

Chapter 12

HAZARDOUS WASTE SITE INVESTIGATIONS

General

Hazardous waste site investigations are geologic by nature. Site geology affects how the contaminants enter and migrate through the environment, controls the severity of the contamination problem, and determines if and how the contamination is remediated. An accurate characterization of site geology is critical for the successful removal and/or remediation of hazardous waste.

Investigations at hazardous waste sites use the same basic tenets of geology commonly applied in other areas of engineering geologic exploration. Even though these engineering geologic investigation techniques are universal, certain specialized criteria and regulations are required at hazardous waste sites which differ from traditional geologic work. This chapter assumes that accepted geologic procedures and equipment are used at hazardous waste sites and only discusses the variations in the planning, implementation, and documentation of geologic field work required at such sites. Documentation at hazardous waste sites plays a very prominent role and involves much more effort than other geologic investigations.

This chapter provides a general overview of documents, terminology, processes, requirements, and site specific factors for an investigation. This information can be used to better prepare or conduct a field program. Much information provided here is extracted from numerous Environmental Protection Agency (EPA) guidance documents. Hazardous waste investigations involve a

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myriad of documents and processes, mostly referred to by acronyms. See the appendix for an explanation of the more common acronyms.

In hazardous waste investigations, understanding the contaminant's physical and chemical properties is very important. These properties are useful for predicting pathways that allow contaminant migration through complex subsurface conditions. The understanding of subsurface conditions permits a program designed to better investigate and sample potentially contaminated soil, rock, and water.

Common Terminology and Processes

The "typical" hazardous waste site remediation process involves several investigation phases. Each phase usually has a different emphasis and a different level of detail.

In general, there are two sets of regulations involved in hazardous waste site remediation: Resource Conservation Recovery Act (RCRA) and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). RCRA regulations are largely confined to *operators and generators* of existing facilities, whereas CERCLA regulations are confined to the investigation of *abandoned* sites (Superfund). Although most Bureau of Reclamation (Reclamation) activities involve CERCLA investigations, wastes generated during the investigation may fall under RCRA regulations.

According to EPA guidelines (*Guidance for Performing Preliminary Assessments Under CERCLA*, EPA/540/G-91/013), EPA uses a structured program to determine appropriate response for Superfund sites. The CERCLA/

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Superfund Amendments and Reauthorization Act of 1986 (SARA) process ideally evolves through the following phases: (1) discovery, (2) preliminary assessment, (3) site inspection, (4) hazard ranking, (5) remedial investigation, (6) feasibility study, (7) record of decision, (8) remedial design, (9) remedial action, and (10) operation and maintenance. Removal actions may occur at any stage.

Documentation

Proper documentation at jobs involving hazardous waste is more important than at more "traditional" geologic investigation sites. The alleged low concentration values for risks to human health and the associated costs for contaminant testing are primary reasons for good documentation. Soil contaminants are typically reported in parts per million (ppm) (milligram per kilogram [mg/Kg]) and water contaminants are typically reported in parts per billion (ppb) (microgram per liter [$\mu\text{g/L}$]). Since relatively low concentration levels may influence a decision for an expensive cleanup, the prevention of cross contamination and proper testing procedures is a necessity. Also, proper documentation is necessary for legally defensible data.

EPA has established documentation requirements for investigations. This chapter discusses the various documents needed by EPA under the Superfund program with an emphasis on the Sampling and Analysis Plan (SAP). Other documents such as the Health and Safety Plan (HASP), Spill Prevention Plan, and Community Relation Plan are often pertinent to the field operation.

The SAP will assist in preparing the required documents necessary before actual site work begins. Specific requirements for individual programs vary greatly, and

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common sense and regulatory concurrence dictate the level of detail needed. The EPA report *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA*, Interim Final, October 1988 (EPA/540/G-89/004) provides additional details regarding EPA-required documentation.

Work Plan (WP)

The WP includes a review of the existing data (background and study rationale), documents the decisions to be made during the evaluation process, and presents anticipated future tasks. The WP also designates responsibilities and sets the project schedule and cost. The primary use of the WP is to provide an agreed procedure to accomplish the work. The WP also provides other interested agencies (such as local government agencies) the opportunity to review proposed work. The WP is placed in the Administrative Record.

The WP may include an analysis and summary of the site background and physical setting, an analysis and summary of previous studies and response actions, a presentation of the conceptual site model (including the nature and extent of contamination), a preliminary assessment of human health and environmental impacts, additional data needs to conduct a baseline risk assessment, the preliminary identification of general response actions and alternatives, and the data needs for the evaluation of alternatives.

Sampling and Analysis Plan (SAP)

The SAP provides the "nuts and bolts" of the procedures to be used at a site and must be site specific. The SAP should consist of three parts:

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(1) A Field Sampling Plan (FSP) that provides guidance for all field work by defining in detail the sampling and data-gathering methods to be used on a project.

(2) An Analysis Plan (AP) that describes analysis of the collected data, such as the contaminant chemical data, the groundwater quality, and the geologic setting.

(3) A Quality Assurance Project Plan (QAPP) that describes the quality assurance and quality control protocols necessary to achieve Data Quality Objectives (DQOs). Data Quality Objectives are qualitative and quantitative statements that clarify the study objective, define the type of data to collect, determine the appropriate collection conditions, and specify tolerable decision error limits on the quality and quantity of data needed to support a decision.

The level of detail contained within the SAP varies. Depending on the WP, the testing, analysis, and quality control may be delegated to a differing lead agency or contractor. Whether the SAP contains individual FSP, AP, and/or QAPP, the SAP indicates the field personnel roles and responsibilities, the acquired data goals, the analytical methods, and how these methods meet the DQOs. Guidance for the selection and definition of field methods, sampling procedures, and custody can be obtained from the EPA report *Compendium of Superfund Field Operations Methods*, December 1987 (EPA/540/P-87/001 or National Technical Information Service [NTIS] publication PB88-181557). This report is a compilation of demonstrated field techniques that have been used during remedial response activities at hazardous waste sites.

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The FSP specifies the actual data collection activities to be performed. The AP provides the details if changes in sampling methods or number of samples need to be made. If the AP is a separate document, the FSP should spell out in detail exactly how and why samples will be collected in the field.

Included with the SAP (sometimes as an appendix to the FSP) are the standard operating procedures (SOPs) to be used during the investigations. The SOPs describe, in item-by-item detail, the exact steps to be followed for each sampling procedure. Included in the SOPs are calibration and maintenance requirements for equipment to be used. Manufacturer's recommendations and usage manuals can serve as part of the individual SOPs. Further details regarding standardized tasks are given in the EPA Quality Assurance Technical Information Bulletin *Creating SOP Documents*.

The QAPP is a companion document typically written when the FSP is final. The QAPP ensures that data and the subsequent analyses are of sufficient quantity and quality to accurately represent the conditions at the site. The QAPP often describes policy, organization, and functional activities not addressed within the work plan.

The following is a suggested SAP format.

Example Sampling and Analysis Plan

FSP

1. Site Background
2. Sampling Objectives
3. Sample Location and Frequency
4. Sample Designation
5. Sampling Equipment and Procedures
6. Sample Handling and Analysis

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AP

1. Objective(s) of the Data Collection
2. Analytical Methods and Software
3. Parameters Available and Required
4. Analytical Assumptions (Boundaries, Estimated Data)
5. Data Management and Manipulation
6. Evaluation of Accuracy (Model Calibration and/or Sensitivity Analysis)

QAPP

1. Project Organization and Responsibilities
2. QA Objectives for Measurement
3. Sample Custody
4. Calibration Procedures
5. Data Reduction, Validation, and Reporting
6. Internal Quality Control
7. Performance and System Audits
8. Preventative Maintenance
9. Data Assessment Procedures
10. Corrective Actions
11. Quality Assurance Reports

Health and Safety Plan (HASP)

Each field activity will vary as to amount of planning, special training, supervision, and protective equipment needed. The HASP, prepared to support the field effort, must conform to the Reclamation Safety and Health Standards. The site-specific HASP should be prepared concurrently with the SAP to identify potential problems early in the planning stage, such as availability of trained personnel and equipment. The HASP preparer should review site historical information along with proposed activities to identify potentially hazardous operations or exposures and to require appropriate protective measures. Appendix B of the *Occupational Safety and*

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Health Guidance Manual for Hazardous Waste Site Activities (National Institute for Occupational Safety and Health/Occupational Safety and Health Administration/U.S. Coast Guard/U.S. Environmental Protection Agency, 1985) provides an example of a generic format for an HASP. Commercial computer programs that allow preparers to "fill in the blanks" to produce rudimentary HASPs are also available.

A HASP should include, as appropriate, the following elements:

1. Name of site health and safety officer and names of key personnel and alternates responsible for site safety and health.
2. Listing of the potential contaminants at the site and associated risk(s).
3. A health and safety risk analysis for existing site conditions and for each site task and operation.
4. Employee training assignments.
5. A description of personal protective equipment to be used by employees for each of the site tasks and operations being conducted.
6. Medical surveillance requirements.
7. A description of the frequency and types of air monitoring, personnel monitoring, and environmental sampling techniques and instrumentation to be used.
8. Site control measures.
9. Decontamination procedures.
10. Standard operating procedures for the site.

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11. A contingency plan that meets the requirements of 29 CFR 1910.120(l)(1) and (l)(2).
12. Entry procedures for confined spaces.
13. Local emergency numbers, notification procedures, and a clear map (and written instructions) showing the route to the nearest medical facility *capable of handling emergencies arising from a hazardous waste site*.

Spill Prevention Plan (SPP)

All samples, equipment, cuttings, and other materials that have been exposed to potential contaminants must be decontaminated and/or tested and treated according to Applicable or Relevant and Appropriate Requirement (ARAR). Contingencies must be made for accidentally releasing and spreading contaminants into the environment during field activities at hazardous waste sites. Contaminants may originate from substances brought onto the site for specialized testing (e.g., standards for chemical testing), from accumulations of "free" contaminants, or from contaminated natural water which is released during sampling or investigations. Sufficient equipment (e.g., drums, absorbents, etc.) must be onsite to effectively control spills. In addition, key personnel should be identified for the control of spills. Paramount to such planning are spill prevention measures. Spill prevention plans may be incorporated into appropriate sections of a SAP or HASP, if desired.

Contaminant Characteristics and Migration

A primary difference between conventional engineering geology investigations and hazardous waste investigations is that drilling methods may impact the contaminant sampling results and increase migration

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paths. Lubricants, fuels, and equipment may mask specific chemical testing or react with the contaminant of concern (COC). All samples, waste discharges, and equipment used in the investigations require evaluation in relation to the potential contaminant(s). The following unique site factors are also important.

Contaminant Properties

Some contaminants are inherently mobile, for example, volatile organic compounds (VOCs). When released, VOCs can migrate rapidly through air, soil, and groundwater. Other contaminants, such as heavy metal solids, are less mobile. Heavy metals tend to accumulate on the surface of the ground. Although heavy metals may not readily migrate into and through the subsurface, heavy metals may still migrate through the air as airborne particles. Understanding the behavior of COCs is very important because behavior will significantly influence the ultimate design of the exploration program. For example, investigations to find gasoline, a light nonaqueous phase liquid (LNAPL), should concentrate on the water table surface. Dense, nonaqueous phase liquid (DNAPL) investigations should concentrate towards the bottom of the aquifer(s) or water table. Note that some contaminants react with investigation materials; e.g., TCE in high concentrations reacts with polyvinyl chloride (PVC) pipe.

When possible, the typical contaminant investigation will estimate the source type and location. The source type may be barrels, storage tanks, pipelines, injection wells, landfills, or holding ponds. In investigations that involve groundwater contamination, the investigation must address collecting samples of material that may be moving or have moved off site.

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Identifying the contaminant and its behavior within the hydrogeologic environment must be kept foremost in mind while developing the program. Hydrochemical parameters such as density, diffusivity, solubility, soil sorption coefficient, volatilization (vapor pressure), and viscosity may impact the specific contaminant movement. Biological activities or meteoric waters may impact various COCs in the subsurface. Some contaminants degrade over time and under some environmental conditions. In some instances, the degradation product (TCE to vinyl chloride) is worse than the original product.

A general introductory geological hazardous waste investigation reference is the *Standard Handbook for Solid and Hazardous Waste Facility Assessments*, by Sara, 1994. A general introductory reference for environmental chemistry is *Fundamentals of Environmental Chemistry*, by Manahan, 1993. A reference on DNAPL materials is *DNAPL - Site Evaluation* by Cohen and Mercer, 1993. A reference for groundwater chemical and physical properties is *Groundwater Chemicals - Desk Reference*, by Montgomery, 1996. *Toxicological Profile Series* published by the U.S. Department of Health and Human Resources describes physical, chemical, and biological processes which effect contaminant fate and transport.

Geologic Factors

The migration of contaminants is dependent on the subsurface materials and water. The arrangement of the geologic materials impacts the direction and flow rate of the contaminants and groundwater. Geologic factors such as stratigraphy, structure, and lithology control the occurrence and movement of water.

Various geologic factors to consider include: depth of soil, depth to bedrock, depth to the water table, seasonal

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variations in water table, water quality characteristics of site aquifers, mineralogic compositions of soil and rock, gradation, consolidation, and fracturing. Contaminant characteristics, such as property differences between solid or liquid materials, differences in liquid viscosity, or differences in liquid density relative to water, may influence how the contaminants interact with geologic factors and how the contamination plumes will behave.

Hydrologic Factors

Groundwater flow is a function of precipitation, runoff, and infiltration (figure 12-1).

Groundwater flow occurs through two zones: the unsaturated (vadose or aeration) zone and the saturated zone. Each zone can be either soil or rock. Groundwater movement is affected by the characteristics of the material pore spaces (porosity) and the interconnectivity of the pore spaces (permeability). Water movement occurs under a hydraulic gradient.

Other terms often used in groundwater are transmissivity and storativity. Both terms are bulk terms used to describe the water over the entire hydrologic unit. Transmissivity is directly related to permeability. Storativity is a dimensionless value often incorrectly equated with specific yield. For a more detailed description, see the Bureau of Reclamation Water Resource Technical Publication, *Ground Water Manual*, second edition, 1995 or *Groundwater*, by Freeze and Cherry, 1979.

An unconfined aquifer, often referred to as a "water table" aquifer, has no overlying confining layer. Water infiltrating into the ground percolates downward through air-filled interstices of the vadose zone to the saturated zone. The water table, or surface of the saturated groundwater

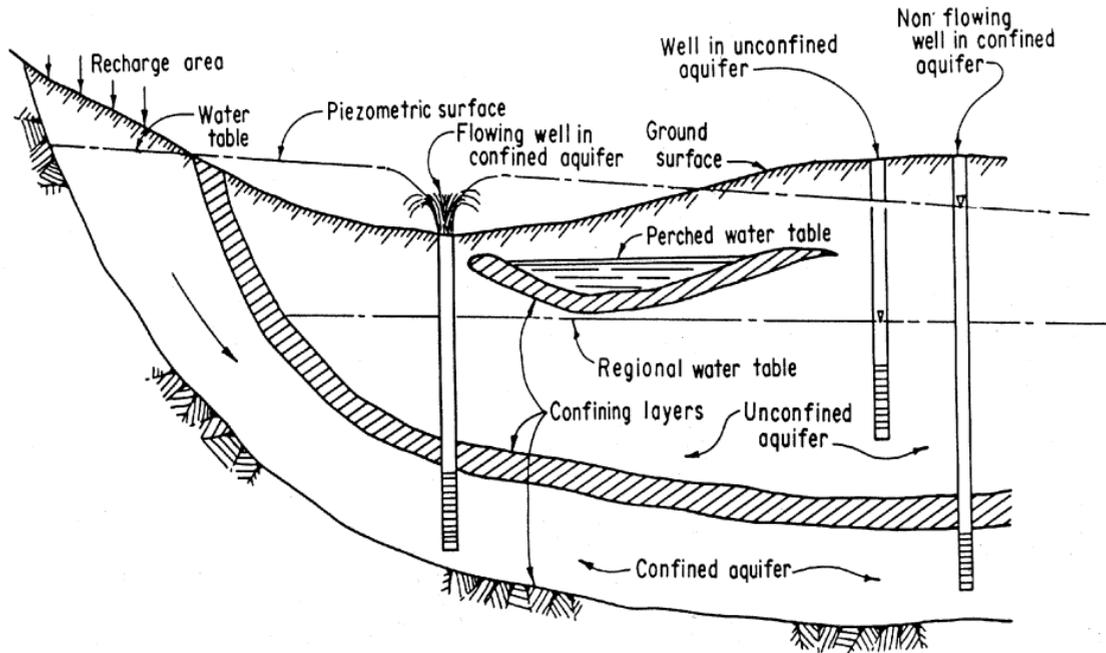


Figure 12-1. Aquifer types.

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body, is in contact with the atmosphere through the open pores of the material above and is in balance with atmospheric pressure.

A confined, or artesian, aquifer has an overlying, confining layer of lower permeability than the aquifer. Water in an artesian aquifer is under pressure, and when the confining layer is penetrated, the water will rise above the bottom of the confining bed to an elevation controlled by the aquifer pressure. If the confining layer transmits some water into adjacent layers, the aquifer is said to be a "leaky aquifer." A perched aquifer is created by beds of clay or silt, unfractured rock, or other material with relatively lower permeability impeding the downward percolation of water. An unsaturated zone is present between the bottom of the perching bed and the regional aquifer. Such an aquifer may be permanent or may be seasonal.

Aquifers are typically anisotropic; i.e., flow conditions vary with direction. In granular materials, the particle shapes, orientation, and the deposition process usually result in vertical permeability being less than horizontal permeability. The primary cause of anisotropy on a microscopic scale is the orientation of platy minerals. In some rock, the size, shape, orientation, and spacing of discontinuities and other voids may result in anisotropy. These factors should always be considered when modeling contaminant migration from hazardous waste sites.

After the natural flow conditions at a site are characterized, the presence of artificial conditions which may modify the flow direction or velocity of groundwater is determined. Such items as surface water impoundments and drainages may influence overall groundwater flow models. Also, if existing water wells are present in the area, pumping may be drawing the contaminants toward the wells. All possible influences affecting the

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groundwater flow must be identified to model contaminant plume migration rates and paths.

Classification and Handling of Materials

Classification of soils for engineering properties is described in chapter 3. Instructions for Logging Soils and Surficial Deposits (chapter 11) describes logging procedures, but there are two significant differences for hazardous waste investigations.

- (1) Logging of the soil is often limited to visual inspection of cuttings. The sampling protocol may prohibit the handling or poking of samples. Often the samples are sealed for chemical testing, and time for classification is restricted to the period when the sample is being packaged. Size of samples is kept to a minimum to reduce the amount of investigation-derived waste.
- (2) All material recovered or generated during an investigation (samples, cuttings, water, etc.) should be considered hazardous waste unless proven otherwise. Material removed should not be considered normal waste unless tested and permitted.

The RCRA statutory definition for hazardous waste is broad and qualitative and does not have clear bounds. Hazardous waste is defined as material meeting the regulatory definition contained in 40 CFR 261.3. However, the definitions of solid and hazardous waste contained in 40 CFR 261 are relevant only in identifying the waste. Material may still be considered solid or hazardous waste for purposes of other sections of RCRA. Some waste defined under the present regulatory statutes could become hazardous waste in the future.

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From the RCRA document, the definition of hazardous waste is any

. . . solid waste or combination of solid wastes which because of its quantity, concentration, or physical, chemical, or infectious characteristics may: (A) cause, or significantly contribute to, an increase in mortality or an increase in serious irreversible, or incapacitating reversible, illness; or (B) pose a substantial present or potential hazard to humans or the environment when improperly treated, stored, transported, or disposed of, or otherwise managed.

The level of contamination acceptable within the subsurface is based on a complex formula that involves the risk of exposure; toxicity, mobility, and volume of contaminants; and the cost of remediation. Soil and rock removed from a site cannot be returned to a site after the investigation has been completed.

Investigation waste water must be tested and handled under a different set of rules. If the water is mixed with cuttings, the material is considered a combination of solid wastes. If the water is discharged on a site, the water typically must meet drinking water standards. EPA currently requires that sole source aquifers have special project review criteria for Federal actions possibly affecting designated aquifers. Water withdrawn for public drinking water supplies currently falls under the Safe Drinking Water Act (SDWA) (Public Law 93-523) regulations, as amended and reauthorized (1974). (See 40 CFR 141 G for applicable water supply systems. See 40 CFR 143 for applicable water supply systems.) Note that the number of regulated constituents and their respective maximum contaminant levels (MCLs) are frequently updated.

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Identifying and classifying hazardous waste is described in *Hazardous Waste*, by Wagner, 1990. Procedures for site evaluation are contained in *EPA Guidance for Conducting Remedial Investigation and Feasibility Studies Under CERCLA*, 1988.

Field Sampling Protocol

One of the most difficult parts of any investigation is collecting representative samples. A sampling strategy must be efficiently and logically planned which delineates site location, number of samples collected, types of samples collected, testing methods to be used, and the duration and frequency of sampling. The difficulties of drilling in the right location and the problems associated with collecting representative samples is similar to traditional investigations. However, for hazardous waste investigation, the COC must be considered in both time and space. Statistical considerations should be part of the sampling program. The following are references for sampling statistical considerations:

Harvey, R.P. Statistical Aspects of Air Sampling Strategies. In: *Detection and Measurement of Hazardous Gases*; edited by C.F. Cullis and J.G. Firth. Heineman Educational Books, London, 1981.

Mason, B.J. *Protocol for Soil Sampling: Techniques and Strategies*. EPA Environmental Systems Laboratory, Contract No. CR808529-01-2. March 30, 1982. EPA-600/54-83-0020.

Smith, R., and G.V. James. *The Sampling of Bulk Materials*. The Royal Society of Chemistry, London. 1981.

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Environmental Protection Agency. *Handbook for Sampling and Sample Preservation of Water and Wastewater*. September 1982. EPA 600/4-82-029.

Sampling Strategies

Investigators must determine the correct number and types of samples to be collected, the proper chemical testing methods (analytical procedures), and the proper sampling equipment before field activities begin. Sample containers, preservatives, sample quantities, and proper holding times are also dictated by the chosen methods.

Table 12-1 is a list of recommended sampling containers and holding times for various classes of contaminants in soils.

Several sampling strategies are available, each with advantages and disadvantages. *Random sampling* uses the theory of random chance probabilities to choose representative sample locations. This is appropriate when little information exists concerning the material, locations, etc. Random sampling is most effective when the number of sampling locations is large enough to lend statistical validity to the random selection.

Systematic random sampling involves the collection of randomly selected samples at predetermined, regular intervals (i.e., a grid). The method is a common sampling scheme, but care must be exercised to avoid over-sampling of one material or population type over others.

Stratified sampling is useful if data are available from previous investigations and/or the investigator has experience with similar situations. This scheme reduces the number of samples needed to attain a specified precision. Stratified sampling involves the division of the

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Table 12-1. EPA recommended sampling containers, preservation requirements, and holding times for soil samples

Contaminant	Container ¹ Preservation ²	Holding time ³
Acidity	P, G	14 days
Alkalinity	P, G	14 days
Ammonia	P, G	28 days
Sulfate	P, G	28 days
Sulfide	P, G	28 days
Sulfite	P, G	48 hours
Nitrate	P, G	48 hours
Nitrate-Nitrite	P, G	28 days
Nitrite	P, G	48 hours
Oil and grease	G	28 days
Organic carbon	P, G	28 days
Metals		
Chromium VI	P, G	48 hours
Mercury	P, G	28 days
Other metals	P, G	6 months
Cyanide	P, G	28 days
Organic compounds		
Extractables		
Including: Phthalates, nitro-samines, organic pesticides, PCBs, nitroaromatics, isophorone, polynuclear aromatics hydrocarbons, haloethers, chlorinated hydrocarbons, and tetrachlorodibenzo-p-dioxin (TCDD)	G, Teflon®-lined cap	7 days until extraction
		30 days after extraction

Footnotes at end of table.

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Table 12-1. EPA recommended sampling containers, preservation requirements, and holding times for soil samples (continued)

Contaminant	Container ¹ Preservation ²	Holding time ³
Purgeables		
Halocarbons and aromatics	G, Teflon®-lined septum	14 days
Acrolein and acrylonitrile	G, Teflon®-lined septum	3 days
Orthophosphate	P, G	48 hours
Pesticides	G, Teflon®-lined cap	7 days until extraction 30 days after extraction
Phenols	G	28 days
Phosphorus	G	48 hours
Phosphorus, total	P, G	28 days
Chlorinated organic compounds	G, Teflon®-lined cap	7 days

¹ P = polyethylene, G = glass.

² All samples are cooled to 4 °C. Preservation is performed immediately upon collection. For composites, each aliquot preserved at collection. When impossible to preserve each aliquot, samples may be preserved by maintaining 4 °C until compositing and sample splitting is completed.

³ Samples are analyzed as soon as possible. Times listed are maximum holding if analysis is to be valid.

Source: Description and Sampling of Contaminated Soils, EPA/625/11-91/002 (1991).

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sample population into groups based on sample characteristics. The procedure involves handling each group or division separately with a simple random sampling scheme.

Judgement sampling introduces a certain amount of judgment into the sampling approach and should be avoided if a true random sample is desired. Judgment sampling allows investigator bias to influence decisions, which can lead to poor quality data or improper conclusions. If the local geology is fairly well understood, judgement sampling may provide the most efficient and cost-effective sampling scheme; however, regulatory concurrence, rationale, and proper documentation will be necessary.

Hybrid sampling is a combination of the types previously described. For example, an initial investigation of drums might be based on preliminary information concerning contents (judgement, stratified) and then random sampling of the drums within specific population groups (random). Hybrid schemes are usually the method of choice for sampling a diverse population, reducing the variance, and improving precision within each subgroup.

After the appropriate sampling scheme has been chosen, the specific type of samples necessary for characterization must be identified. The unique characteristics of the site COCs will play an important role in determining which media will be sampled. Some sampling devices are described in this manual or the *Earth Manual*, parts 1 and 2, USBR, 1990 and 1999. A summary of sampling devices is shown in table 12-2.

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Table 12-2. Summary of soil sampling devices

Sampling device	Applications	Limitations
Hand-held samplers		
Spoons and scoops	Surface soil samples or the sides of pits or trenches	Limited to relatively shallow depths; disturbed samples
Shovels and picks	A wide variety of soil conditions	Limited to relatively shallow depths
Augers¹		
Screw auger	Cohesive, soft, or hard soils or residue	Will not retain dry, cohesionless, or granular material
Standard bucket auger	General soil or residue	May not retain dry, cohesionless, or granular material
Sand bucket auger	Bit designed to retain dry, cohesionless, or granular material (silt, sand, and gravel)	Difficult to advance boring in cohesive soils
Mud bucket auger	Bit and bucket designed for wet silt and clay soil or residue	Will not retain dry, cohesionless, or granular material
Dutch auger	Designed specifically for wet, fibrous, or rooted soils (marshes)	

¹ Suitable for soils with limited coarse fragments; only the stoney soil auger will work well in very gravelly soil.

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Table 12-2. Summary of soil sampling devices (continued)

Sampling device	Applications	Limitations
Augers¹		
In situ soil recovery auger	Collection of soil samples in reusable liners; closed top reduces contamination from caving sidewalls	Similar to standard bucket auger
Eijkelcamp stoney soil auger	Stoney soils and asphalt	
Planer auger	Clean out and flatten the bottom of predrilled holes	
Tube samplers²		
Soil probe	Cohesive, soft soils or residue; representative samples in soft to medium cohesive soils and silts	Sampling depth generally limited to less than 1 meter
Thin-walled tubes	Cohesive, soft soils or residue; special tips for wet or dry soils available	Similar to Veihmeyer tube
Soil recovery probe	Similar to thin-walled tube; cores are collected in reusable liners, minimizing contact with the air	Similar to Veihmeyer tube

¹ Suitable for soils with limited coarse fragments; only the stoney soil auger will work well in very gravelly soil.

² Not suitable for soils with coarse fragments.

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Table 12-2. Summary of soil sampling devices (continued)

Sampling device	Applications	Limitations
Tube samplers¹ (continued)		
Veihmeyer tube	Cohesive soils or residue to depth of 10 feet (3 meters [m])	Difficult to drive into dense or hard material; will not retain dry, cohesionless, or granular material; may be difficult to pull from ground
Peat sampler	Wet, fibrous, organic soils	
Power-driven samplers		
Split spoon sampler	Disturbed samples from cohesive soils	Ineffective in cohesionless sands; not suitable for collection of samples for laboratory tests requiring undisturbed soil
Thin-walled samplers		
Fixed piston sampler	Undisturbed samples in cohesive soils, silt, and sand above or below water table	Ineffective in cohesionless sands
Hydraulic piston sampler (Osterberg)	Similar to fixed-piston sampler	Not possible to limit the length of push or to determine amount of partial sampler penetration during push

¹ Not suitable for soils with coarse fragments.

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Table 12-2. Summary of soil sampling devices (continued)

Sampling device	Applications	Limitations
Thin-walled samplers (continued)		
Free piston sampler	Similar to stationary piston sampler	Not suitable for cohesionless soils
Open drive sampler	Similar to stationary piston sampler	Not suitable for cohesionless soils
Pitcher sampler	Undisturbed samples in hard, brittle, cohesive soils and cemented sands; representative samples in soft to medium cohesive soils, silts, and some sands; variable success with cohesionless soils	Frequently ineffective in cohesionless soils
Denison sampler	Undisturbed samples in stiff to hard cohesive soils, cemented sands, and soft rocks; variable success with cohesionless materials	Not suitable for undisturbed sampling of cohesionless soils or soft cohesive soils
Vicksburg sampler	Similar to Denison sampler except takes wider diameter samples	

In addition, the following references may be consulted for sample collection methods:

Environmental Protection Agency. *Characterization of Hazardous Waste Sites - A Methods Manual, Volume I - Site Investigations*. April 1985. EPA 600/4-84-075.

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Environmental Protection Agency. *Characterization of Hazardous Waste Sites - A Methods Manual: Volume II. Available Sampling Methods*. September 1983. EPA 600/4-83-040, PB84-126929.

Environmental Protection Agency. *A Compendium of Superfund Field Operation Methods*. December 1987. EPA 540/P-87-001, PB88-181557.

Samples can be either grab or composite samples. Grab samples are collected at a discrete point, representing one location and/or time interval. Composite samples are collected from several sources which are then accumulated to represent a broader area of interest. The requirements for testing will often dictate which sampling method is used. For example, composite samples of soil cannot be used for volatile compounds because portions of the contaminants may easily volatilize during collection.

Many soil samples are collected as grab samples. Soil samples should be collected from areas where dumping, spills, or leaks are apparent. Soil samples should be collected from areas upstream and downstream from suspected contaminant entry and in areas where sediment deposition is significant. Samples can be collected readily from the first 18 inches (450 mm) (depending upon the soil type) by using relatively simple tools, such as spades, scoops, and dredge scoops. If scoops are used for collecting surface soil samples, purchase enough scoops to use a new scoop for each sample rather than decontaminating scoops between samples. Not only is time saved, but cross contamination is kept to a minimum. The COC must also be considered. If sampling for heavy metals, metal scoops should not be used, or if sampling for semivolatiles, plastic scoops should be avoided. Samples from greater depths usually require more elaborate methods or equipment, such as test pits, hand augers, thin-wall tube samplers, hand or

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power corers, bucket augers, cutting or wash samples, direct-push tools, etc. The nature of the geologic material to be sampled will influence significantly the methods to use, but every effort should be made to reduce the amount of investigation-derived waste generated from the sampling method. Direct-push sampling (such as the Geoprobe®) is preferable in that drill cuttings and drilling fluids are not generated.

A useful field pocket guide is available from EPA: *Description and Sampling of Contaminated Soils*, EPA/625/12-9/002, November 1991. This guide addresses soil characterization, description, sampling, and sample handling. Within this guide are general protocols for soil sample handling and preparation. The following are procedures from the guide:

Soil Sample Collection Procedures for Volatiles.

1. Tube samples are preferred when collecting for volatiles. Augers should be used only if soil conditions make collection of undisturbed cores impossible. Soil recovery probes and augers with dedicated or reusable liners will minimize contact of the sample with the atmosphere.
2. Place the first adequate grab sample, maintaining and handling the sample in as undisturbed a state as possible, in 40-milliliter (mL) septum vials or in a 1-liter (L) glass wide mouth bottle with a Teflon®-lined cap. *Do not mix or sieve soil samples.*
3. Ensure the 40-mL containers are filled to the top to minimize volatile loss. Secure the cap tightly, but do not overtighten.

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4. Examine the hole from which the sample was taken with an organic vapor instrument after each sample increment. Record instrument readings.
5. Label and tag sample containers, and record appropriate data on soil sample data sheets (depth, location, etc.).
6. Place glass sample containers in sealable plastic bags, if required, and place containers in iced shipping container. Samples should be cooled to 4 degrees Centigrade ($^{\circ}\text{C}$) as soon as possible.
7. Complete chain of custody forms and ship as soon as possible to minimize sample holding time. Scheduled arrival time at the analytical laboratory should give as much holding time as possible for scheduling of sample analyses.
8. Follow required decontamination and disposal procedures.

Soil Sample Collection and Mixing Procedures for Semivolatiles and Metals.

1. Collect samples.
2. If required, composite the grab samples or use discrete grab samples.
3. If possible, screen the soils in the field through a precleaned O-mesh (No. 10, 2-millimeter [mm]) stainless steel screen for semivolatiles, or Teflon[®]-lined screen for metals.
4. Mix the sample in a stainless steel, aluminum (not suitable when testing for aluminum), or glass mixing container using appropriate tool (stainless steel spoon, trowel, or pestle).

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5. After thorough mixing, place the sample in the middle of a relatively inexpensive 1-meter (m) square piece of suitable plastic, canvas, or rubber sheeting.
6. Roll the sample backward and forward on the sheet while alternately lifting and releasing opposite sides or corners of the sheet.
7. After thorough mixing, spread the soil out evenly on the sheet with a stainless steel spoon, trowel, spatula, or large knife.
8. Take sample container and check that a Teflon® liner is present in the cap, if required.
9. Divide the sample into quarters, and take samples from each quarter in a consecutive manner until appropriate sampling volume is collected for each required container. Separate sample containers would be required for semivolatiles, metals, duplicate samples, triplicate samples (split), and spiked samples.
10. Secure the cap tightly. The chemical preservation of solids is generally not recommended.
11. Label and tag sample containers, and record appropriate data on soil sample data sheets (depth, location, etc.).
12. Place glass sample containers in sealable plastic bags, if required, and place containers in iced shipping container. Samples should be cooled to 4 °C as soon as possible.
13. Complete chain of custody forms and ship as soon as possible to minimize sample holding time. Scheduled arrival time at the analytical laboratory

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should give as much holding time as possible for scheduling of sample analyses.

14. Follow required decontamination and disposal procedures.

Water Quality Sample Collection Methods

Surface Water Collection. Surface water on or adjacent to a suspected hazardous waste site can yield significant information with minimal sampling effort. Surface water can reveal the presence of contamination from several pathway mechanisms. If only a knowledge of the presence or absence of contamination in the water is needed, the collection of grab samples will usually suffice. If the water source is a stream, samples also should be collected upstream and downstream from the area of concern. Additional monitoring of surface water is required of seeps, spills, surface leachates, etc. If the site has National Pollutant Discharge Elimination System (NPDES) outfalls, the discharges should be sampled.

Water quality samples are often the most important material collected at a site. Determining the appropriate number of samples and appropriate test method is critical to a successful program. A good guidance document to develop a water quality sampling program and provide the reasoning for collecting appropriate water samples is EPA's *Handbook, Ground Water*, volumes I and II, EPA/625/6-90/016. There are several factors to consider in the selection of appropriate sampling devices. Time and money are obvious factors; however, the data use, formation permeability, water depth, and contamination type are considerations. Water monitoring goals and objectives should be addressed, such as:

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Is the investigation to determine source(s)?

Are the investigations included for a time critical removal action?

Have the potential contaminants been identified?

Will there be a follow up risk assessment and/or remediation?

Are there potential responsible parties (PRPs) involved?

Water samples can be routinely analyzed for current EPA listed priority pollutants. Alkalinity, acidity, total organic halogens, and chemical oxygen demand are often indicators of contamination. Routine tests can be used as screening techniques before implementing more costly priority pollutant analyses. Bioassessment samples, if needed, are described in *Rapid Bioassessment Protocols for Use in Streams and Rivers*, EPA/444/4-89-001. If technical impracticability (*Guidance for Evaluating the Technical Impracticability*, EPA Directive 9234.2-25, or natural attenuation are potential remediation options, additional water quality parameters may need testing consideration.

Groundwater Collection. Groundwater contamination is usually difficult and costly to assess, control, and remove. Monitoring wells sample a small part of an aquifer, depending on screen size, length, placement depth, pumping rates, and other factors. The use of wells and piezometers can introduce additional problems due to material contamination, inadequate construction, and uncertainties of the water zone sampled. Guarding against cross contamination of multiple aquifers is important. Proper well construction requires significant skill. General guidelines for design and construction of monitoring wells can be found in *American Society for Testing Materials (ASTM)*

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D5092-90, and guidelines for sampling can be found in RCRA *Groundwater Monitoring Draft Technical Guidance*, EPA/530-R-93-001. For general details on groundwater quality monitoring well construction, see figure 12-2. The location of the screen and designing and development of the screen and sand pack is extremely important in hazardous waste wells. Meeting the turbidity requirement of less than five nephelometric turbidity units (NTUs) is difficult to achieve in the best circumstances. Drilling exploration and monitoring wells in sequence from least to most contaminated areas is good practice because this minimizes the possibility of introducing contaminants into cleaner aquifers or areas.

Although the *Compendium of ERT Groundwater Sampling Procedures*, EPA/540/P-91/007, provides standard operating procedures for emergency response teams, the recommended water quality sampling procedures for groundwater should be in accordance with EPA's *Low-Flow (Minimal Drawdown) Ground-Water Sampling Procedures*, EPA/540/S-95/504. The Minimal Drawdown (MD) method requires using a submersible pump placed within a riser and not operated until the well has stabilized. The use of bailers and hand pumps, including automated hand pump systems for water quality sampling, is discouraged under the MD method.

Limiting water column disturbance is a primary reason for installing a dedicated submersible pump. Lowering a temporary sampling device into the water column creates a mini-slug test. The surge of water may induce sediments into the monitoring well. As a result, the water may not meet the five NTU limit that is part of the requirement for water quality monitoring wells. Sediments can significantly impact testing. If sediment

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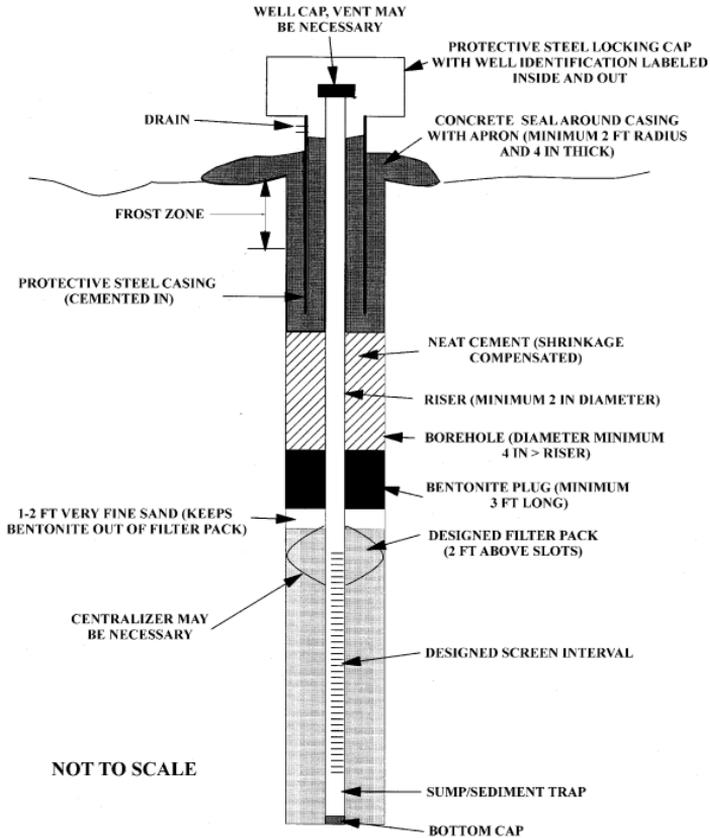


Figure 12-2. Typical monitoring well construction for water quality sampling.

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content is great, additional tests, such as comparing total versus dissolved solids, should be considered.

Some sampling devices may induce volatilization. Peristaltic pumps, bailers, or hand pumps in low-flow conditions can impact the test results for semi-volatile and volatile compounds. Peristaltic pumps may induce volatilization if the samples are lifted from depths greater than about 25 feet.

The MD method is the preferred sampling collection method because the method uses a low pumping rate (as low as 0.1 liter per minute) and attempts to limit drawdown to less than 0.3 foot. If the extraction rate exceeds the ability of the formation to yield water for low permeability wells, turbulent conditions can be induced within the borehole. Water may trickle and fall down the casing. This may potentially increase air exposure and can entrain air in the water.

Although preferred water quality sampling uses the MD method, other methods may be acceptable to EPA or other regulatory agencies. Devices such as bailers or peristaltic and hand pumps are routinely used at some sites. However, if these devices are used and surge the well, water sampling protocols often require that the well be purged of at least three well volumes of water prior to collecting a sample.

Whatever sample device is selected, stabilization of typical water quality parameters, such as pH, redox potential, conductivity, dissolved oxygen, and turbidity, are usually required. Which water quality parameters are specified may be dependent on the site conditions and regulatory requirements. The water extraction devices and procedures should be specified in the FSP and

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correlated to match the site conditions, contaminants, and the regulatory agency requirements.

Vadose Zone. In addition to sampling aquifers at hazardous waste sites, significant information can be obtained by vadose zone sampling. Leachates from COCs migrate through the vadose zone toward the water table. Samples collected from this zone can indicate the types of contaminants present and can aid in assessing the potential threat to the aquifer below. The various types of vadose zone monitors can be used to collect water samples or interstitial pore space vapors for chemical analyses and to determine directional flow of COCs. The main advantage is that such sampling is relatively inexpensive, simple to do, and can begin supplying information before aquifer monitoring is started. The types of vadose zone monitors, their applications, and their use in satisfying the requirements of RCRA are discussed in *Vadose Zone Monitoring at Hazardous Waste Sites*, EMSL-LV KT-82-018R, April 1983.

Geophysical Methods

Geophysical methods can be used effectively at hazardous waste sites to assist in defining the subsurface character of the site, to assist in the proper placement of monitoring wells, to identify buried containers and debris, and to decrease the safety risks associated with drilling into unknown buried materials. A good overview of the subject of geophysical methods for surveying hazardous waste sites is: *Geophysical Techniques for Sensing Buried Wastes and Waste Migration*, prepared for EPA by Technos, Inc., available from the National Water Well Association.

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Miscellaneous Methods

Ambient concentrations of volatile and semivolatile organics, trace metals, and particulate matter in the air can provide important data on the atmospheric migration path and the populations at risk and can be used for source evaluations and personnel monitoring. Portable monitoring devices such as organic vapor analyzers, stain detector tubes, or other monitors can detect the presence of various atmospheric hazards. Other monitors commonly used at hazardous waste sites are explosimeters, oxygen indicators, and personal sampling pumps.

Other specialized sampling techniques may be necessary at hazardous waste sites to sample media normally not found in the geologic environment. Wipe samples may be used to document the presence of toxic materials and to determine that site or equipment decontamination has been adequate. Wipe sampling consists of rubbing a moistened filter paper, such as Whatman 541 filter paper, over a measured area of 15 in² (100 cm²) to 10 ft² (1 m²). The paper is then sent to a laboratory for analysis.

Sample Analysis

Onsite laboratories and field analytical equipment, such as portable gas chromatographs (GCs) and immunoassay kits, can be very beneficial for rapid analyses. Rapid-analysis equipment, such as GCs, immunoassay, and colorimetric kits, are a cost-effective alternative for providing qualitative and semi-quantitative chemical data and for screening large numbers of samples prior to submittals for laboratory testing. Another beneficial use of field screening techniques is to provide general contaminant level data for samples to be tested in the laboratory. If a sample has a very high contaminant

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concentration, the sample may have to be diluted before being analyzed to protect the laboratory instruments from costly contaminant saturation problems.

There are many standardized testing procedures and methods for hazardous waste evaluation. Table 12-3 lists some common method series. Each series contains numerous individual methods. There are over 25 series-500 (determination of organic compounds in drinking water) methods. Method 502.1 is for halogenated volatile organics (purgeable halocarbons) by GC (48 compounds); Method 502.2 is for nonhalogenated volatile organics by GC (6 compounds); Method 503.1 is for aromatic and unsaturated volatile organics (purgeable aromatics) by GC (28 compounds); Method 507 is for nitrogen and phosphorus containing pesticides by GC (66 substances).

The following references discuss some of the common methods:

Methods for the Determination of Organic Compounds in Drinking Water. EPA-600/4-88/039, December 1988 (500 Series).

Guidelines Establishing Test Procedures for the Analysis of Pollutants Under the Clean Water Act. 40 CFR Part 136, October 26, 1984 (600 Series, for effluent - wastewater discharged to a sewer or body of water).

Test Methods for Evaluating Solid Waste. SW-846, 2nd Edition, Revised, 1985 (8000 Series for groundwater, soil, liquid, and solid wastes).

Methods for Chemical Analysis of Water and Wastes. EPA-600/4-79-020, March 1983.

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Table 12-3. Common laboratory testing methods¹

Method testing series	Analytes
100 - EPA method	Physical properties - water
200 - EPA method	Metals - water
300 - EPA method	Inorganic, non-metallics - water (i.e., alkalinity)
400 - EPA method	Organics - water (i.e., chemical oxygen demand, total recoverable petroleum hydrocarbons [TRPH])
500 - EPA method	Organic compounds in drinking water
600 - EPA method	Organic compounds in effluent
900 - EPA method	Biologic - water (i.e., coliform, fecal streptococcal)
1000 - SW-846 method	Ignitability, toxicity characteristic leaching procedure (TCLP), extractions, cleanup, headspace - solids
3000 - SW-846 method	Acid digestion, extractions, cleanup, headspace - solids
4010 - SW-846 method	Screening for pentachlorophenol by immunoassay - solids
5000 - SW-846 method	Organic (purge and trap, gas chromatograph/mass spectrometer [GC/MS], sorbent cartridges)
6000 - SW-846 method	Inductively coupled plasma (spectrometry)
7000 - SW-846 method	Metals - solid waste
8000 - SW-846 method	Organic compounds in solid waste
9000 - SW-846 method	Inorganics, coliform, oil and grease extractions - solids

¹ This list is not inclusive. Significant overlap and exceptions are present. Methods listed are basic guides to provide the investigator with the general structure of the testing method scheme. Numerous individual methods exist within each series.

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Standard Methods for the Examination of Water and Wastewater, 19th edition, Greenberg; American Public Health Association, Washington, DC, 1995.

Reference guides are also available from several sources, such as the Trace Analysis Laboratory Reference Guides from Trace Analysis Laboratory, Inc., 3423 Investment Boulevard, No. 8, Hayward, California 94545, telephone (415) 783-6960.

An important consideration in planning any field investigation program is scheduling the anticipated activities. Sufficient time must be allowed for the peculiarities of hazardous waste work. Several factors must be considered: (1) time for establishing work zones and erecting physical barriers, (2) time for establishing equipment, personnel, and vehicle decontamination stations, (3) time needed to decontaminate equipment and personnel, (4) loss of worker efficiency due to safety monitoring, safety meetings, and the use of protective clothing, (5) documentation requirements and sample-handling procedures, and (6) inventory and procurement of specialized sample containers, preservative preparation, and reference standards, and equipment calibrations.

Safety at Hazardous Waste Sites

A major factor during hazardous waste site investigations is the safety of both the general public and the site investigators. The following references may be of assistance:

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Interim Standard Operation Safety Guides. Revised September 1982, U.S. EPA, Office of Emergency and Remedial Response (OERR).

Guidance Manual for Protection of Health and Safety at Uncontrolled Hazardous Substances Sites. EPA, Center for Environmental Research Information (ORD) (in draft, January 1983).

Reclamation Safety and Health Standards. U.S. Department of the Interior, Bureau of Reclamation, Denver, Colorado, 1993.

Chemical Substance Hazard Assessment and Protection Guide. OWENS/URIE Enterprises, Inc., Henahan, Urie, & Farlern, Wheat Ridge, Colorado, 1994.

Sample Quality Assurance and Quality Control

Sample QA procedures confirm the quality of the data by documenting that integrity is present throughout the sample history. Several sample types are used. *Field blanks* are samples of a "pure" substance, either water, solid, or air, which are collected in the field using the same procedures as are used for actual environmental samples. The purpose of the field blank is to ensure that outside influences are not contaminating the true samples (i.e., vehicular exhaust) during sampling. If "hits" are discovered in the field blank, the question arises whether contamination not associated with the site is affecting the true samples.

Trip blanks are samples of a "pure" substance (analyte-free deionized water which accompanies samples with volatile contaminants) prepared in a laboratory or other

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controlled area and placed in a shipping container with environmental samples. The purpose of the trip blank is to ensure that samples were not cross contaminated during shipment and storage. "Hits" in a trip blank indicate that COCs were present in a container to a degree sufficient to infiltrate into the trip blank sample jar and, hence, possibly into true samples.

Equipment blanks are used when sampling equipment is cleaned and re-used for subsequent sample collection. The blanks verify the effectiveness of field cleaning procedures. The final rinse for the sampling equipment is often made with analyte-free deionized water. The rinse water is run on or through the sampling equipment, collected in appropriate containers and preserved. These samples are usually collected on a schedule, such as once every 10 episodes.

Duplicates are samples collected at the same time, in the same way, and contained, preserved, and transported in the same manner as a corresponding duplicate. Duplicates are used to determine the precision of the laboratory method and integrity of the sample from collection through testing. Duplicates are typically collected once every 10 samples.

Matrix spikes provide the best overall assessment of accuracy for the entire measurement system. For water investigation episodes, a laboratory usually prepares the spike samples, sends them to the site, and the spike sample(s) are included in the sample handling and shipping process. The samples are analyzed blind by the off-site laboratory. Matrix spikes can also be made from certified mixtures of a contaminant and clean soil in the field.

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All types of blanks and duplicates must be prepared in the same sample containers as actual samples including labeling and identification schemes so that the laboratory analyzes the sample without knowing that the samples are quality control (QC) samples (blind testing).

In addition to field QC samples, the analytical laboratory also uses QC samples. *Method blanks* are organic-free or deionized water carried through the analytical scheme like a sample. Method blanks measure contamination associated with laboratory activities. *Calibration blanks* are prepared with standards to create a calibration curve. *Internal standards* are measured amounts of certain compounds added after preparation or extraction of a sample. *Surrogates* are measured amounts of certain compounds added before preparation or extraction of a sample to determine systematic extraction problems. *Duplicates and duplicate spikes* are aliquots of samples subjected to the same preparation and analytical scheme as the original sample. *Laboratory control standards (LCSs)* are aliquots of organic-free or deionized water to which known amounts of analyte have been added. LCSs are subjected to the sample preparation or extraction procedure and analyzed as samples.

Field, laboratory, data validation, and report presentation documents must be meticulously maintained during hazardous waste site investigations. All field activities should be recorded in bound, consecutively numbered log books. Each entry should be made with indelible ink, and all strike outs should be made by a single line which allows the original error to be legible and initialed and dated by the person making the correction. Entries should include date, weather conditions, personnel involved with the activity, the type of activity being performed, unusual circumstances or variations made to the SOPs, and data appropriate to the activity being

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performed. This is a diary of all activities on a site. The investigator responsible for the activity is responsible for maintaining the field log book. An important purpose of the field log book is to document any changes made to SOPs. If such changes may affect data quality, concurrence with managers or regulatory personnel is required in writing. All records must be under control at all times. Unique project numbers should be assigned to all log books, documents, and reports. All records must be maintained and custody documented so that unauthorized changes or tampering are eliminated. Log book entries should be photocopied on a regular schedule to ensure that field data are not lost if the original book is lost or destroyed.

Activities during an investigation must be reviewed to ensure that all procedures are followed. System audits should consist of inspections of training status, records, QC data, calibrations, and conformance to SOPs. System audits are performed periodically on field, laboratory, and office operations. Each major investigation type should be subject to at least one system audit as early as practicable. Performance audits include evaluation and analysis of check samples, usually from laboratory activities. Readiness reviews occur immediately prior to beginning each type of field activity to assess the readiness of the team to begin work. A checklist of prerequisite issues, such as necessary equipment, controlled documents, training, assignments, spare parts, field arrangements, etc., are discussed and documented.

If any weaknesses or deficiencies are identified, the investigator must resolve them before field activities proceed.

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Sample Management

There must be control and documentation of all samples after the environmental samples are collected in the field. The proper quantity of a sample must be collected to have sufficient volume for the subsequent analysis. The proper sample container and preservative must be used so that sample integrity is not compromised. Many types of samples (e.g., volatiles) must be cooled, usually to 4 °C, throughout their history after collection. The proper analytical methods must be identified to obtain the desired result. The laboratory must handle and track the received samples in a timely and accurate manner to ensure that the results are correct.

Sample Custody

Sample custody is a prime consideration in the proper management of samples. Sample custody is designed to create an accurate, written, and verified record that can be used to trace the possession and handling of the samples from collection through data analyses and reporting. Adequate sample custody is achieved by means of QA-approved field and analytical documentation. A sample is considered in custody if the sample is (1) in one's actual physical possession, (2) is in one's view after being in one's physical possession, (3) is in one's physical possession and then locked up or otherwise sealed so that tampering will be evident, or (4) is kept in a secure area restricted to authorized personnel only. Personnel who collect samples are personally responsible for the care and integrity of these collected samples until the samples are properly transferred or dispatched. To document that samples are properly transferred or dispatched, sample identification

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and chain of custody procedures must be followed. Sample custody in the field and in transit involves the steps described below.

Sample Identification. The sample must first be properly and uniquely identified. Sample identification entails establishing a scheme which ensures that each sample is identified in such a way that one sample cannot be mistaken for another. Examples of sample labels are shown in figure 12-3. Labels must be filled out immediately after the sample is collected to ensure that containers are not later misidentified. Indelible ink must be used on all labels, and the writing must be legible. For samples which require preservation, the sample labels must have a space on the label reserved for noting the preservative added, or other treatments, such as filtering, compositing, etc. Labels can be removed from a sample jar during shipment, especially if the accompanying ice melts and saturates the shipping labels. Double-label samples such as sacked soil whenever possible or completely wrap the label over the sample bottle with wide, water-proof tape. Also record the collection of each sample in the field log book and chain of custody records.

Chain of Custody. Once all samples for a specific sampling task have been collected, the sampler(s) will complete the chain of custody record (figure 12-4). Specific procedures for completing this form should be included in the work plan documents specific to the project. This record accompanies the samples to their destination. All samples typically are transferred from the sample transport container (e.g., cooler) and kept in the exclusion zone until transferred to a noncontaminated sample transport container in the contamination reduction zone. The samples, with accompanying documentation, are

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Soil Sample Identification Label

Bureau of Reclamation Chemistry Laboratory Sample ID	
Project	_____
Feature (dam, river, etc)	_____
Sampling date	_____ Time _____
ID:	_____

Analysis Request	_____
Comments:	_____

Water Sample Identification Labels

*****TRACE ELEMENTS*****	
DATE _____	SITE _____
TIME _____	
SAMPLED _____	SAMPLER _____
PLASTIC, 250 ML, RAW	
ACIDIFIED WITH HNO ₃	

*****UNTREATED SAMPLE*****	
DATE _____	SITE _____
TIME _____	
SAMPLED _____	SAMPLER _____
PLASTIC, 250 ML, RAW	

Figure 12-3. Soil and water sample identification labels.

Chain of Custody Record

Project Manager			Project name					Batch identification												
Samped by and title (signatures)								Date Time					Remarks	Initials and date sample destroyed						
Laboratory																				
Field identification	Date collected	Time	Lab identification	Sample type																
Relinquished by (signature)		Date	Time	Relinquished by (signature)		Date	Time	Relinquished by (signature)		Date	Time									
Received by (signature)		Date	Time	Received by (signature)		Date	Time	Received by lab (signature)		Date	Time									

Point of contact: _____

Remarks: _____

DISTRIBUTION: Original: Accompanies shipment. Pink copy: Field records. Yellow copy: Associate laboratory

Sample shipped via

Priority Mail Bus Other

Express Mail UPS

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Figure 12-4. Chain of custody record.

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then prepared for either distribution to the onsite laboratory or shipment to an analytical laboratory in the support zone.

When transferring the possession of samples, the individuals relinquishing and receiving the samples will sign, date, and note the time on the chain of custody record. This record documents sample custody transfer from the sampler to the analyst. Note that some commercial shippers (such as Federal Express) do not sign chain of custody records but do prepare separate shipping documents which indicate receipt of the cooler(s). When samples are passed among field personnel while still onsite, chain of custody records do not need to be signed, as long as physical possession is retained by identified, responsible personnel during transit of the container(s).

Packaging

Samples must be packaged properly for shipment and dispatched to the appropriate laboratory for analysis; a separate record accompanies each shipment. Samples within shipping containers will be sealed for shipment to the laboratory by using custody seals (figure 12-5). Seals are made of paper, with adhesive backing, so that they will tear easily to indicate possible tampering. There are two methods of using custody seals. One method is to place several sample containers in individual plastic bags (or boxes) within the shipping container and then place the custody seal along the only opening of each bag. An advantage of this scheme is that the seal is not exposed to outside influences; but the disadvantages are that the bags are very pliable, and shifting may cause the seal to break, and the seal may become immersed in water if ice melts around the bags. The second method is to place the custody seal on the outside of the cooler, along a seam of

 <p>UNITED STATES BUREAU OF RECLAMATION OFFICIAL SAMPLE SEAL</p>	SAMPLE NO.	DATE	SEAL BROKEN BY	DATE
	SIGNATURE			
	PRINT NAME AND TITLE (Inspector, Analyst or Technician)			

7-2284 (3-81)
Bureau of Reclamation

Figure 12-5 Custody seal.

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the lid. The advantage of this method is that the seal is stuck to the solid body of the cooler. The main disadvantage is that the seal is exposed to handling by the shipping company and other personnel from the field to the laboratory. The seal must not be broken accidentally because a broken seal will place all the samples represented by the seal in jeopardy of disqualification due to tampering. An option may be to place clear tape over the seal as added protection.

The samples within a container must be packed to avoid rattling and breakage. Styrofoam "popcorn" or bubble pack sheeting are acceptable packing materials. Organic packing materials, including sawdust, should be avoided due to the possibility of becoming wet from melting ice. Each sample jar should be wrapped such that jar-to-jar contact is avoided. Also, it is usually desirable to place ice at the bottom of the container, and place the samples above the ice, with a water-proof barrier between the ice and samples. This way, if the ice melts, there is a lessened probability of the samples becoming immersed. If time is available, ice should be double-wrapped, using several "ice packages" to lessen spillage potential. Chemical ice packs and dry ice should be avoided, if possible, to lessen the chance of chemical contamination. The chain of custody record must accompany each container and list only the samples contained within the specified cooler. The original chain of custody record should be sealed in a "zip-lock" plastic bag and taped to the inside top of the cooler lid. When the laboratory opens a cooler, the number and identification of each sample contained within the cooler must exactly match the corresponding chain of custody record. A copy of the chain of custody record is to be retained by the investigator or site manager, and a copy is also retained by the laboratory. A three-carbon copy type chain of custody record is best.

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The water drain at the lower edge of the cooler must be sealed so there is no possibility of the drain opening. If any leakage occurs from a cooler containing environmental samples, the shipping company will cease shipment and delay the arrival of the samples, possibly exceeding the holding times of the contained samples. A shipping company may have unique requirements; but as a general rule, the weight of a cooler should not exceed 50 to 70 pounds. If sent by mail, the package must be receipt requested. If sent by common carrier, a government bill of lading can be used. Proper shipment tracking methods must be in place. Copies of all receipts, etc., must be retained as part of the permanent documentation.

Upon arrival at the laboratory, the containers will be opened, the custody seals inspected and documented, and any problems with chain of custody, temperature, or sample integrity noted. The laboratory custodian will then sign and date the chain of custody record and enter the sample identification numbers into a bound, paginated log book, possibly assigning and cross-referencing a unique laboratory number to each sample received. The laboratory then controls the samples according to the SOPs specified in their work plan documents.

Decontamination

Decontamination consists of removing contaminants and/or changing their chemical nature to innocuous substances. How extensive decontamination must be depends on a number of factors, the most important being the type of contaminants involved. The more harmful the contaminant, the more extensive and thorough decontamination must be. Less harmful contaminants may

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require less decontamination. Only general guidance can be given on methods and techniques for decontamination. The exact procedure to use must be determined after evaluating a number of factors specific to the site.

When planning site operations, methods should be developed to prevent the contamination of people and equipment. For example, using remote sampling techniques, using disposable sampling equipment, watering down dusty areas, and not walking through areas of obvious contamination would reduce the probability of becoming contaminated and require a less elaborate decontamination procedure.

The initial decontamination plan is usually based on a worst-case situation. During the investigations, specific conditions are evaluated including: type of contaminant, the amount of contamination, the levels of protection required, and the type of protective clothing needed. The initial decontamination system may be modified by adapting it to actual site conditions.