the simulation after it had been collected. It was also suggested that the ability to click on flags to edit within the simulation or to make direct edits on the .csv summary Excel file would be useful refinements for the software.

(c) Simulation software may have limited utility for response activities. For use in response, it would be necessary to rapidly upload a three-dimensional representation of the impacted building structures and interior contents. It was assumed that these environments could not be built fast enough to use in the response unless they were already generated. It was noted that the NYC Prioritized Area Targeted Sampling (PATS) has pre-determined sampling locations in high-value locations. This situation where the simulation software could include these data as an environment for training may be a very good idea.

(4) Suggestions for Next Groups for Future Reviews of Process

The suggestions for groups for future reviews of the process was outside the scope of the BPD and BPG.

(a) The next overall review of the process should include the EPA regions, contractors, and a set of potential waste receivers. The next set of reviewers for the overall process should include the EPA regions and their contractors (e.g., START and TSDF representatives that have extensive experience in waste characterization). The group would be able to provide feedback on the acceptability of proposed waste characterization approaches. These representatives maintain ongoing contact with waste facilities. As noted earlier, they should be asked to review the utility of the lines of evidence concept (i.e., acceptable or generator knowledge) during a wide-area incident. Some players noted that POTWs were unlikely to accept waste regardless of the incident, but others disagreed because the POTW might recognize its system was already contaminated by uncontrolled discharges as might occur during a wide-area incident. For the future, groups representing POTWs may be an appropriate contact to begin the education process and determine if they would find the lines of evidence approach acceptable. *Some wording changes were made to the BPD to emphasize the complexity of POTW issues. Other waste-related comments were compiled for future consideration.*

(5) Format and Content of Exercise

The suggestions for improvements in the format and content of the exercise were outside the scope of the BPD and BPG. *No changes were made in the BPD and BPG in response to these comments. However, the comments were compiled for future consideration.*

(a) **To ensure a review of the actual BPD, a facilitator could be assigned to each group as they work through the exercise tasks to ensure that they are able to utilize the document.** Given that players only had access to the quick reference BPG prior to the exercise, players did not have time to acquaint themselves more fully with the full-size BPD for maximum use during the exercise. As a result, the waste characterization process was a greater focus of the review than the BPD. Another suggestion to allow for a more comprehensive review of the BPD was to provide training on the BPD prior to the exercise or include more training within the exercise.

(b) **The reversal of the exercise questions may be helpful for players to work through the scenario tasks easier.** As an example, the exercise could have started with a review of the DQO process supplied in an appendix in the BPD. This review would have provided the players with a more solid grasp of the waste acceptance criteria and desired sampling approaches. This sequencing of the presentation of exercise material would also reinforce the idea that the exercises, although focused on small areas, were actually part of a wide-area incident and therefore had unique waste management challenges.

(c) **Additional assumptions were needed to complete the tasks in the exercise.** Players felt that more complete assumptions were needed for them to efficiently complete the table-top tasks. Necessary data might include the volume of waste that each identified facility would accept or if the facility would accept the waste at all. Specifically, players wondered if a wastewater system would accept water treated on-site, especially if the system was already contaminated from uncontrolled discharge, as might occur during a wide-area incident. A control cell was included in the exercise, but players did not use that as an opportunity to ask questions. Future exercises should emphasize the importance of asking questions if players feel that they need additional information or are having difficulty with a specific assigned task.

Attachment F1. Player and Attendee List

The following is a list of the exercise players and attendees for the exercise.

Players

Consequence Management and Assessment Division
U.S. Environmental Protection Agency
David Bright
Elise Jakabhazy
Paul Kudarauskas
Michael Nalipinski
Shannon Serre

National Homeland Security Research Center
U.S. Environmental Protection Agency
Sarah Taft

Environmental Response Team,
U.S. Environmental Protection Agency
Lawrence Kaelin
Christopher Gallo

Office of Resource Conservation and Recovery
U.S. Environmental Protection Agency
Christina Langlois-Miller

Region 3
U.S. Environmental Protection Agency
Jessica Duffy
Charlie Fitzsimmons

Attendees

U.S. Environmental Protection Agency, National Homeland Security Research Center
Timothy Boe
Paul Lemieux
Matthew Magnuson
Erin Silvestri
Stuart Willison

Battelle
Stephanie Hines
Ryan James

Spectral Laboratories
John Rolando
Rhett Barnes

Attachment F2. Agenda for Exercise

Agenda

Date: October 19, 2017

Location: U.S. EPA Region 2
2890 Woodbridge Ave, Bldg 238
Edison, NJ 08837
Room 801

Best Practices to Minimize Laboratory Resources for Waste Characterization During a Wide-Area Release of Chemical Warfare Agents

8:00 Introduction

8:15 Begin Table-top exercise
- Scenario introduction and objectives
- TTX Worksheet

9:15 Discussion from Table-top

9:45 Wrap-up and Lessons Learned

10:00 Break

10:15 Begin Simulation exercise
- New Player Tutorial, Sample Collection Review Discussion, Player Use of Software (Note: Players can walk through all locations and then collect samples in one or two locations to test out simulation software)

10:30 Participants walkthrough simulation and perform simulation exercises

11:30 Discussion from Simulation

12:00 Wrap-up and Lessons Learned from Simulation and additional comments from TTX

12:30-12:45 Adjourn

F3. Presentation Provided to Players

Best Practices to Minimize Laboratory Resources for Waste Characterization During a Wide-Area Release of Chemical Warfare Agents TTX Exercise

US EPA Region 2

Edison, New Jersey

October 19 2017

Disclaimer: This document is distributed solely for the purpose of pre-dissemination peer review under applicable information quality guidelines. It has not been formally disseminated by the U.S. Environmental Protection Agency. It does not represent and should not be construed to represent any agency determination or policy.

1

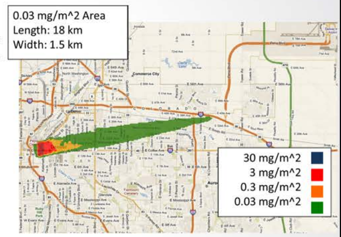
Agenda for Exercise

- Exercise Scenario Overview
- Review of Waste Characterization
- Table-top Exercise with Hotwash
- Break
- Simulation Exercise with Hotwash
- Review of Best Practices for Waste Characterization Document and Exercise Format

2

Exercise Scenario Overview

- Urban wide-area release of chemical blister agent
  - Agent Yellow – 55 gallons of 50/50 mixture of Mustard and Lewisite, agent is relatively persistent, low volatility and water solubility, rapid hydrolysis, potentially strong sorption to some materials
- Released to air in an urban area, with transport through air and movement of contaminated vehicles and individuals
- Hundreds of buildings impacted over 5-mile area from release
- Waste is generated during all phases of the incident



Agent Yellow surface concentrations

We're excited to be able to add a 3-D simulation element to this review process and are interested in your feedback on this element of the exercise.

3

Waste Characterization Exercise

- Table-top
  - Set of waste-containing barrels to characterize
  - Contents include decontamination rinsate, used PPE, and other materials
  - Apply best practices to characterize with limited number of samples
- Computer Simulation
  - Increased complexity in waste characterization task
    - Office
    - Warehouse
    - Industrial Park
  - Apply best practices to characterize with limited number of samples
- We need your help to review the Best Practices process!

4

What is Waste Characterization?

- Waste Characterization is the use of sampling and/or knowledge of the waste (i.e., lines of evidence) to document waste meets regulatory requirements and any additional requirements of waste receivers
- Type of data
  - Lines of Evidence
    - Information or data from various sources that can be used to support waste characterization decisions.
    - Lines of evidence can include technical data on agent fate and transport, persistence in defined environmental conditions, and efficacy of decontamination technologies.
  - Sampling
- Who determines the standards for waste characterization?
  - Must meet Federal/state/local regulatory requirements
  - Must meet any meet any other identified requirements of waste receivers (e.g., Landfill or POTW operators)

5

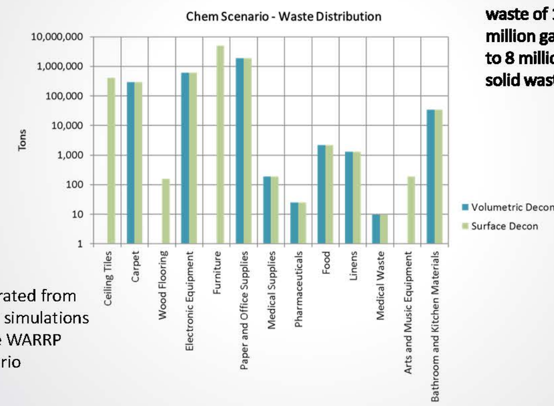
Waste in Wide-Area Incident

- Waste is any material that is intended for disposal and will not be re-used or recycled
- Waste streams will be generated throughout the incident
  - Personal Protective Equipment (PPE) – gloves, suits, boot covers
  - Decontaminated items for disposal or further management
    - Office materials, dry wall, carpet, ceiling tiles, cubicles, furniture, paper
  - Decontamination rinsate
- Volume of waste material prevents from use of typical sampling approaches used for industrial processes or typical Superfund remedial setting

6

Wide-area Waste Volumes

Estimated total liquid waste of 15 to 36 million gallons and 3 to 8 million tons of solid waste



Generated from WEST simulations of the WARRP Scenario

7

Wide-area Incident Waste Characterization Challenges

- Why do we need to limit the number of analysis samples?
  - Capacity for laboratory analysis of samples cannot meet the sampling demand in chemical agent wide-area event
  - Sampling is used extensively in wide-area incident for site characterization, decontamination efficacy, waste characterization, and clinical or medical samples
    - Waste will likely be a low priority for analysis
  - Potential for sampling to be a chokepoint in response and recovery process
- Best practices designed to reduce the number of samples sent to laboratories for analysis for waste characterization

8

Development of Best Practices Document

- Process to generate Best Practices Document
  - Targeted literature search to identify published, open-source data available
    - Wide-area event sampling considerations and waste characterization
    - General waste characterization approaches that may be applied or customized for use
- Important pre-planning activity to identify and address data gaps
- Continuing technical peer review

Table of Contents

9

Waste Management Resources

- Pre-incident Waste Management Plan
  - Describes planning activities that have been conducted for incident
  - Identifies anticipated waste streams, volume of materials, potential management locations/entities and associated waste acceptance criteria
  - Tool to develop the pre-incident waste management plan are available and will be discussed in more detail later today
- Additional information in binders
  - Four-step Waste Management Planning Process
  - All-hazard Waste Management Decision Diagram

10

Waste Characterization Flow Chart

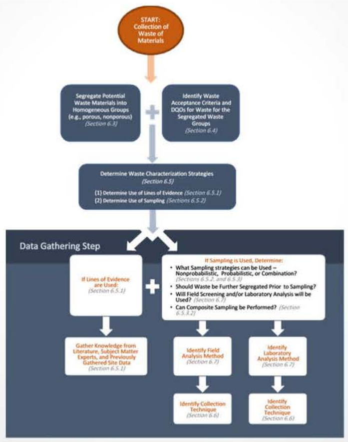


Figure 5 in Best Practices Document

11

Best Practices for Waste Characterization to Minimize Sample Numbers

- Segregate wastes
  - Group similar wastes to consolidate sampling tasks
- Identify Waste Acceptance Criteria and DQOs for segregated waste groups
- Determine Waste Characterization Strategy for segregated waste groups
  - Strategy: Lines of Evidence and/or Sampling
- Identify Analysis Method (if sampling)
  - Determine Laboratory Method or Field Screening
- Identify Sampling Collection Technique (if sampling)

12

Table-top

13

Table-top Scenario

- 7 days after the release of Agent Yellow
- Temperatures have been approximately 70F in the daytime and 50F at night
- Building HVAC systems have not run since the evening of the release
- Waste was generated during sampling to determine the extent of contamination in an office suite of one building
  - Average concentration levels derived from wipe samples from nonporous surfaces
    - First floor office – 7 $\mu g/cm^2$ for Sulfur Mustard and 7 $\mu g/m^2$ for Lewisite
    - Second floor office – 0.01 $\mu g/cm^2$ for Sulfur Mustard and 0.001 $\mu g/cm^2$ for Lewisite

14

Table-top Scenario Task

- The exercise task is to perform waste characterization for the following collection of waste materials:
  - Eight 55-gallon drums containing decontamination rinsate that used a bleach and water mixture to decontaminate material
  - Two labeled 55 gallon drums with an assortment of used PPE
  - Two labeled 55-gallon drums of mixed soaked porous materials treated with bleach and water
  - You have **2** samples that can be sent to laboratory analysis
- Hint 1: Remember Available Sampling Data
  - Average concentration levels derived from wipe samples from nonporous surfaces
    - First floor office – 7 µg/cm^2 for Sulfur Mustard and 7 µg/m^2 for Lewisite
    - Second floor office – 0.01 µg/cm^2 for Sulfur Mustard and 0.001 µg/cm^2 for Lewisite
- Hint 2: Many Ways to Segregate Waste
  - Consider ways that best reduce or eliminate laboratory sampling
- We acknowledge that there may be some elements of the scenario that may not be true to all elements of wide-area incident
  - Please refrain from fighting the scenario

15

Table-top Drum Detail

8 Decontamination Rinsate Drums

Labels identify that waste was generated from decontamination of personnel, equipment, and other materials and identify the office floor materials removed from (First or Second Floor)

2 drums labeled to contain assorted used PPE, the PPE in each drum is contained in a bag

2 drums labeled to contain decontaminated office materials and removed from second floor, office materials are contained in a bag in each drum

16

Table-top Resources

- Review Binder Contents
  - Best Practices Document (Full length)
  - Best Practices Guide (3 pager brief)
  - NRT Quick Reference Guide (QRG) for Mustard-Lewisite Mixture
  - Pre-incident Waste Management Plan and Waste References
    - Identifies est. waste quantities, regulatory requirements, management strategies, waste acceptance criteria, waste management facilities
  - Scenario and table-top tasks
  - Summary Table Handout (Exercise Use Only)
    - Waste acceptance criteria, method detection limits, generalized DQOs

- Control Cell – Available to ask questions, copies of selected NHSRC SAM documents
- We will distribute Waste Characterization Worksheets to the group for use.

17

Overview of Waste Characterization Worksheet

Best Practices for Waste Characterization Worksheet

(1) **Segregate the waste into homogeneous groups relevant for waste characterization and complete this worksheet for each segregated waste group that was identified. (Section 6.3)**

Segregated Waste Group Name: ______________________________

(2) **Please consider the following questions collectively before identifying your final response to each.**

(a) Identify Waste Acceptance Criteria for the segregated waste group (Section 6.4 and Pre-incident Waste Management Plan).

Waste Acceptance Criteria: ______________________________

____

(b) Identify relevant DQOs for the segregated waste group (Section 6.4 and Summary Table).
For exercise purposes, consider using these example DQOs:
- Acceptable waste characterization strategies can take the form of concentration-based or performance-based criteria,
- The detection limits must be at or lower than the identified waste acceptance criteria, and
- For acceptance of the waste, none of the samples from a segregated waste group can exceed the waste acceptance criteria.

DQOs: ______________________________

18

Overview of Waste Characterization Worksheet

(a) Determine Waste Characterization Strategy (Section 6.2 including Figure 3, Section 6.5)
(Note: More than one strategy can be used)

Will Lines of Evidence be Used? (Section 6.5.1) Yes No

Will Sampling be Used? (Section 6.5.2) Yes No

If Lines of Evidence will be used, describe the basis for the determination:

____

____

If sampling will be used, determine the sampling strategy. (Section 6.5.2, Table 1)

(b) Which sampling strategy will be used?

Nonprobabilistic Probabilistic Combination of Both

Further define sampling strategy (e.g., judgmental, simple random)

____

(c) Will composite sampling be performed? (Section 6.5.3.2) Yes No

(d) If sampling will be used, describe sample number(s) and location/material

____

19

Overview of Waste Characterization Worksheet

(g) Identify the sample collection method(s). (Section 6.6 and Table 2)
(Note: More than one strategy can be used)

Field Analysis Collection Method: ____________________

Laboratory Analysis Collection Method: ____________________

Identify type of sampling and the analysis method. (Section 6.7)
(Note: More than one strategy can be used)

Field Analysis Yes No Method: ____________________

Laboratory Analysis Yes No Method: ____________________

Waste Characterization Summary Box

Segregated Waste Group Name: ______________________________

Describe Approach to Segregation: ______________________________

____

Waste Characterization Strategy: ______________________________
(Identify Lines of Evidence, Sampling or Combination)

Total Sample Number Sent to Laboratory for Analysis: ____________________

Total Number of Field Samples Collected: ____________________

20

Table-top Scenario Task

- The exercise task is to perform waste characterization for the following collection of waste materials:
  - Eight 55-gallon drums containing decontamination rinsate that used a bleach and water mixture to decontaminate material
  - Two labeled 55 gallon drums with an assortment of used PPE
  - Two labeled 55-gallon drums of mixed soaked porous materials treated with bleach and water
  - You have **2** samples that can be sent to laboratory analysis
- Hint 1: Remember Available Sampling Data
  - Average concentration levels derived from wipe samples from nonporous surfaces
    - First floor office – 7 $\mu g/cm^2$ for Sulfur Mustard and 7 $\mu g/m^2$ for Lewisite
    - Second floor office – 0.01 $\mu g/cm^2$ for Sulfur Mustard and 0.001 $\mu g/cm^2$ for Lewisite
- Hint 2: Many Ways to Segregate Waste
  - Consider ways that best reduce or eliminate laboratory sampling
- We acknowledge that there may be some elements of the scenario that may not be true to all elements of wide-area incident
  - Please refrain from fighting the scenario

21

Table-top Exercise – Hotwash

- How did you approach the waste characterization task?
- How much prior knowledge (defined as knowledge you walked in to exercise with and prior to use of the Best Practices document) did you utilize in performing the waste characterization task?
- What elements of the Best Practices document were most helpful to perform this task? What elements can be improved? How?
- Where there any concepts or ideas that were not in the BPD that you feel should be added? Any references missing?
- What available resources provided the most assistance?

22

Simulation

Simulation Scenario and Task

- It is now 10 days after the release of Agent Yellow in the same scenario
- Temperature and relative humidity have stayed the same
- The office floor, warehouse, and outdoor locations have been decontaminated with a bleach and water solution
- You are to identify and characterize the waste present in each location
  - Segregate, Identify Waste Acceptance Criteria and DQOs, Waste Characterization Strategy, and Collect Data
- You have a total of 24 samples for the three locations
- You will complete sampling at one location before entering the next location

Simulation Resources

- Same resources in binder as used in the table-top
- Please remember
  - Complete the Notes section in software thoroughly to document your sampling choices
  - Control Cell – Available to ask questions
  - We will distribute Waste Characterization Worksheets to the group for use.

25

Sample Capture Process

- Simulation mirrors waste characterization flow chart

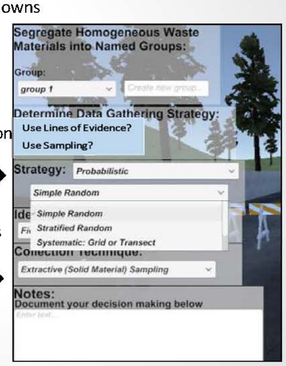
BP Section6.3

BP Section 6.5.1 and 6.5.2

- When you choose sampling, follow flow downs

BP Section 6.5.2

BP Sections 6.6 and 6.7



Please complete notes to document thought process

26

Simulation Scenario and Task

- It is now 10 days after the release of Agent Yellow in the same scenario
- Temperature and relative humidity have stayed the same
- The office floor, warehouse, and outdoor locations have been decontaminated with a bleach and water solution
- You are to identify and characterize the waste present in each location
  - Segregate, Identify Waste Acceptance Criteria and DQOs, Waste Characterization Strategy, and Collect Data
- You have a total of 24 samples for the three locations
- You will complete sampling at one location before entering the next location

27

Simulation - Hotwash

- How did you approach this waste characterization task?
- Review selected player sample captures
- The simulation introduced a more challenging waste characterization task in a more complex environment. Did that affect your data gathering strategy? How was your strategy affected?
- Did the Best practices document provide sufficient information to help you reduce sample numbers? What was most useful? Least useful?

28

Wrap-up Discussion

- After using the Best Practices document for table-top and simulation tasks, what did you find most useful about the Best Practices document?
- What are suggested improvements to the Best Practices document to improve effectiveness to reduce sampling number or increase ease of use?
- Was there sufficient description in the Best Practices document to select an appropriate data gathering strategy?
- Did the waste characterization document sufficiently describe the available data gathering strategies to aid in decision-making?

29

Wrap-up Discussion

- Did you have sufficient technical information to reduce samples sent to the laboratory for waste characterization?
- Did you find listing the pros/cons of the sampling strategies useful in the Best Practices document ?
- Is the exercise format (table-top, simulation) used for today's meeting a useful approach to review the Best Practices document ?
- Could this simulation be used for a wide-area incident? Are there other simulations that you would like to see?
- Do you think the simulation format would be a useful training tool?

30

Next Steps

- Thank your for your help!
- We will use your feedback to revise and the strengthen Best Practices for Waste Characterization document and associated waste characterization processes.

- Thank you for your assistance and safe travels home!

31

Attachment F4. Overall Scenario Provided to Players

The scenario is based on the Wide-Area Recovery & Resiliency Program (WARRP) scenario for a hypothetical wide-area incident involving chemical blister agent. However, it is modified to facilitate its use for the tabletop and simulation environment evaluation of the Standard Operating Guideline (SOG) draft documents.

The chemical Agent Yellow is released in an urban environment. Agent Yellow is a 50/50 mixture of the blister agents Mustard and Lewisite, and approximately 55 gallons are released from an airplane in a coarse spray over the Denver urban area. Agent Yellow is relatively persistent and expected to present a hazard for 24 hours or more. Mustard and Lewisite have low volatility, low water solubility, but potentially strong sorption to specific material types. Mustard may exhibit a delayed toxic response, whereas Lewisite may cause immediate and significant health effects.

The agent release by air directly contacts and contaminates exposed individuals, building exteriors, streets, vehicles, and other urban infrastructure. Agent is then further transported from the immediate release area through vapors that travel downwind and movement of contaminated individuals and/or vehicles traveling away from the contaminated area. If they enter buildings to take cover, individuals may track contamination into buildings. Agent Yellow vapor may also be taken up by building HVAC systems and serve as a pathway for the contaminated outdoor air to be transported into building interiors.

This same scenario will be used for the tabletop and simulation exercises. The exercises will focus on decision-making associated with sampling and characterization of waste and subsequent steps needed to properly manage wastes generated from the interior of a contaminated building during response and recovery activities. Waste management decisions are made throughout the response and recovery effort. Collectively, hundreds of facilities could be contaminated over a five-mile area from the release location (DHS, 2012), with an estimated 15 to 36 million gallons of aqueous waste and 3 to 8 million tons of solid waste associated with the incident (EPA, 2012). Federal and state requirements for waste management note that all waste must be appropriately characterized as part of a proper management plan. Waste streams might include PPE, items decontaminated for disposal or further management, and decontamination wastewater.

References

EPA, 2012. *WARRP Waste Management Workshop*, U.S. Environmental Protection Agency, Office of Homeland Security: Denver, CO, March 15-16.

DHS, 2012. *Wide Area Recovery and Resiliency Program (WARRP) Key Planning Factors for Recovery from a Chemical Warfare Agent Incident*. U.S. Department of Homeland Security. Summer 2012. https://www.fema.gov/media-library/assets/documents/31719.

Attachment F5. Traditional Table-top Scenario and Task

<u>Table-top Scenario</u>

- 7 days after the release of Agent Yellow
- Temperatures have been approximately 70 ºF in the daytime and 50 ºF at night
- Building HVAC systems have not run since the evening of the release
- Waste was generated during sampling to determine the extent of contamination in an office suite of one building
  - Average concentration levels derived from wipe samples from nonporous surfaces
    - First floor office – 7 µg/cm^2 for Sulfur Mustard and 7 µg/m^2 for Lewisite
    - Second floor office – 0.01 µg/cm^2 for Sulfur Mustard and 0.001 µg/cm^2 for Lewisite

<u>Table-top Task</u>

- The exercise task is to perform waste characterization for the following collection of waste materials:
- Eight 55-gallon drums containing decontamination rinsate that used a bleach and water mixture to decontaminate material
- Two labeled 55-gallon drums with an assortment of used PPE
- Two labeled 55-gallon drums of mixed soaked porous materials treated with bleach and water
- You have <u>two</u> samples that can be sent to laboratory analysis

<u>Hints Provided</u>

Hint 1: Remember Available Sampling Data

- Average concentration levels derived from wipe samples from nonporous surfaces
  - First floor office – 7 µg/cm^2 for Sulfur Mustard and 7 µg/m^2 for Lewisite
  - Second floor office – 0.01 µg/cm^2 for Sulfur Mustard and 0.001 µg/cm^2 for Lewisite

Hint 2: Many Ways to Segregate Waste

- Consider ways that best reduce or eliminate laboratory sampling
- We acknowledge that there may be some elements of the scenario that may not be true to all elements of wide-area incident, please refrain from fighting the scenario

Attachment F6. Waste Characterization Worksheet

Best Practices for Waste Characterization Worksheet

(1) Segregate the waste into homogeneous groups relevant for waste characterization and complete this worksheet for each segregated waste group that was identified. (Section 6.3)

Segregated Waste Group Name: ____

(2) Please consider the following questions collectively before identifying your final response to each.

(a) Identify Waste Acceptance Criteria for the segregated waste group (Section 6.4 and Pre-incident Waste Management Plan).

Waste Acceptance Criteria:

____

____

(b) Identify relevant DQOs for the segregated waste group (Section 6.4 and Summary Table).

For exercise purposes, consider using these example DQOs:

- Acceptable waste characterization strategies can take the form of concentration-based or performance-based criteria,
- The detection limits must be at or lower than the identified waste acceptance criteria, and
- For acceptance of the waste, none of the samples from a segregated waste group can exceed the waste acceptance criteria. (e.g., If/Then Statement: If any concentrations of sulfur mustard >0.1 µg/cm^2 are detected in the wipes of the sampled containers from a waste lot, then the waste in that lot will not be disposed of in the Subtitle C landfills without further decontamination and reassessment or the waste might be sent to hazardous waste incinerators.)

DQOs:

____

____

____

(c) Determine Waste Characterization Strategy (Section 6.2 including Figure 3, Section 6.5)
(Note: More than one strategy can be used)

Will Lines of Evidence be Used? Yes No
(Section 6.5.1)

Will Sampling be Used? Yes No
(Section 6.5.2)

If Lines of Evidence will be used, describe the basis for the determination. (Section 6.5.1)

____

____

If sampling will be used, determine the sampling strategy (Section 6.5.2 and Table 1)

(d) Which sampling strategy will be used?

Nonprobabilistic Probabilistic Combination of Both
Further define sampling strategy (e.g., judgmental, simple random)

____

(e) Will composite sampling be performed? (Section 6.5.3.2) Yes No

(f) If sampling will be used, describe sample number(s) and location/material

____

____

(g) Identify the sample collection method(s). (Section 6.6 and Table 2)
(Note: More than one strategy can be used)

Field Analysis Collection Method:

____

Laboratory Analysis Collection Method:

____

Identify type of sampling and the analysis method. (Section 6.7 and Summary Table)

(Note: More than one strategy can be used)

Field Analysis Yes No Method:

Laboratory Analysis Yes No Method:

Waste Characterization Summary Box
Segregated Waste Group Name:

Describe Approach to Segregation:

Waste Characterization Strategy:

(Identify Lines of Evidence, Sampling or Combination)

Total Sample Number Sent to Laboratory for Analysis:

Total Number of Field Samples Collected:

Attachment F7. Computer Simulation Scenario and Tasks

- It is now 10 days after the release of Agent Yellow in the same scenario
- Temperature and relative humidity have stayed the same
- The office floor, warehouse, and outdoor locations have been decontaminated with a bleach and water solution
- You are to identify and characterize the waste present in each location
    - Segregate, Identify Waste Acceptance Criteria and DQOs, Waste Characterization Strategy, and Collect Data
- You have a total of 24 samples for the three locations
- You will complete sampling at one location before entering the next location

Attachment F8. Summary Table Identifying Potential Waste Acceptance Criteria for Water, Soils, and Surface Wipes for Mustard and Lewisite. (For Exercise Use Only- The table was used for the purposes of this exercise and this inherent approach should not necessarily be used for a specific incident)

	Water		Soils		Surface Wipes	
	Mustard	**Lewisite**	**Mustard**	**Lewisite**	**Mustard**	**Lewisite**
Potential Waste Acceptance Criteria for POTW (Water), Soil and Surface Wipes (Subtitle C Solid Waste Landfill)						
Quick Reference Guide (QRG) Exposure Guidelines (NRT, 2015b)	140 µg/L[a]	80 µg/L[b]	Residential Exposure Scenario 0.01 mg/kg (10^{-5} cancer risk)	Residential Exposure Scenario 0.3 mg/kg	*No Data*	*No Data*
Condensed Chemical Agent Field Guidebook for Consequence Management (NRT, 2015b)	140 µg/L [a]	28 µg/L[b]	Residential Exposure Scenario 0.01 mg/kg (10^{-5} cancer risk)	Residential Exposure Scenario 0.3 mg/kg	8.1×10^{-5} µg/cm^2	6.0×10^{-2} µg/cm^2[c]
Method Detection Limits						
QRG Real-time Field Screening Equipment Identified Detection Limits[3]	M272 (water) 2.0 mg/L (2000 µg/L)	M272 (water) 0.1-2 mg/L (100 to 2000 µg/L)	*No Data*	*No Data*	*No Data*	*No Data*
SAM Rapid Screening and Preliminary Identification Techniques and Methods (EPA, 2012)	Photoionization mass spectrometry 0.07 to 0.7 mg/L (70 to 700 µg/L)	Spectrophotometry (fieldable) Detection range 0.02 to 0.20 mg/L, (20 to 200 µg/L) Measures total arsenic	GC – MS – EI, EPA Method 3571/3572 with 8271 (EPA SW-846 Compendium) No detection limit identified. Recovery levels for direct injection soil recovery, 103 to 112(+/-19)%	X-ray Fluorescence (fieldable), EPA Method 6200/SW-846 (EPA SW-846 Compendium) Interference free detection limit 40 mg/kg, Measures total arsenic	GC – MS – EI, EPA Method 3571/3572 with 8271 (EPA SW-846 Compendium) No detection limit identified. Recovery levels for direct injection soil recovery, 103 to 112(+/-19)%	X-ray Fluorescence (fieldable), EPA Method 6200/SW-846 (EPA SW-846 Compendium) Interference free detection limit 40 mg/kg, Measures total arsenic

	Water		Soils		Surface Wipes	
	Mustard	**Lewisite**	**Mustard**	**Lewisite**	**Mustard**	**Lewisite**
Standardized Analytical Methods for Environmental Restoration Following Homeland Security Events (SAM) (EPA, 2012)	CWA Protocol (EPA NHSRC) Calibration range in full scan mode for water, 5.7 to 57 µg/L	Analyze for total arsenic	CWA Protocol (EPA NHSRC) Calibration range in full scan mode for soils 10 to 100 µg/kg (0.01 mg/kg to 0.1 mg/kg)	Analyze for total arsenic ICP-AES, EPA SW-846 Method 3050B Instrument detection limit, 30 µg/L for extraction	CWA Protocol (EPA NHSRC) Calibration range in full scan mode for wipes 0.01 to 0.1 $\mu g/cm^2$	Analyze for total arsenic NIOSH Method 9102 Instrument detection limit, 30 µg/L for extraction

Attachment F8 Table Notes:

Generalized Data Quality Objectives (DQOs) for Waste Characterization

1 Acceptable waste characterization strategies can take the form of concentration-based criteria or performance-based criteria. Concentration-based, also termed numerical-based criteria, identify chemical-specific concentrations that must be met and will include the presentation of analytical results to document attainment. The second type of waste acceptance criteria, performance-based criteria, identify the technologies or treatment processes that must be used and the necessary information to document that the processes were effectively implemented (i.e., lines of evidence).

2 All waste must be appropriately segregated prior to sampling. Segregation must be performed to account for potential variability in contaminant concentrations that may affect ability to gather representative samples. Examples of considerations include: material type (e.g., porous, nonporous), expected contamination levels, and application of similar decontamination technologies.

3 The detection limits must be at or lower than the identified waste acceptance criteria when sampling is performed.

4 For acceptance of the waste, none of the samples from a segregated waste group can exceed the waste acceptance criteria. Further decontamination or reassessment of the waste will be necessary. An example of an acceptable decision statement for type of decision statement this DQO is: Determine whether each lot of decontaminated waste can be disposed of in a Subtitle C landfills. The theoretical decision rule in the form of an if/then statement is as follows: If any concentrations of sulfur mustard >0.1 $\mu g/cm^2$ are detected in the wipes of the sampled containers from a waste lot, then the waste in that lot will not be disposed of in the Subtitle C landfills without further decontamination and reassessment or the waste might be sent to hazardous waste incinerators. Otherwise the lot of waste will be considered acceptable for disposal in the Subtitle C landfills.

Summary Table Notes:

[a]The U.S. Army's Military Exposure Guidelines (MEGs) were used due to the absence of public health values; the MEG at 5 L/day, for 7 days = 140 ug/L (NRT, 2015).

[b]The U.S. Army's Military Exposure Guidelines (MEGs) were used due to the absence of public health values; the MEG at 5 L/day, for 7 days = 80 ug/L (NRT, 2015).

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

Attachment F9. Reference Materials Provided to Players

(1) Draft Best Practices Guide to Minimize Laboratory Resources for Waste Characterization During a Wide-Area Release of Chemical Warfare Agents (BPG) (See revised BPG in Appendix G)

(2) Draft Best Practices Document to Minimize Laboratory Resources for Waste Characterization During a Wide-Area Release of Chemical Warfare Agents (BPD)

(3) National Response Team Reference Guide (QRG). Mustard – Lewisite Mixture (HL). July 2015 Update.

(5) Waste Management Resources including: Pre-incident All Hazards Waste Management Plan Guidelines: Four-step Waste Management Planning Process.

(6) All-hazards Waste Management Decision Diagram

(7) Summary Table Identifying Potential Waste Acceptance Criteria for Water, Soils, and Surface Wipes for Mustard and Lewisite (Marked "For Exercise Use Only")

Attachment F10. Player Evaluation Form

Player Evaluation
Draft Chemical Agent Waste Management Review Exercise
October 19, 2017

Please provide input for each of the following statements provided below:

(1) What did you find useful about the waste characterization best practices document?

2) Please identify suggested improvements for the Waste Characterization document that would increase its effectiveness to reduce sample number or increase its ease of use.

3) Did the waste characterization document provide the necessary technical information to reduce the number of samples sent to the laboratory for waste characterization tasks during a wide area incident?

4) Did the waste characterization document sufficiently describe the different sampling strategies that are available to allow for a decision to be made regarding the type of sampling strategy needed for waste characterization?

5) Did you find listing the sampling strategies and their respective advantages and tradeoffs useful within the waste characterization document?

6) Are there any waste characterization resources that you currently using that are missing within the waste characterization document?

1

7) What sampling strategy (sampling, process knowledge, and combination of sampling and process knowledge) did you use in the Tabletop and simulation for waste characterization and why?

8) Did you find the TableTop exercise and Simulation useful for applying the Waste Characterization document to a scenario?

9) Could the simulation be used for a wide area incident? If useful, what other simulations would you like to see developed?

10) Did you find the format used for today's meeting a useful approach to review the waste characterization best practices document and its content? What would you have preferred to see if something was not adequately covered?

11) Were you able to easily use the simulation software after the initial training?

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

Appendix G. Best Practices Guide (BPG)

QUICK REFERENCE

Best Practices Guide (BPG) to Minimize Laboratory Resources for Waste Characterization During a Wide-Area Release of Chemical Warfare Agents

This quick reference document summarizes the waste characterization process described in Best Practices to Minimize Laboratory Resources for Waste Characterization During a Wide-Area Release of Chemical Warfare Agents (Best Practices Guide, BPD). The full BPD will assist users in minimizing the number of samples sent for laboratory analysis for waste characterization tasks while still meeting the data needs of regulators and receivers of the waste. The purpose of this document is to provide a quick reference to the BPD, particularly for use during tabletop/simulation/training events. This document includes the central flow chart to the waste characterization process, along with identification and brief description that should enable the participant in such events to locate relevant sections of the BPD as quickly as possible. The quick reference is not intended to replace the full BPD in terms of information or strategy.

A wide-area release of chemical warfare agent may result in the contamination of several square miles of urban area, potentially affecting hundreds of buildings. The response and recovery activities from this type of incident could generate several tons of solid waste and millions of gallons of liquid waste.

Materials that are not going to be reused or recycled from the incident area will become waste when they are identified for disposal. All waste generated during management of the wide-area incident must be appropriately characterized. However, laboratory demand during a wide-area incident will likely be greater than the available capacity due to the need for sampling and analysis during site characterization, assessment of decontamination efficacy, waste characterization, and clinical or medical testing. As a result, laboratory analysis could become a chokepoint and limit overall progress in incident management.

Waste characterization is a process that uses knowledge of the waste and/or sampling results to document that the waste meets regulatory requirements and any additional requirements of waste receivers.

Important concepts to reduce the number of laboratory samples include:

- Waste characterization is a legal requirement for all generated wastes, but sampling might not be necessary if acceptable to regulators and waste receivers.
- Appropriate waste segregation is critical for efficient waste characterization.
- Waste characterization strategies should leverage the use of lines of evidence to the extent possible as a primary means to reduce sample numbers for laboratory analysis.

- Field screening can be combined with lines of evidence or the use of a limited number of confirmatory laboratory samples to reduce the number of laboratory samples analyzed.
- Waste characterization strategies must be acceptable to regulators and waste receivers, and these entities should be involved throughout the process especially in the beginning where many decisions are made that drive characterization and decontamination waste stream.

> ***Lines of Evidence are information or data from various sources that can be used to support waste characterization decisions. Lines of evidence can include technical data on agent fate and transport, persistence in defined environmental conditions, and efficacy of decontamination technologies.***

Waste Characterization Process

Figure 1, detailed and referring to sections in the BPD, provides a description of the overall waste characterization process. For clarity, progression through the Figure 1 is intended to be a stepwise process. However, there are multiple factors within the process that might be optimized to reduce the number of laboratory samples and may result in the simultaneous determination of several process decisions or dictate an iterative nature to waste characterization decisions. Site- or incident-specific conditions might also dictate the sequence of decision-making.

Step 1: Segregate waste into homogeneous groups (Section 6.3), Identify waste acceptance criteria and associated data quality objectives (DQOs) for each waste group (Section 6.4). Identify laboratories with analysis capabilities for desired analyses that will accept material (Section 6.7)

Waste materials are segregated to facilitate reduced sampling requirements by grouping materials assumed to have similar characteristics. Waste group characteristics that might be relevant for segregation are described in further detail in the BPD. Individual waste groups might be targeted for different waste management options, with varying waste acceptance criteria and DQOs based on the waste receiver(s). Waste acceptance criteria are specific to each waste receiver that will accept the waste. There might also be unique acceptance criteria for locations that hold or stage waste prior to its final management. It will be helpful to identify contractor and waste receiver resources that will be present on-scene during an incident who can provide region-specific knowledge for waste characterization and available waste receivers. The criteria can be concentration-based or performance-based standards (i.e., decontamination technology) and include the volume of waste that will be accepted (Section 6.4). It is important to recognize that degradation products (Table B-1) and non-CWA constituents of the waste should also be considered in the waste characterization process. If laboratory analysis of samples will be performed, laboratories that can perform the analysis and that will accept the waste material must be confirmed (Section 6.7).

Step 2: Determine the waste characterization strategy (Section 6.5). The waste characterization strategy is developed to demonstrate if the waste material meets the identified waste acceptance criteria and DQOs. The strategy might consist of application of lines of evidence, field and/or laboratory sampling, or a combination of the two approaches. Lines of evidence should be considered as a first approach. Software tools are available to assist with the development of sampling strategies (Section 6.5.3.1).

Step 3: Gather Data. Lines of evidence data can be gathered from the published literature, subject matter experts, waste receivers, regulators, and previously gathered site data (Section 6.5.1). In the case of sampling, decisions to gather data are made for the overall sampling strategy (i.e., non-probabilistic, probabilistic, combination), (Sections 6.5.2 and 6.5.3, Table 1), sample collection (Section 6.6, Table 2), and analysis (Section 6.7).

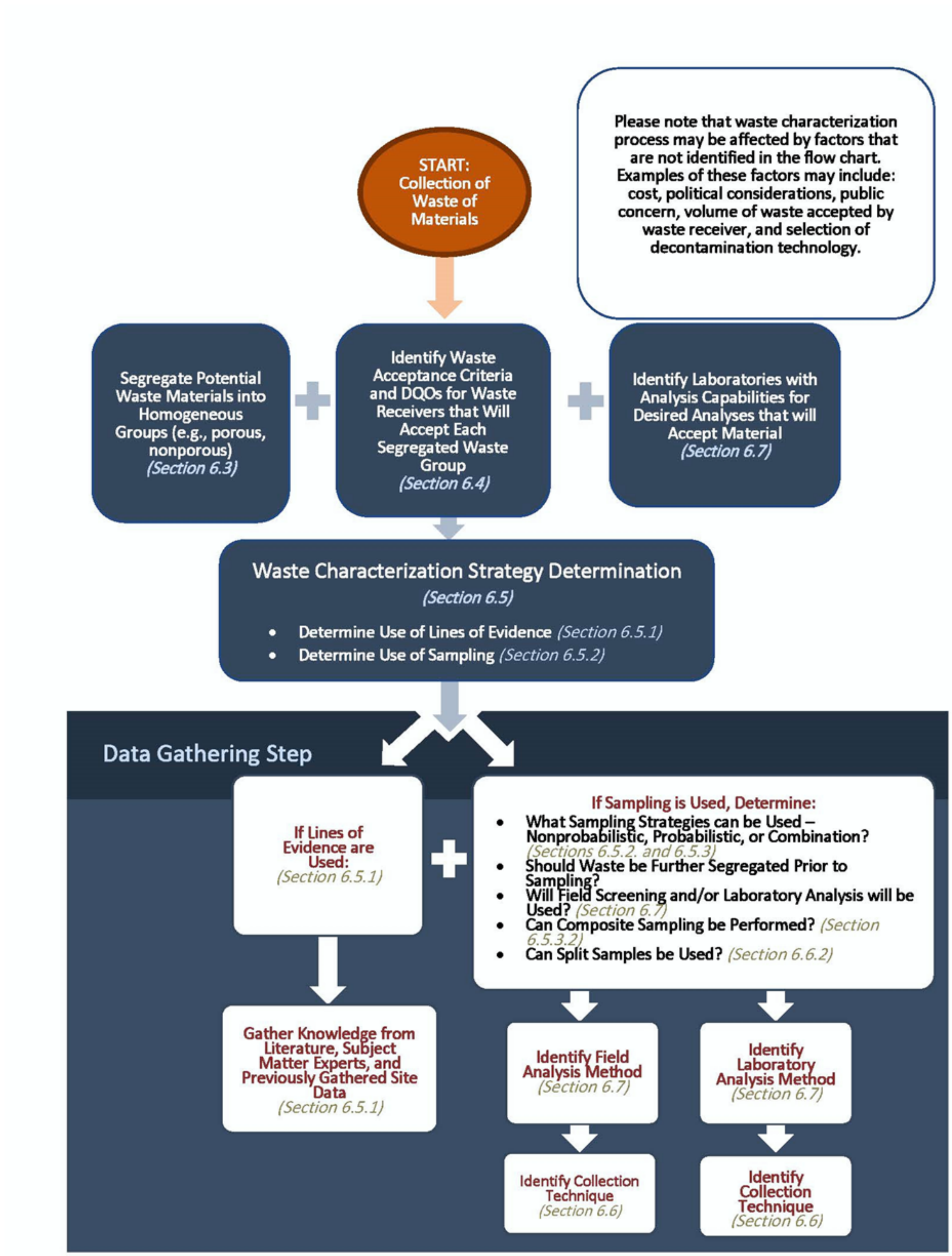


Figure G-1. Waste characterization process flow chart

Table G-1. Features of Sampling Design for Waste Characterization

Sampling Strategy	*Non-Probabilistic*	*Probabilistic*	
	Judgmental	*Simple Random*	*Stratified Random*
Definition	Selection of samples based on professional judgement without randomization. Biased sampling (a type of judgmental sampling) is intended to collect samples with the highest contamination.	A set of sampling units are independently selected at random from a population.	Prior information is used to determine groups (lots) that are sampled independently.
Application	• Small-scale conditions are under investigation • Screening for presence/absence of a contaminant • Might be used in conjunction with simple random sampling of containerized waste (i.e., samples collected from within the container might be judgmentally sampled in an attempt to maximize the collection of biological agent)	• Relatively uniform or homogeneous populations • Selecting a sample aliquot from a composite sample	• Used to produce estimates with pre-specified precision for important subpopulations • Monitoring of trends • Used to gain specific information (i.e., mean) regarding each group; potentially more efficient approach for sampling heterogeneous wastes if waste can be segregated
Laboratory Resources	Low: site information used to minimize laboratory resources	Medium: sample number is predetermined	Medium: sample number is predetermined
Wide-Area Pros	• Can be very efficient and cost effective if site is well known • Ideal for presence/ absence screening • Quick implementation to achieve time and funding constraints	• Enables uncertainty and statistical inferences to be calculated • Protects against sampling bias • Easy to understand and implement • Sample size formulas are available for determining sample numbers (EPA, 2002a)	• Provides an estimate of the population to effectively define groups and specify sample sizes • Sample size formulas are available to aid in determining adequate sample numbers (EPA, 2002)
Wide-Area Cons	• Dependent upon expert knowledge • Cannot reliably evaluate precision • Personal judgement is needed to interpret data • Confidence statements regarding absence of contamination difficult to make	• Random locations might be difficult to locate • Sampling design depends upon the accuracy of the conceptual model • All prior site information site is ignored • Sampling can be costly if there are difficulties in obtaining samples due to location	• Random locations might be difficult to locate • Sampling design depends upon the accuracy of the conceptual model • All prior information regarding the site is ignored • Sampling can be costly if there are difficulties in obtaining samples due to location
Cautions or Additional Critical Information	• Does not ensure that unsampled items are free of contamination • Degradation by-products might be of concern depending upon the parent agent, and create a hazardous environment incident after the parent (or tested agent) is no longer present	• Simple random sampling is often used as the last stage of sampling when multiple iterations are conducted – selecting an aliquot from a composite sample • All populations should be relatively uniform • Degradation by-products might be of concern depending upon the parent agent, and create a hazardous environment incident after the parent (or tested agent) is no longer present	• Each group should be homogeneous within itself • Groups should be defined before determining sample sizes • Degradation by-products might be of concern depending upon the parent agent, and create a hazardous environment incident after the parent (or tested agent) is no longer present • Potentially more efficient approach for sampling heterogeneous wastes, if it can be segregated
Reference(s)	EPA (2006); EPA (2002a); EPA (1998); EPA (2015c); EPA (2013a)	EPA (2002b); EPA (2002c); ITRC (2012); EPA (2006)	EPA (2002b); EPA (2006)

Table G-2. Features of Sample Collection for Waste Characterization

	Extractive (Solid Material) Sampling	*Wipe (Surface) Sampling*	*Liquid (Surface) Sampling*	*Liquid (Drum) Sampling – Discrete Depth Samplers*	*Liquid (Drum) Sampling – Profile Samplers*	*Air Sampling*
Description	Extractive sampling refers to whole objective sampling or the cutting/removal of a portion of the material sampled. Might also be referred to as bulk sampling or direct extraction.	Surface sampling techniques using wipes, cotton-balls/wipes, or gauze sponge.	The collection of liquid samples from the surface (or shallow depths) might be obtained with various devices including a bailer, dipper, liquid grab sampler, swing sampler, or solid phase microextraction fibers.	Liquid samples might be obtained from discrete depths with a variety of devices include a syringe sampler, discrete level sampler, lidded sludge/water sampler, or solid phase microextraction fibers.	Liquid samples might be obtained from throughout a vertical column of liquid or sludge with a variety of devices include a composite liquid waste sampler (COLIWASA), drum thief, valved drum sampler, plunger type sampler or solid phase microextraction fibers.	Air sampling devices, such as those that might be used to sample the headspace of waste containers for volatile compounds could include solid phase adsorbent media (tubes), solid phase microextraction fibers, or air samplers (e.g., SUMMA® canisters).
Application	• Applicable for the sampling of targeted areas (sink materials) where liquid agent might remain, especially porous surfaces or collection of spilled powder • Applicable for sampling materials that are not amenable to wipe sampling such as materials that are wet, irregularly shaped, and/or porous • Might be applicable for sampling heterogeneous waste; cutting, chipping, or drilling of waste samples (and subsequent grinding/mixing together) can make the samples more homogeneous and amenable to being sampled simply with a spoon or scoop	• Generally used for sampling smooth, non-porous surfaces, but might also be used on porous surfaces (EPA, 2012b) • Applicable for relatively small sample areas	• Although designed for groundwater sampling, bailers can be used to collect liquid samples from tanks and surface impoundments; bailers collect samples of 0.5 to 2 liters • The dipper, liquid grab sampler, and swing sampler generally collect 0.5 to 1.0 liter samples from the surface of drums, tanks, and surface impoundments	• The syringe sampler and discrete level sampler can collect 0.2 to 0.5 liter samples from drums, tanks, and surface impoundments • A lidded sludge/water sampler can collect 1.0 liter volumes from tanks and ponds	These sampling devices typically collect between 0.1 to 3 liter samples from tanks and drums, as well as surface impoundments	Air sampling, especially of the headspace of waste containers might be helpful in confirming that adequate decontamination of wastes materials has occurred
Wide-Area Pros	Extractive-based sampling minimizes the loses of agent that might arise with other sampling protocols' collection inefficiencies	Can be an easy and quick way of assessing surface contamination levels	• The bailer, dipper, liquid grab sampler, and swing sampler are generally easy to use and inexpensive	• A syringe sampler is easy to use and decontaminate; it can also be used to sample	• The COLIWASA, drum thief, and valved drum sampler are inexpensive, easy to use, and	Analysis of some sampling devices can be performed in the field for some analytes

Table G-2 (continued). Features of Sample Collection for Waste Characterization

	Extractive (Solid Material) Sampling	*Wipe (Surface) Sampling*	*Liquid (Surface) Sampling*	*Liquid (Drum) Sampling – Discrete Depth Samplers*	*Liquid (Drum) Sampling – Profile Samplers*	*Air Sampling*
			• Analysis of some sampling devices can be performed in the field for some analytes.	discrete depths, including the bottom • The jar in the lidded sludge/water sampling device serves as the sample container reducing the chance of cross-contamination • Solid phase microextraction fibers can be taken into the field to sample. These samples might be returned to the laboratory for analysis or the fibers can be analyzed in the field using portable GC/MS systems	available as reusable or single-use models • The plunger type sampler is easy to operate, relatively inexpensive, and is available in various lengths • Solid phase microextraction fibers can be taken into the field to sample. These samples might be returned to the laboratory for analysis or the fibers can be analyzed in the field using portable GC/MS systems	
Wide-Area Cons	• Extractive-based sampling might be difficult for personnel working in personal protective equipment. • Extractive-based sampling techniques are not well defined/established • Extracted samples might require more extraction solvent and more time to process than other surface sampling approaches • Small concentrations of a contaminant might be diluted within a larger bulk sample	• Wipe sampling might not result in high agent recoveries from porous materials, such as wood • Wipe sampling procedures can vary based on the agent of interest and the material sampled • Limited in sample area (100 cm^2)	These sampling devices are not intended to collect samples from specific/deep subsurface depths (unless a point-source bailer is used)	• The maximum depth that can be reached with a syringe sampler is about 1.8 meters • The lidded sludge/water sampling devise is rather heavy and limited to one jar size	• The COLIWASA, drum thief, and valved drum sampler can be difficult to decontaminate, and it might be difficult to collect samples from the bottom of the container • The drum thief cannot sample depths longer than the drum thief itself	Might be difficult to implement depending upon the accessibility of the containerized waste to be sampled
Cautions or Additional Critical Information	• Extraction efficiencies and agent recoveries will vary with material and extraction approach	• Agent recovery will vary depending upon the area sampled, material type, wipe material, amount and type of wetting	• Liquid samples should be collected with the appropriate neutralizers and stabilizers added	• Liquid samples should be collected with the appropriate neutralizers and stabilizers added • Larger sample volumes or multiple samples	• Liquid samples should be collected with the appropriate neutralizers and stabilizers added • Larger sample volumes or multiple samples	For sampling vapors that are heavier than air (e.g., sulfur mustard and Lewisite), include low lying areas where

Table G-2 (continued). Features of Sample Collection for Waste Characterization

	Extractive (Solid Material) Sampling	*Wipe (Surface) Sampling*	*Liquid (Surface) Sampling*	*Liquid (Drum) Sampling – Discrete Depth Samplers*	*Liquid (Drum) Sampling – Profile Samplers*	*Air Sampling*
	• Constituents within some materials might interfere with detection technologies • Extractive-based sampling techniques are not well defined/established • Neutralization might be needed to inhibit any residual decontamination solution that could possibly bias/lower the agent recoveries • Evidence collection sampling might have been conducted in this manner	solution, wipe pattern, etc. • Recovery might be affected by the presence of dirt and other residues as well as background chemical constituents.	• Larger sample volumes or multiple samples might be required such that filtration can be used to detect low levels of contamination	might be required such that filtration can be used to detect low levels of contamination	might be required such that filtration can be used to detect low levels of contamination	vapors might accumulate
Reference(s)	EPA (2012d); Nassar et al. (1998); NRT (2015a)	EPA (2008); EPA (2014a); Koester and Hoppes (2010); Nassar et al. (1998); NRT (2015a); Qi et al. (2013)	EPA (2002b); NRT (2015a); Popiel and Sankowska (2011)	EPA (2002b); NRT (2015a); Popiel and Sankowska (2011)	EPA (2002b); NRT (2015a); Popiel and Sankowska (2011)	Kimm et al. (2002); NRT (2015a); Popiel and Sankowska (2011); Smith et al. (2011)

EPA
United States
Environmental Protection
Agency

PRESORTED STANDARD
POSTAGE & FEES PAID
EPA
PERMIT NO. G-35

Office of Research and Development (8101R)
Washington, DC 20460