



Engineering Bulletin

Technology Preselection Data Requirements

Purpose

Section 121(b) of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) mandates the Environmental Protection Agency (EPA) to select remedies that "utilize permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable" and to prefer remedial actions in which treatment "permanently and significantly reduces the volume, toxicity, or mobility of hazardous substances, pollutants, and contaminants as a principal element." The Engineering Bulletins are a series of documents that summarize the latest information available on selected treatment and site remediation technologies and related issues. The summaries and references are designed to help remedial project managers, on-scene coordinators, contractors, and other site cleanup managers understand and select technologies that may have potential applicability to their Superfund or other hazardous waste sites.

This bulletin provides a listing of soil, water, and contaminant data elements needed to evaluate the potential applicability of technologies for treating contaminated soils and water. With this base set of data in hand, experts familiar with the applicability of treatment technologies can better focus the advice and assistance they give to those involved at Superfund sites. The data compiled should permit preselection of applicable treatment methods and the direct elimination of others.

This bulletin emphasizes the site physical and chemical soil and water characteristics for which observations and measurements should be compiled. However, several other kinds of information may be equally helpful in assessing the potential success of a treatment technology including the activity history of the site, how and where wastes were disposed, topographic and hydrologic detail, and site stratigraphy. Gathering and analyzing the information called for in this bulletin prior to extensive field investigations [i.e., the Remedial Investigation and Feasibility Study (RI/FS)] will facilitate streamlining and targeting of the sampling and analytical objectives of the overall program.

Additional information on site data requirements for the selection of specific treatment technologies may be found in several EPA publications [1] [2] [3] [4] [5].* These documents form much of the basis for this Engineering Bulletin. The bulletin may be updated by periodically-issued addenda.

Abstract

A base set of soil and water analytical (measured) data requirements has been developed to enable prescreening of technologies that may have potential applicability at Superfund sites. Data requirements for soils include the traditional engineering properties of soils and data on soil chemistry, including contaminants and oxygen demand. Analytical data requirements for water (usually groundwater) include chemistry, oxygen demand, and pH. Of particular importance in chemical characterization of both soils and water are contaminating metals and organic chemicals, whose presence or absence is often suggested by historical site activities. Sampling and measurements at this stage need not be in great detail, but should be sufficient to preliminarily characterize the site variability in three dimensions. Topography, groundwater flow, stratigraphy of the contaminated zone, and degree of consolidation will also affect the choice of treatment technology.

The relationships between each of the data requirements and specific treatment technologies are briefly summarized. The detailed reasoning may be found in one or more of the references.

The guidance presented in this bulletin is not exhaustive. The data elements are those that have wide technological applicability and those that can be collected in a straightforward manner. Data gaps are still likely to exist. However, an almost certain result is that the additional data needs will be better focused.

Background Information

The background information collected during the Site Screening Investigation and Preliminary Assessment identifies the probable types and locations of contaminants present. Study of the chemicals used or stored at the site and the disposal methods used during the period(s) of operation is essential. When chemical-use records are unavailable for an industrial site, knowledge of the Standard Industrial Classification may indicate the probability of the presence of metals, inorganics, pesticides, dioxins/furans, or other organics. Information on what classes and concentrations of chemicals contaminate the site, where they are distributed, and in what media they appear is essential in beginning the preselection of treatment technologies [2, p. 7].

* [reference number, page number]

The contaminant distribution, types, and concentrations will affect the choice of treatment technology. Other considerations in the selection of treatment options include the proximity of residential areas and the location of buildings and other structures. These aspects should be determined early in the investigation process. Much of the determination of the range and diversity of contamination, as well as likely contaminant sources, may be observational, rather than measurement-based.

Basic Measurement Data Requirements

The discussion of data requirements is divided into two sections, soil and water. For each of the two media, the vertical and horizontal contaminant profiles should be defined as much as possible. Information on the overall range and diversity of contamination across the site is critical to treatment technology selection. This generally means that samples will be taken and their physical and chemical characteristics determined. The following subsections present the characteristics and rationale for collection of preselection data for each of the two media. Other documents present similar data requirements, especially for soils [6].

The minimum set of soil measurement data elements usually necessary for soil treatment technology preselection is presented in Table 1. Table 2 presents the basic set of data necessary for contaminated water treatment technology preselection. It is common for the two media at one site to be contaminated with the same substances, thus many of the required data elements are similar. The information contained in Table 1 and Table 2 is based on professional judgement.

The ratings in Table 1 and Table 2 are related to measured values of the parameters. The values are described as "higher" and "lower" in defining their tendency toward preselecting a technology group. In general, these descriptors are related to the tendency of the parameter to enhance or to inhibit particular processes. Where no symbol is shown for a characteristic in Table 1 and Table 2, the affect on the associated technology is considered inconsequential.

Each characteristic is judged, or rated, as to its effect in preselecting each of the treatment technology groups which represent various treatment processes. A rating applies generally to a technology, but it does not ensure that the rating will be applicable to each specific technology within a technology group. Examples of specific treatments within the technology groups are as follows:

- Physical

Soil washing	Vapor extraction
Soil flushing	Carbon adsorption
Steam extraction	Filtration
Air stripping	Gravity separation
Solvent extraction	
- Chemical

Oxidation	Reduction
Hydrolysis	Precipitation
Polymerization	

- Thermal

Incineration	Pyrolysis
Plasma Arc	Thermal desorption
- Biological

Aerobic	Anaerobic
Slurry reactor	Land treatment
- Solidification/Stabilization

Cement-based	Vitrification
Fly ash/lime	Asphalt
Kiln dust	

Soil

Site soil conditions are frequently process-limiting. Process-limiting characteristics such as pH or moisture content [6] may sometimes be adjusted. In other cases, a treatment technology may be eliminated based upon the soil classification (e.g., particle-size distribution) or other soil characteristics.

Soils are inherently variable in their physical and chemical characteristics. Frequently the variability is much greater vertically than horizontally, resulting from the variability in the sedimentation processes that originally formed the soils. The soil variability, in turn, will result in variability in the distribution of water and contaminants and in the ease with which they can be transported within, and removed from, the soil at a particular site.

Many data elements are relatively easy to obtain, and in some cases, more than one test method exists [6] [7] [8] [9] [10] [11] [12]. Field procedures, usually visual inspection and/or operation of simple hand-held devices (e.g., auger), are performed by trained geologists or soils engineers to determine the classification, moisture content, and permeability of soils across a site. Due to the fact that zones of gross contamination may be directly observed, field reports describing soil variability may lessen the need for large numbers of samples and measurements in describing site characteristics. Common field information-gathering often includes descriptions of natural soil exposures, weathering that may have taken place, trench cross-sections, and subsurface cores. Such an effort can sometimes identify probable areas of past disposal through observation of soil type differences, subsidence, overfill, etc.

While field investigations are important, they cannot eliminate the need for or lessen the importance of soil sampling and measurements sufficient to define those characteristics that are essential to the selection and design of soil treatment technologies.

Soil **particle-size distribution** is an important factor in many soil treatment technologies. In general, sands and fine gravels are easiest to deal with. Soil washing may not be effective where the soil is composed of large percentages of silt and clay because of the difficulty of separating fine particles from each other and from wash fluids [13, p. 1]. Fine particles also can result in high particulate loading in flue gases due to

TABLE 1. SOIL CHARACTERISTICS THAT ASSIST IN TREATMENT TECHNOLOGY PRESELECTION

CHARACTERISTIC	TREATMENT TECHNOLOGY GROUP				
	PHYSICAL	CHEMICAL	BIOLOGICAL	THERMAL	S/S
Particle size	■	▼	▼	■	■
Bulk density	▼			■	
Particle density	■				
Permeability	■		■		
Moisture content	▼		■	□	□
pH and Eh		▼	▼	▼	
Humic content	□	□	□	▼	□
Total organic carbon (TOC)		▼	■	■	▼
Biochemical oxygen demand (BOD)			■		
Chemical oxygen demand (COD)		■	■		
Oil and grease	▼	□			□
Organic Contaminants					
Halogenated volatiles	▼	▼	□	■	□
Halogenated semivolatiles	▼	▼	□	■	□
Nonhalogenated volatiles	▼	▼	▼	■	□
Nonhalogenated semivolatiles	▼	▼	▼	■	□
PCBs	▼	▼	▼	■	□
Pesticides	▼	▼	▼	■	□
Dioxins/Furans	▼	▼	▼	■	□
Organic cyanides	▼	▼	▼	■	□
Organic corrosives	▼	▼	▼	□	□
Light Nonaqueous-Phase Liquid	▼		▼	■	□
Dense Nonaqueous-Phase Liquid	▼		▼	▼	□
Heating value (Btu content)				■	
Inorganic Contaminants					
Volatile metals		▼		□	
Nonvolatile metals	■	▼	□	□	■
Asbestos				□	■
Radioactive materials	▼	▼	□	□	▼
Inorganic cyanides		▼		▼	▼
Inorganic corrosives		▼		□	▼
Reactive Contaminants					
Oxidizers		▼			
Reducers		▼			

■ = higher values support preselection of technology group.
 □ = lower values support preselection of technology group.
 ▼ = Effect is variable among options within a technology group.
 Where no symbol is shown, the effect of that characteristic is considered inconsequential

TABLE 2. WATER CHARACTERISTICS THAT ASSIST IN TREATMENT TECHNOLOGY PRESELECTION

CHARACTERISTIC	TREATMENT TECHNOLOGY GROUP			
	PHYSICAL	CHEMICAL	BIOLOGICAL	THERMAL
pH, Eh		▼	▼	▼
Total organic carbon (TOC)		▼	■	■
Biochemical oxygen demand (BOD)			■	
Chemical oxygen demand (COD)		■	■	
Oil and grease	▼	□		
Suspended solids	▼	▼	▼	
Nitrogen & phosphorus			▼	
Organic Contaminants				
Halogenated volatiles	▼	▼	□	■
Halogenated semivolatiles	▼	▼	□	■
Nonhalogenated volatiles	▼	▼	▼	■
Nonhalogenated semivolatiles	▼	▼	▼	■
PCBs	▼	▼	▼	■
Pesticides	▼	▼	▼	■
Dioxins/Furans	▼	▼	□	■
Organic cyanides	▼	▼	▼	■
Organic corrosives	▼	▼	▼	□
Light Nonaqueous-Phase Liquid	▼		▼	■
Dense Nonaqueous-Phase Liquid	▼		▼	▼
Inorganic Contaminants				
Asbestos				□
Radioactive materials	▼	▼	□	□
Metals (Drinking Water Stds.)	▼	■	□	□

■ = higher values support preselection of technology group.
 □ = lower values support preselection of technology group.
 ▼ = Effect is variable among options within a technology group.
 Where no symbol is shown, the effect of that characteristic is considered inconsequential

turbulence in rotary kilns. Heterogeneities in soil and waste composition may produce non-uniform feed streams for incineration that result in inconsistent removal rates [1][14]. Fine particles may delay setting and curing times and can surround larger particles causing weakened bonds in solidification/stabilization processes. Clays may cause poor performance of the thermal desorption technology due to caking [15, p. 2]. High silt and clay content can cause soil malleability and low permeability during steam extraction, thus lowering the efficiency of the process [16, p. 2]. Bioremediation processes, such as in slurry reactors, are generally facilitated by finer particles that

increase the contact area between the waste and microorganisms [14] [17, p. 1].

In situ technologies dependent on the subsurface flowability of fluids, such as soil flushing, steam extraction, vacuum extraction, and in situ biodegradation, will be negatively influenced by the impeding effects of clay layers [15, p. 2] [18, p. 4]. Undesirable channeling may be created in alternating layers of clay and sand, resulting in inconsistent treatment [2, p. 79]. Larger particles, such as coarse gravel or cobbles, are undesirable for vitrification and chemical extraction processes and also may not be suitable for the stabilization/solidification technology [2, p. 93].

The **bulk density** of soil is the weight of the soil per unit volume including water and voids. It is used in converting weight to volume in materials handling calculations [19, p. 3-3]. Soil bulk density and particle size distribution are interrelated in determining if proper mixing and heat transfer will occur in fluidized bed reactors [2, p. 39].

Particle density is the specific gravity of a soil particle. Differences in particle density are important in heavy mineral/metal separation processes (heavy media separation). Particle density is also important in soil washing and in determining the settling velocity of suspended soil particles in flocculation and sedimentation processes [13, p. 1].

Soil **permeability** is one of the controlling factors in the effectiveness of in situ treatment technologies. The ability of soil-flushing fluids (e.g., water, steam, solvents, etc.) to contact and remove contaminants can be reduced by low soil permeability or by variations in the permeability of different soil layers [16, p. 2] [19, p. 4-9]. Low permeability also hinders the movement of air and vapors through the soil matrix, lessening the volatilization of VOCs in vapor extraction [17, p. 2]. Similarly, nutrient solutions, used to accelerate in situ bioremediation, may not be able to penetrate low-permeability soils in a reasonable time [1]. Low permeability may also limit the effectiveness of in-situ vitrification by slowing vapor releases [2, p. 59].

Soil **moisture** may hinder the movement of air through the soil in vacuum extraction systems [3, p. 90] [17, p. 1]. High soil moisture may cause excavation and material transport problems [20, p. 2] and may negatively impact material feed in many processes [2] [15, p. 2] [19, p. 4] [21]. Moisture affects the application of vitrification and other thermal treatments by increasing energy requirements, thereby increasing costs. On the other hand, increased soil moisture favors in situ biological treatment [22, p. 40].

Many treatment technologies are affected by the **pH** of the waste being treated. For example, low pH can interfere with chemical oxidation and reduction processes. The solubility and speciation of inorganic contaminants are affected by pH. Ion exchange and flocculation processes, applied after various liquid extraction processes, may be negatively influenced by pH [1, p. 5, 16]. Microbial diversity and activity in bioremediation processes can be reduced by extreme pH ranges. High pH in soil normally improves the feasibility of applying chemical ex-

traction and alkaline dehalogenation processes [2, p. 67].

Eh is the oxidation-reduction (redox) potential of the material being considered. For oxidation to occur in soil systems, the Eh of the solid phase must be greater than that of the organic chemical contaminant [22, p. 19]. Maintaining anaerobiosis, and thus a low Eh, in the liquid phase, enhances decomposition of certain halogenated organic compounds [23].

Humic content (humus) is the decomposing part of the naturally occurring organic content of the soil. The effects of high humic content upon treatment technologies are usually negative. It can inhibit soil-vapor extraction, steam extraction, soil washing, and soil flushing due to strong adsorption of the contaminant by the organic material [2, p. 76] [17, p. 2]. Reaction times for chemical dehalogenation processes can be increased by the presence of large amounts of humic materials. High organic content may also exert an excessive oxygen demand, adversely affecting bioremediation and chemical oxidation [24, p. 2] [25, p. 1].

Total organic carbon (TOC) provides an indication of the total organic material present. It is often used as an indicator (but not a measure) of the amount of waste available for biodegradation [2, p. 109]. TOC includes the carbon both from naturally-occurring organic material and organic chemical contaminants. Ordinarily, not all of the organic carbon is contaminating, but all of it may compete in redox reactions, leading to the need for larger amounts of chemical reduction/oxidation reagents than would be required by the organic chemical contaminants alone [2, p. 97].

Biochemical oxygen demand (BOD) provides an estimate of the biological treatability of the soil contaminants by measuring the oxygen consumption of the organic material which is readily biodegraded [3, p. 89]. **Chemical oxygen demand (COD)** is a measure of the oxygen equivalent of organic content in a sample that can be oxidized by a strong chemical oxidant. Sometimes COD and BOD can be correlated, and COD can give another indication of biological treatability or treatability by chemical oxidation [2, p. 97]. COD is also useful in assessing the applicability of wet air oxidation [2, p. 51].

Oil and grease, when present in a soil, will coat the soil particles. The coating tends to weaken the bond between soil and cement in cement-based solidification [14]. Similarly, oil and grease can also interfere with reactant-to-waste contact in chemical reduction/oxidation reactions thus reducing the efficiency of those reactions [2, p. 97].

Identification of the site **organic and inorganic contaminants** is the most important information necessary for technology prescreening. At this stage, it may not be necessary to identify specific contaminants, but the presence or absence of the groups shown in Table 1 should be known. These groups have been presented in the other Engineering Bulletins in order to describe the effectiveness of the particular treatment technology under consideration.

The soil may be contaminated with organic chemicals that

are not miscible with water. Often, they will be lighter than water and float on top of the water table. These are called light nonaqueous-phase liquids (LNAPLs). Those heavier than water are called dense nonaqueous-phase liquids (DNAPLs). Most of these liquids can be physically separated from water within the soil, especially if they are not adsorbed to soil particles.

Volatile, semivolatile, and other organics may be adsorbed in the soil matrix. Volatiles may be in the form of vapors in the pores of non-saturated soil, and may be amenable to soil-vapor extraction. Fuel value, or Btu content, of the contaminated soil is directly related to the organic chemical content. High Btu content favors thermal treatment, or perhaps recovery for fuel use.

High halogen concentrations, as in chlorinated organics, lead to the formation of corrosive acids in incineration systems. Volatile metals produce emissions that are difficult to remove, and nonvolatile metals remain in the ash [14].

Metals may be found sometimes in the elemental form, but more often they are found as salts mixed in the soil. Radioactive materials are not ordinarily found at waste disposal sites. However, where they are found, treatment options are probably limited to volume reduction, and permanent containment is required. Asbestos fibers require special care to prevent their escape during handling and disposal; permanent containment must be provided. Radioactive materials and asbestos require special handling techniques to maintain worker safety.

Often, specific technologies may be ruled out, or the list of potential technologies may be immediately narrowed, on the basis of the presence or absence of one or more of the chemical groups. The relative amounts of each may tend to favor certain technologies. For example, significant amounts of dioxin/furans, regardless of the concentrations of other organics, will ordinarily lead to preselection of thermal treatment as an alternative.

Data available from the preliminary assessment, the site inspection and the National Priorities List (NPL) activities may provide most of the contaminant information needed at the technology prescreening stage. If the data are not sufficient, waste samples may be scanned for selected priority pollutants or contaminants from the CERCLA Hazardous Substances List. During the ensuing RI/FS scoping phase, these data are evaluated to identify additional data which must be gathered during the site characterization. Guidance is available on the RI/FS process and on field methods, sampling procedures, and data quality objectives [4][5][6][12] and therefore is not discussed in this bulletin.

Water

It is common for groundwater and surface water drainage to be contaminated with the same substances found in soils derived from previous activities. At Superfund sites, many of the required data elements are similar, e.g., pH, TOC, BOD, COD, oil and grease, and contaminant identification and quantification. Frequently, many of the water data elements will be

available from existing analytical data. Some initial data requirements may even be precluded by the collection of existing regional or local information on surface and groundwater conditions. When data are not available, knowledge of the site conditions and its history may contribute to arriving at a list of contaminants and cost-effective analytical methods.

As with soils, the pH of groundwater and surface water is important in determining the applicability of many treatment processes. Often, the pH must be adjusted before or during a treatment process. Low pH can interfere with chemical redox processes. Extreme pH levels can limit microbial diversity and hamper the application of both in situ and above-ground applications of biological treatment [2, p. 97]. Contaminant solubility and toxicity may be affected by changes in pH. The species of metals and inorganics present are influenced by the pH of the water, as are the type of phenolic, and nitrogen-containing compounds present. Processes such as carbon adsorption, ion exchange, and flocculation may be impacted by pH changes [1, p. 5].

Eh helps to define, with pH, the state of oxidation-reduction equilibria in groundwater or aqueous waste streams. The Eh must be below approximately 0.35 volts for significant reductive chlorination to take place, but exact requirements depend on the individual compounds being reduced. As noted earlier in the soils section, maintaining anaerobiosis (low Eh) enhances decomposition of certain halogenated compounds [23].

BOD, COD, and TOC measurements in contaminated water, as in soils, provide indications of the biodegradable, chemically oxidizable, or combustible fractions of the organic contamination, respectively. These measurements are not interchangeable, although correlations may sometimes be made in order to convert the more precise TOC and/or COD measurements to estimates of BOD. Interpretation of these data should be made by an expert in the technologies being considered.

Oil and grease may be present in water to the extent that they are the primary site contaminants. In that case, oil-water separation may be called for as the principal treatment. Even in lower concentrations, oil and grease may still require pretreatment to prevent clogging of ion exchange resins, activated carbon systems, or other treatment system components [3, p. 91].

Suspended solids can cause resin binding in ion exchange systems and clogging of reverse osmosis membranes, filtration systems and carbon adsorption units. Suspended solids above 5 percent indicate that analysis of total and soluble metals should be made [1, p. 14].

Standard analytical methods are used to identify the specific **organic and inorganic contaminants**. Properties of organic chemical contaminants important in treatment processes include solubility in water, specific gravity, boiling point, and vapor pressure. For the identified contaminants, these properties can generally be found in standard references [26] or in EPA/RREL's Treatability Database [27].

Insoluble organic contaminants may be present as non-aqueous phase liquids (NAPLs). DNAPLs will tend to sink to the bottom of surface waters and groundwater aquifers. LNAPLs will float on top of surface water and groundwater. In addition, LNAPLs may adhere to the soil through the capillary fringe and may be found on top of water in temporary or perched aquifers in the vadose zone.

As noted previously, volatile organics may be in the form of vapors in the pores of non-saturated soil, or they may be dissolved in water. Even low-solubility organics may be present at low concentrations dissolved in water. Some organics (e.g. certain halogenated compounds, pesticides, and dioxins/furans in water) resist biological treatment, while others may be amenable to several technologies.

Dissolved metals may be found at toxic levels or levels exceeding drinking water standards. Often they will require chemical treatment. The speciation of metals may be important in determining the solubility, toxicity, and reactivity of metal compounds.

Status of Data Requirements

The data requirements presented in Tables 1 and 2 are based on currently available information. Preselection of new and evolving technologies, or of currently used technologies that have been modified, may require the collection of additional data. New analytical methods may be devised to replace or supplement existing methods. Such improvements in analytical technology also could require additional data to be collected. This bulletin may be updated if major changes occur in data requirements for preselection of treatment technology alternatives.

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Acknowledgments

This engineering bulletin was prepared for the U.S. Environmental Protection Agency, Office of Research and Development (ORD), Risk Reduction Engineering Laboratory (RREL), Cincinnati, Ohio, by Science Applications International Corporation (SAIC) under EPA Contract No. 68-C8-0062. Mr. Eugene Harris served as the EPA Technical Project Monitor. Mr. Gary Baker was SAIC's Work Assignment Manager. Mr. Jim Rawe (SAIC) and Mr. Robert Hartley (SAIC) were the authors of the bulletin.

The following other Agency and contractor personnel have contributed their time and comments by participating in the expert review meetings and/or peer reviewing the document:

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