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Guide for Conducting Treatability Studies under CERCLA: Thermal Desorption Remedy Selection

Interim Guidance

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September 1992

GUIDE FOR CONDUCTING TREATABILITY STUDIES UNDER CERCLA: THERMAL DESORPTION REMEDY SELECTION

INTERIM GUIDANCE

Risk Reduction Engineering Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

and

Office of Emergency and Remedial Response
Office of Solid Waste and Emergency Response
U.S. Environmental Protection Agency
Washington, D.C. 20460

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DISCLAIMER

The information in this document has been funded wholly or in part by the U.S. Environmental Protection Agency (EPA) under Contract No. 68-C8-0062, Work Assignment 3-46, to Science Applications International Corporation (SAIC). It has been subjected to the Agency's peer and administrative reviews and it has been approved for publication as an EPA document. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

FOREWORD

Today's rapidly developing and changing technologies and industrial products and practices frequently carry with them the increased generation of materials that, if improperly dealt with, can threaten both public health and the environment. The U.S. Environmental Protection Agency is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. These laws direct the EPA to perform research to define our environmental problems, measure the impacts, and search for solutions.

The Risk Reduction Engineering Laboratory is responsible for planning, implementing, and managing research, development, and demonstration programs to provide an authoritative, defensible engineering basis in support of the policies, programs, and regulations of the EPA with respect to drinking water, wastewater, pesticides, toxic substances, solid and hazardous wastes, and Superfund-related activities. This publication is one of the products of that research and provides a vital communication link between the researcher and the user community.

The primary purpose of this guide is to provide standard guidance for designing and implementing a thermal desorption treatability study in support of remedy selection. Additionally, it describes a three-tiered approach, that consists of 1) remedy screening, 2) remedy selection, and 3) remedy design to thermal desorption treatability testing. It also presents a guide for conducting treatability studies in a systematic and stepwise fashion for determination of the effectiveness of thermal desorption (in conjunction with other treatment technologies) in remediating a CERCLA site. The intended audience for this guide comprises Remedial Project Managers (RPMs), On-Scene Coordinators (OSCs), Potentially Responsible Parties (PRPs), consultants, contractors, and technology vendors.

E. Timothy Oppelt, Director
Risk Reduction Engineering Laboratory

ABSTRACT

Systematically conducted, well-documented treatability studies are an important component of the remedial investigation/feasibility study (RI/FS) process and the remedial design/remedial action (RD/RA) process under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). These studies provide valuable site-specific data necessary to aid in the selection and implementation of the remedy. This manual focuses on thermal desorption treatability studies conducted in support of remedy selection prior to developing the Record of Decision.

This manual presents a standard guide for designing and implementing a thermal desorption remedy selection treatability study. The manual presents a description of and discusses the applicability and limitations of thermal desorption technologies and defines the prescreening and field measurement needed to determine if treatability testing is required. It also presents an overview of the process of conducting treatability tests and the applicability of tiered treatability testing for evaluating thermal desorption technologies. The specific goals for each tier of testing are defined and performance levels are presented that define which levels should be met before additional tests are conducted at the next tier. The elements of a treatability study work plan are also defined with detailed discussions on the design and execution of the remedy screening and remedy selection treatability studies.

The manual is not intended to serve as a substitute for communication with experts or regulators nor as the sole basis for the selection of thermal desorption as a particular remediation technology. Thermal desorption must be used in conjunction with other treatment technologies since it generates residuals. This manual is designed to be used in conjunction with the Guide for Conducting Treatability Studies Under CERCLA (Interim Final).[28] The intended audience for this guide comprises Remedial Project Managers (RPMs), On-Scene Coordinators (OSCs), Potentially Responsible Parties (PRPs), consultants, contractors, and technology vendors.

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SECTION 1
INTRODUCTION

1.1 BACKGROUND

Section 121(b) of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) mandates 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 that "permanently reduces the volume, toxicity, or mobility of hazardous substances, pollutants, and contaminants is a principal element." Treatability studies provide data to support treatment technology selection and remedy implementation. If treatability studies are used, they should be performed as soon as it is evident that insufficient information is available to ensure the quality of the decision. Conducting treatability studies early in the remedial investigation/feasibility study (RI/FS) process reduces uncertainties associated with selecting the remedy and provides a sound basis for the Record of Decision (ROD). EPA Regional planning should factor in the time and resources required for these studies.

Treatability studies conducted during the RI/FS phase indicate whether the technology can meet the cleanup goals for the site, whereas treatability studies conducted during the remedial design/remedial action (RD/RA) phase establish design and operating parameters for optimization of technology performance. Although the purpose and scope of these studies differ, they complement one another since information obtained in support of remedy selection may also be used to support the remedy design.[38]

This document refers to three levels or tiers of treatability studies: remedy screening, remedy selection, and remedy design. Three tiers of treatability studies are also defined in the Guide for Conducting Treatability Studies Under CERCLA, Interim Final,[28] referred to as the "generic guide" hereafter in this document. The generic guide refers to the three treatability study tiers, based largely on the scale of test equipment described as laboratory screening, bench-scale testing, and pilot-scale testing. Laboratory screening is typically used to screen potential remedial technologies and is equivalent to remedy screening. Bench-scale testing is typically used for remedy selection, but may fall short of providing enough information for remedy selection. However, bench-scale studies can, in some cases, provide enough information for full-scale design. Pilot-scale studies are normally used for remedial design, but may be required for remedy selection in some cases due to the complexity of equipment needed for some processes. Because of the overlap between these tiers, and because of differences in the applicability of each tier to different technologies, the functional description of treatability study tiers (i.e., remedy screening, remedy selection, and remedy design) has been chosen for this document.

The need for and the level of treatability testing required are management decisions. Some or all of the levels may be needed on a case-by-case basis. The time and cost necessary to perform the testing are balanced against the improved confidence in the selection and design of treatment alternatives. These decisions are based on the quantity and quality of data available and on other factors (e.g., state and community acceptance of the remedy, new site data, or experience with the technology). Section 3 discusses using treatability studies in remedy selection in greater detail.

1.2 PURPOSE AND SCOPE

This guide helps ensure a reliable and consistent approach in evaluating whether thermal desorption should be considered for site remediation. This guide discusses the remedy screening and remedy selection levels of treatability testing. Remedy screening studies provide a quick and relatively inexpensive indication of whether thermal desorption is a potentially viable remedial technology. The remedy selection treatability test provides data to help determine if reductions in contaminant concentrations will allow cost-effective treatment of residual contamination to meet site cleanup goals. Remedy selection studies also provide a preliminary estimate of the cost and performance data necessary to scope either a remedy design study or a full-scale thermal desorption system. In general, remedy design studies will also be required to determine if thermal desorption is a viable treatment alternative for a site by providing detailed cost and operating parameters acceptable for scale-up.

1.3 INTENDED AUDIENCE

Intended use of this document is by Remedial Project Managers (RPMs), On-Scene Coordinators (OSCs), Potentially Responsible Parties (PRPs), consultants, contractors, and technology vendors. Each has different roles in conducting treatability studies under CERCLA. Specific responsibilities for each can be found in the generic guide.[28]

1.4 USE OF THIS GUIDE

This guide is organized into seven sections, which reflect the basic information required to perform treatability studies during the RI/FS process. Section 1 is an introduction which provides background information on the role of the guide and outlines its intended audience. Section 2 describes different thermal desorption processes currently available and discusses how to conduct a preliminary screening to determine if thermal desorption is a potentially viable remediation technology. Section 3 provides an overview of the different levels of treatability testing and discusses how to determine the need for treatability studies. Section 4 provides an overview of the remedy screening and remedy selection treatability studies, describes the contents of a typical work plan, and discusses the major issues to consider when conducting a treatability study. Section 5 discusses sampling and analysis and quality assurance project plans. Section 6 explains how to interpret the data produced from treatability studies and how to determine if further remedy design testing is justified. Section 7 lists the references.

This guide, along with guides being developed for other technologies, is a companion document to the generic guide.[28] In an effort to avoid redundancy, supporting information in the generic guide and other readily available guidance documents is not repeated in this document.

The document is not intended to serve as a substitute for communication with regulators and/or experts in the field of thermal desorption. This document should never be the sole basis for the selection of thermal desorption as a remediation technology or the exclusion of thermal desorption from consideration.

As treatability study experience is gained, EPA anticipates further comment and possible revisions to the document. For this reason, EPA encourages constructive comments from outside sources. Direct written comments to:

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SECTION 2
TECHNOLOGY DESCRIPTION AND PRELIMINARY SCREENING

This section presents a description of thermal desorption systems that can be used for remediation of Superfund sites. Subsection 2.1 describes the technology and the types of residual streams produced. Subsection 2.2 discusses recommended literature and database searches, the technical assistance available, and the review of field data required to prescreen the thermal desorption technology. Also presented in this subsection are the major limitations and considerations imposed by application of the technology to a Superfund site.

2.1 TECHNOLOGY DESCRIPTION

This subsection presents a description of the principle of operation for the technology, an overview of the current status of application of thermal desorption at Superfund sites, general materials handling and preparation requirements, a focused discussion on the major configurations of thermal desorbers, and a brief discussion of the type of residuals produced. Four types of desorption units are described: rotary dryers, thermal screws, vapor extractors, and distillation chambers.

Additional information on thermal desorption systems are described in an EPA Engineering Bulletin.[26] The bulletin provides information on the technology applicability at Superfund sites, limitations, the types of residuals produced, the latest performance data, site requirements (for full-scale operation), the status of the technology and sources of further information. This bulletin should be consulted for an overview of the status of the technology.

Thermal desorption in this guide is limited to any number of ex situ processes that use either direct or indirect heat exchange to vaporize organic contaminants from soil or sludge. Air, combustion gas, or inert gas is used as the transfer medium for the vaporized components. Thermal desorption systems are physical separation processes and are not specifically designed to provide organic decomposition. Thermal desorption is <u>not</u> incineration, since the decomposition of organic contaminants is not the desired result, although some decomposition may occur. The concentration of contaminants and the specific cleanup levels for the site will influence the technology's applicability for that site. System performance is typically measured by comparison of untreated soil/sludge contaminant levels with those of the processed soil/sludge. For the purpose of clarity and brevity in this report, the term medium will refer to contaminated soil, sludge, sediment, or combinations of these. The medium is typically heated to a target temperature of 200 to 1,000°F based on the thermal desorption system selected, although certain systems operate at higher temperatures. An important operating design parameter is time-at-temperature, which is defined as the elapsed time that the average medium temperature is at or above the target temperature. Figure 2-1 is a general schematic of the thermal desorption process.[26]

Thermal desorption is most applicable for separation of organic contaminants from soils or sludges. Thermal desorption units have been selected in the Record of Decision for one or more operable units at approximately fourteen Superfund sites.[19][26][33] These sites include: McKin (Maine), Ottati & Goss (New Hampshire), Cannon Engineering (Massachusetts), Resolve (Massachusetts), Wide Beach (New York), Fulton-Terminals (New York), Metaltec/Aerosystems (New Jersey), Caldwell Trucking (New Jersey), Outboard Marine/Waukegan Harbor (Illinois), Reich Farms (New Jersey), Waldick Aerospace Devices (New Jersey), Wamchem (South Carolina), and two Stauffer Chemical sites in Alabama.

If a site is contaminated with organics, thermal desorption offers the advantage of separating the contaminant from the medium to an offgas stream where the vapors are either treated directly or condensed before treatment. Vapor or liquid phase treatment includes: carbon adsorption, catalytic or thermal oxidation, condensation, and/or chemical neutralization. The total volume of chemicals requiring subsequent treatment is typically small in comparison to the volume of contaminated medium at any given site. Thermal desorption may be viewed as a step in the sequence of remediating a site where isolating and concentrating the contaminants is useful. The technology must be used in concert with other treatment technologies since its purpose is simply the physical separation of contaminants from the medium[21].

Groups of organic contaminants can be selectively removed from the medium by careful control of the treatment temperature in the desorption unit. Knowing how vapor pressure varies as a function of temperature for specific contaminants is important in evaluating the applicability of a particular thermal desorption system. Medium type, the interaction between contaminant and medium (i.e., adsorption), moisture content, thermal properties of contaminant mixtures, and contamination

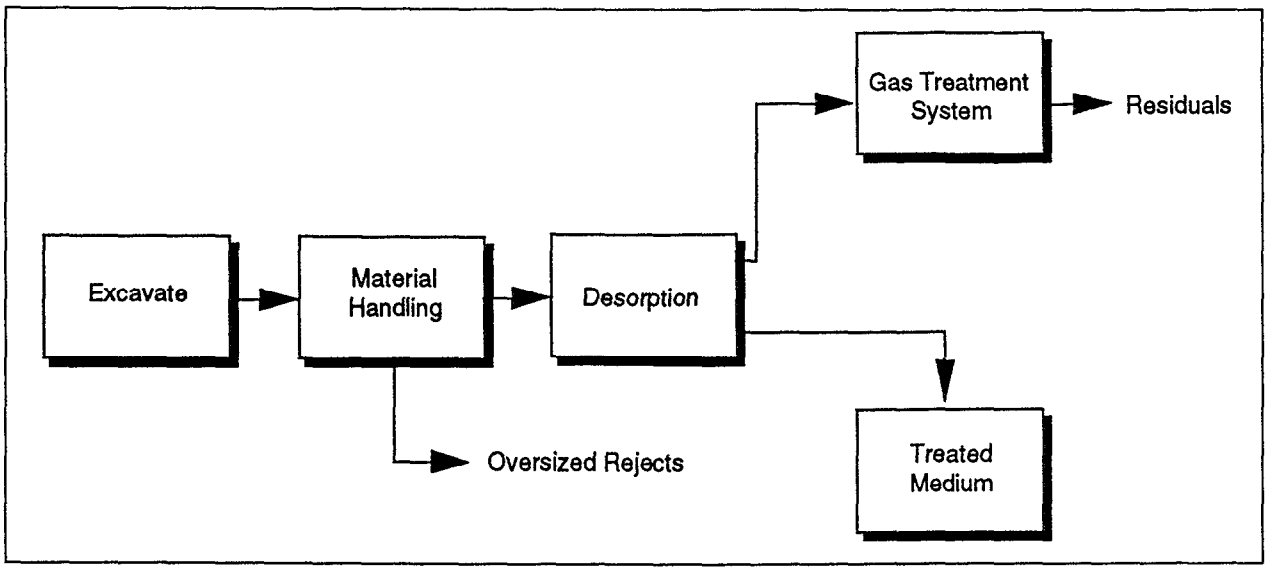

Figure 2-1. Schematic diagram of thermal desorption.

levels are also important design considerations in determining if thermal desorption is applicable at a specific site.

All thermal desorption systems require excavation and transport of the contaminated medium, using material handling/classification equipment and feeding of the material into the desorption unit. Excavation is accomplished by backhoe, front-end loader, or similar equipment. Belt conveyors are typically used to transfer the medium from a hopper to vibratory screens (or similar device) to remove large objects such as rock, glass, and metal from the medium. Consolidated media larger than about 38 mm (1.5 inches) on any edge are typically rejected. These large objects may restrict the passages in some desorption units and can result in uneven heating of the media. If the rejected objects are contaminated, they may be crushed and fed through the desorption unit. If they are not processed by the thermal desorption system, they should be containerized and sampled so that subsequent treatment, if required, can be selected. The larger rejects, such as oversized gravel, cobbles, and boulders, may be amenable to soil washing techniques before they are returned to the site. Additionally, some soil types may tightly agglomerate and require milling or shearing operations to prepare the medium for thermal desorption equipment. This problem should be identifiable during the excavation process or during the remedy screening or remedy selection testing. The classified medium is conveyed, via belt or screw conveyors, to a feed hopper and then metered into the desorber.

Precautions to minimize fugitive dust (particulates) and volatile releases may be required during excavation and transport of contaminated medium. These methods include consideration of weather conditions during excavation (e.g., high winds), aerodynamic considerations (e.g., excavating on a still side of a hill or behind a windscreen), application of foams, water sprays, organic/inorganic control agents, synthetic covers, or by simply minimizing the surface area of waste exposed to the air. The most sensitive sites may require physical enclosures and independent dust/vapor controls over the excavation, classification, and feed systems. In addition, real time air monitoring can be employed in some situations to minimize air impacts.

Significant variation exists in the configuration and operation of thermal desorption units. Volatilization of the contaminants can be effected by use of a rotary dryer, thermal screw, vapor extractor, or distillation chamber. The following subsection presents a description of these basic systems.

2.1.1 Full-Scale Thermal Desorption Units

Rotary Dryer

Rotary dryers are horizontal cylinders which can be indirect- or direct-fired. The dryer is normally inclined and capable of being rotated. The dryer rotates as the contaminated medium is metered into it. Turning vanes or lifters inside the dryer drum pick up the medium and move it in the dryer where it is heated. In direct-fired units, hot gases are produced by the combustion of fossil fuel (natural gas, fuel oil, propane) and directed through the dryer by use of a blower or induced draft fan. The hot gases may flow in the same or in an opposite direction with the contaminated medium (co-current or countercurrent). In indirect-fired units, the hot gases are created in a separate firing section so the medium does not directly contact the flame. A typical indirect-fired unit would consist of an outer furnace which is heated and a rotating inner drum containing the contaminated medium. The inner drum rotates inside of the furnace. The medium is primarily heated by direct contact with the drum and by radiation from the drum walls.

The heat exchange between the medium and hot gases (direct-fired) or between the medium and the walls of the rotary dryer (indirect-fired) volatilizes water and certain contaminants. The specific contaminants separated by the process are a function of the time-temperature history in the dryer and moisture content of the medium. Residence time in the desorber unit is carefully controlled

by the angle of inclination of the dryer, its rotational speed, and the arrangement of the turning vanes. The ability to rapidly exchange heat permits relatively high medium processing rates. Vendor data indicate full-scale units can process 5 to 55 tons per hour (TPH).[4]

Thermal Screw

Screw conveyers or hollow augers are used to transport the medium continuously through an enclosed trough. Hot oil or steam circulate through the conveyor or auger, although molten salts have been used in limited applications, to indirectly heat the medium. A heat transfer fluid is also pumped through the walls of the trough for additional heat transfer.

One, two, or four augers may be arranged in a trough to provide mixing in the process of heating and conveying the medium. More than one trough system can be configured in series to achieve the bed temperature and residence time desired. A clean sweep gas (such as nitrogen or steam) is typically used to convey the vaporized contaminants and water from the trough(s). The sweep gas also may be used to ensure contaminants are not oxidized by reducing the source of oxygen. The maximum medium-bed temperature is limited by the thermal properties of the heat transfer fluid and the materials used to construct the equipment. It is also dependent on the speed of conveyance of the medium through the trough(s) and the operating temperature of the heat transfer fluid. Advantages of this type of desorption unit include simplicity of operation and temperature control as well as reduced fines or dust generation. Equipment capacity can range from 3 to 13 TPH[4].

Vapor Extractor

A vapor extraction system mixes hot gases and the contaminated medium to volatilize the contaminants. Classified material is fed continuously into the unit on a belt conveyor where it contacts a hot gas stream (1,000-1,500 °F) generated in a fossil fuel-fired air heater. Hot gases are injected into the unit through a series of gas jets at a rate sufficient to fluidize the feed material. Blades or rollers turn the medium as it is being fluidized by the hot gas to provide effective medium/gas contact. The hot gas (320 °F) flows out of the unit to the gas treatment section while the treated medium is removed from the bottom of the unit. One vendor specifies portable plant system capacities of 10 to 73 TPH.[20]

Distillation Chamber

Distillation chambers are a series of cylinders that are externally heated to a specific temperature. Contaminated medium is introduced into the first of a series of chambers (3 to 5 total) of increasing temperature. This allows the vaporization, condensation, and recovery of specific contaminants from each distillation zone in a segregated fashion. A nitrogen sweep gas is used to transport the volatilized contaminants and prevents oxidation as a system of annular augers conveys the medium through each chamber. The entire system is sealed and operated at negative pressure until the segregated effluents leave the system. The capacity of this type of system is 1 to 17 TPH[4]. The system may be operated in an "oxygen-free" environment, and effect pyrolysis, or cracking of organics.

2.1.2 Offgas Treatment

All thermal desorption systems share the requirement for treatment of residuals and offgas produced by the unit. Since the treated medium is typically dry, less than one percent moisture, spraying and mixing with clean water will suppress dust generation.

Offgas from a thermal desorption unit will contain entrained dust (particulates) from the medium, vaporized contaminants, and water vapor. Particulates are removed by conventional equipment such as cyclone dust collectors, fabric filters, or wet scrubbers. Collected particulates may be recycled through the thermal desorption unit or blended with the treated medium, depending on the amount of carryover contamination present.

The vaporized organic contaminants can be captured by condensing the offgas and then passing it through a carbon adsorption bed or other treatment system. Emissions may also be destroyed by use of an offgas combustion chamber or a catalytic oxidation unit.

When offgas is condensed, the resulting water stream may contain signifcant contamination depending on the boiling points and solubility of the contaminants and may require further treatment (i.e., carbon adsorption). If the condensed water is relatively clean, it may be used to suppress the dust from the treated medium. If carbon adsorption is used to remove contaminants from the offgas or condensed water, spent carbon will be generated, which is either returned to the supplier for reactivation/incineration or regenerated onsite. When offgas is destroyed by a combustion process, compliance with incineration emission standards may be required. Obtaining the necessary permits and demonstrating compliance may be advantageous, however, since the incineration process would not leave residuals requiring further treatment. If incineration is used, the heat from the incineration process may be used in the desorption process unit.

2.2 PRELIMINARY SCREENING AND TECHNOLOGY LIMITATIONS

The determination of the need for and the appropriate level of treatability studies required is dependent on available literature, expert technical judgment, and site-specific factors. The first two elements – the literature search and expert consultation – are critical factors in determining if adequate data are available or whether a treatability study is needed to provide those data.

2.2.1 Literature/Database Review

Several reports and electronic databases exist which should be consulted to assist in planning and conducting treatability studies and to help prescreen thermal desorption for use at a specific site. Existing reports include:

- Guide for Conducting Treatability Studies Under CERCLA, Interim Final. U.S. Environmental Protection Agency, Office of Research and

Development and Office of Emergency and Remedial Response, Washington, D.C. EPA/540/2-89/058, December 1989.

- Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, Interim Final. U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, D.C. EPA/540/2-89/001, March 1989.
- Superfund Treatability Clearinghouse Abstracts. U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, D.C. EPA/540/2-89/001, March 1989.
- The Superfund Innovative Technology Evaluation Program: Technology Profiles. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response and Office of Research and Development, Washington, D.C. EPA/540/5-91/008, November 1991 (updated annually).
- Summary of Treatment Technology Effectiveness for Contaminated Soil. U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, D.C., EPA/540/8-89/053, 1989.
- Technology Screening Guide for Treatment of CERCLA Soils and Sludges. U.S. Environmental Protection Agency. EPA/540/2-88/004, September 1988.

RREL in Cincinnati is currently expanding its Superfund Treatability Database. This database contains data from treatability studies conducted under CERCLA. A repository for the treatability study reports will be maintained at RREL in Cincinnati. The contact for this database is Glenn Shaul (513)569-7408.

The Office of Solid Waste and Energy Response (OSWER) maintains the Cleanup Information (CLU-IN) Bulletin Board System as a tool for communicating ideas, disseminating information, and as a gateway for other OSW electronic databases. Currently, CLU-IN has eight different components, including news and mail services, and conferences and publications on specific technical areas. The contact is Dan Powell at (703)308-8827.

ORD headquarters maintains the Alternative Treatment Technology Information Center (ATTIC), which is a compendium of information from many available databases. The EPA contact for ATTIC is Joyce Perdek at (908) 321-4380. Data relevant to the use of treatment technologies in Superfund actions are collected and stored in ATTIC. ATTIC can be accessed through the RCRA/CERCLA Hotline (800-424-9346) or CLU-IN. ATTIC serves as a mechanism for searching other information systems and databases and integrates the information into a response to a query. It also includes a pointer system to refer the user to individual experts in EPA. The system is currently made up of technical summaries from SITE program abstracts, treatment technology demonstration projects, industrial project results, and international program data. For more information, contact the ATTIC System Operator at (301)670-6294, or access the database via modem by calling (301)670-3808.

2.2.2 Technical Assistance

Technical assistance can be obtained from the Technical Support Project (TSP) team which is made up of six Technical Support Centers and two Technical Support Forums. It is a joint service of OSWER, ORD, and the Regions. The TSP offers direct site-specific technical assistance to OSCs and RPMs and develops technology workshops, issue papers, and other information for Regional staff. The TSP:

- Reviews contractor work plans, evaluates remedial alternatives, reviews RI/FS, assists in selection and design of final remedy
- Offers modeling assistance and data analysis and interpretation
- Assists in developing and evaluating sampling plans
- Conducts field studies (soil gas, hydrogeology, site characterization)
- Develops technical workshops and training, issue papers on groundwater topics, generic protocols
- Assists in performance of treatability studies

The following support center provides technical information and advice related to treatability studies:

Engineering Technical Support Center (ETSC)
Risk Reduction Engineering Laboratory (RREL)
Cincinnati, OH 45268

Contact: Ben Blaney
(513) 569-7406

The Engineering Technical Support Center is sponsored by OSWER but operated by RREL. The Center handles site-specific remediation engineering problems. Access to this support center must be obtained through the EPA remedial project manager.

RREL offers expertise in contaminant source control structures; materials handling and decontamination; treatment of soils, sludges and sediments; and treatment of aqueous and organic liquids. The following are examples of the technical assistance that can be obtained through the ETSC:

- Screening of treatment alternatives
- Review of the treatability aspects of RI/FS
- Oversight of RI/FS treatability studies
- Evaluation of alternative remedies
- Assistance with studies of innovative technologies
- Assistance in full-scale design and start-up

The following program provides technical advice and information on air impacts due to remediation.

Air/Superfund Coordination Program
Office of Air Quality Planning and Standards
Research Triangle Park, NC 27711

Contact: Joseph Padgett
(919) 541-5589

The Air/Superfund Coordination program is designed to help RPM's design ways to mitigate air impacts at Superfund sites, provide Air Office liaisons to Regional Superfund Offices, and provide technical assistance and recommendations.

The Air/Superfund Coordination Program offers:

- Direct support: site evaluation, remedy selection, modeling assistance, monitoring, air pollution control devices
- Support services: inter-program coordination, training, resolution of inter-program issues
- National Technical Guidance Studies (NTGS) to improve quality and consistency of procedures and data collection. NTGS reports cover baseline air emissions, air emissions from remediation, modeling and monitoring protocols, air pathway analysis procedures, and remediation field support procedures.

2.2.3 Prescreening Characteristics

Prescreening activities for the thermal desorption treatability testing include interpreting any available site-related field measurement data. The purpose of prescreening is to gain enough information to eliminate from further treatability testing any treatment technologies which have little chance of achieving the cleanup goals.

The applicability of thermal desorption for general contaminant groups for soil, sludge, sediments, and filter cakes is shown in Table 2-1.[26] The process is applicable for the separation of organics from refinery wastes, coal-tar wastes, wood-treating wastes, creosote-contaminated soils, pesticide-contaminated soils, mixed (radioactive and hazardous) wastes, synthetic-rubber processing wastes, and paint wastes.[7][23][24]

If contamination exists at different medium zones, a medium characterization profile should be developed for each medium type or zone. Available chemical and physical data (including averages and ranges) and the volumes of the contaminated medium requiring treatment should be identified. For "hot spots", separate characterizations should be done so they can be properly addressed in the treatability tests if quantities are such that blending will not provide a homogeneous feed stream. Thermal desorption may be applicable to some parts of a site, but not to other parts.

Characterization test samples should be broadly representative of the medium profile of the site. Grab samples taken from the site ground surface may represent only a small percentage of the contaminated medium requiring remediation. Deeper, subsurface strata affected by contaminants may vary widely in composition (soil classification, total organic carbon, and contamination levels) from those found at the surface, and should also be characterized so that the fractions of volatile organic compounds (VOCs) and semivolatile organic compounds (SVOCs) can be identified as to their location and concentration. The quantity and distribution of rubble and debris at the site should also be determined as part of the characterization process. This material may have to be removed from the feedstock material during full-scale treatment operations. Pretreatment methods can be applied to reduce the dimensions of any oversized debris.

Table 2-1. Effectiveness of Thermal Desorption on General Contaminant Groups for Soil, Sludge, Sediments, and Filter Cakes

	Contaminant Groups	Effectiveness: Soil	Sludge	Sediments	Filter Cakes
Organic	Halogenated volatiles	■	▼	▼	■
	Halogenated semivolatiles	■	▼	▼	■
	Nonhalogenated volatiles	■	▼	▼	■
	Nonhalogenated semivolatiles	■	▼	▼	■
	PCBs	■	▼	▼	▼
	Pesticides	■	▼	▼	▼
	Dioxins/Furans	■	▼	▼	▼
	Organic cyanides	▼	▼	▼	▼
	Organic corrosives	□	□	□	□
Inorganic	Volatile metals	■	▼	▼	▼
	Nonvolatile metals	□	□	□	□
	Asbestos	□	□	□	□
	Radioactive materials	□	□	□	□
	Inorganic corrosives	□	□	□	□
	Inorganic cyanides	□	□	□	□
Reactive	Oxidizers	□	□	□	□
	Reducers	□	□	□	□

■ Demonstrated Effectiveness: Successful treatability test at some scale completed
▼ Potential Effectiveness: Expert opinion that technology will work
□ No Expected Effectiveness: Expert opinion that technology will not work

Chemical and physical properties of the contaminant should also be investigated. Other contaminant characteristics such as volatility and density are important for the design of remedy screening studies and related residuals treatment systems. Prescreening characterization data should be assembled and organized in a concise tabular form before remedy screening. If enough information is obtained by prescreening to allow a decision to be made regarding the potential success of thermal desorption, remedy screening may be skipped. A listing of key prescreening data is presented in Table 2-2.

The need for a treatability study is determined near the beginning of the RI/FS when a literature survey of remedial technologies is performed. Remedial technologies are identified based on compatibility with the type of contaminants present at the site, the medium (soil, water, etc.), and the anticipated cleanup objectives. Remedial technologies are prescreened for effectiveness, implementability, and cost. The prescreening is done using available technical literature, databases, and manufacturer's information. Based upon this initial technology prescreening, thermal desorption may be one of several candidate remedial technologies eliminated before or during the remedial investigation/feasibility study. See the generic guide for more specific details on screening of treatment technologies and on determining the need and type of treatability tests which may be required for evaluating treatment technology alternatives.[28]

2.2.4 Thermal Desorption Limitations

Thermal desorption limitations may be defined as characteristics that hinder cost-effective treatment. Thermal desorption has proven effective in treating contaminated soils, sludges, and sediments. Chemical contaminants for which bench-scale through full-scale treatment data exist include primarily VOCs, SVOCs and even higher boiling point compounds such as polychlorinated biphenyls (PCBs).[1][6][9][13][16][33] The technology is generally not used in separating inorganics from the contaminated medium; although thermal desorption has been used to recover very high concentrations of mercury metal from soil.[11] Inorganic constituents and/or metals that are not particularly volatile will likely not be effectively removed by thermal desorption. The maximum bed temperature and the presence of chlorine or another chlorinated compound may result in volatilization of some inorganic constituents in the waste.

The primary technical factors affecting thermal desorption performance are the maximum bed temperature achieved, total residence time, organic and moisture content, contaminant characteristics, and medium properties. Since the basis of the process is physical removal from the medium by volatilization, bed temperature directly determines the end point concentration. The degree of mixing and, where applicable, the sweep gas rate also affect removal rate. In some cases, achieving and maintaining the desired results are too costly for sites that are heavily contaminated with organics or that have a high moisture content. If the system is direct-heated, flammability of the contaminant must also be considered in order to prevent explosions.[37] As in most systems that use a reactor or other equipment to process wastes, media exhibiting a very high pH (greater than 11) may corrode the system components.[35] Media exhibiting a low pH may similarly corrode system components during processing.

The contaminated medium must contain at least 20 percent total solids (by weight) to facilitate placement of the waste material into the desorption equipment.[1] Some systems specify a minimum of 30 percent solids.[20] If the moisture content of the contaminated medium is high, it may have to be dewatered prior to treatment to reduce the energy required to volatize the water.

Material handling of soils that are tightly aggregated, are largely clay, or contain rock fragments or particles greater than 1.5 inches can result in poor processing performance. This can be minimized by media pretreatment such as screening, crushing, milling, grinding, shredding, etc. Also, if a high fraction of fine silt or clay exists in the matrix, excessive dust may be generated which places a greater dust loading on the downstream air pollution control equipment.[20][35]

The treated medium will typically contain less than 1 percent moisture. Dust can easily form in the transfer of the treated medium from the desorption unit, but can be mitigated by water sprays. Some type of enclosure may be required to control fugitive dust if water sprays are not effective.

Caution should be taken regarding the disposition of the treated material, since pretreatment and/or treatment processes can alter the physical properties of the material. For example, this material could be susceptible to such destabilizing forces as liquefaction, where pore pressures are able to weaken the material to the point of failure. It may be advantageous to avoid backfilling such treated material on sloped areas or places where materials must support a load (i.e. roads for vehicles, subsurfaces of structures, etc.). To achieve or increase the required stability of the treated material, it may have to be mixed with other stabilizing materials and/or compacted in a layered fashion. A thorough geotechnical evaluation of the treated product—based on treatability tests—can provide the necessary design resolution to post-treatment solid stabilization. Screening tests of untreated soils should also be considered as a way of identifying potential impacts on the medium. An example of a prescreening evaluation and the decision to conduct further testing is provided in Example 1.

Table 2-2. Key Prescreening Characteristics For Thermal Desorption Treatability Testing

Parameter	Description of Test	Method	Purpose and Comments	Application of Data	Ref.
Chemical					
Organics – Volatile – Semivolatile – PCB	 GC/MS GC/MS GC	 Method 8240 Method 8270 Method 8080	To determine concentration of target or interfering constituents, pretreatment needs, extraction medium	Remedy Screening	36
Total organic carbon (TOC)	Combustion	Method 9060	To determine the presence of organic matter	Remedy Screening	36
or					
Total recoverable petroleum hydrocarbon	Infrared	Method 9071/ 418.1			36
or					
Oil & Grease	Gravimetric	Method 9071			
Metals	ICP, GFAA, CVAA	Method 3050/ 6000, 7000 series	To determine the potential emissions of volatile metals and inorganic alkali	Remedy Screening	36
Toxicity Characteristic Leaching Procedure (TCLP)	Soil leaching/ analysis of leachate	Method 1311	To determine leachability of selected organic and inorganic compounds in liquid/solid residuals	Remedy Selection	36
Physical					
Grain size analysis/particle size distribution	Sieve screening using a variety of screen sizes	ASTM D422	To determine volume reduction potential, pretreatment needs	Remedy Selection	3
Moisture content	Drying oven at 110°C	ASTM D2216	To determine pretreatment needs and medium processing rate	Remedy Selection	2
Bulk density	Drive cylinder method	ASTM D2937	To estimate total mass of soil to be treated	Remedy Selection	3
	Sand cone method	ASTM D1556			3
pH	Soil pH	Method 9045	Potential for system corrosion	Remedy Selection	36

Example 1. Prescreening Initial Data

BACKGROUND

A 3.0-acre industrial site in the northeastern United States was used from 1950 until 1964 as a storage yard for a company that installed asphaltic roofing materials. From 1968 until 1978 the site was used as a storage facility and transfer station for solvents that were being sent to a recycling facility. Remedial investigations indicated that waste disposal and chemical spills over a period of years have contaminated the surface soil and underlying groundwater. The soil at the site consists primarily of a highly plastic inorganic clay with some debris present near the surface.

USE OF DATA TO PRESCREEN THERMAL DESORPTION

The prescreening was performed by conducting a literature survey, reviewing existing data, and obtaining expert opinion. Contaminants that have been identified on the site include the base neutral compounds pyrene, chrysene, and naphthalene at an average concentration of less than 100mg/kg each. These compounds are primarily located in the top 2 feet of surface soil. The volatile organic compounds methylene chloride, toluene, and 1,1,1-trichloroethane have been identified at concentrations of up to 1,000 mg/kg down to the surface of the groundwater table (depth of approximately 12 feet). The groundwater is also contaminated with VOCs. Arsenic has been identified within an area of the site at a concentration of up to 1,000mg/kg. Arsenic emissions from point sources are regulated under state air toxics regulations.

A risk assessment at the site has established the following preliminary cleanup levels for selected indicator compounds:

- Methylene chloride 5.5 mg/kg
- Toluene 3.0 mg/kg
- 1,1,1-trichloroethane 2.0 mg/kg
- Pyrene 15.5 mg/kg
- Chrysene 13.2 mg/kg
- Naphthalene 25.0 mg/kg

The prescreening study indicates the following:

- Thermal desorption has demonstrated from 90 to greater than 95 percent removal efficiencies for the VOCs that have been identified.
- Thermal desorption has demonstrated 75 to 95 percent removal efficiencies for the base/neutral compounds that have been identified.
- Toluene and pyrene have the highest boiling point temperatures of the volatile and base/neutral compounds, respectively, that have been identified at the site.
- No data on the partitioning of arsenic to the offgas at thermal desorption operating conditions could be located.
- The clay has very cohesive properties at a moisture content of greater than 18 percent.

The experts recommend thermal desorption for further consideration as a site remedy. Remedy screening treatability studies are to be conducted.

SECTION 3
THE USE OF TREATABILITY STUDIES IN REMEDY EVALUATION

This section presents an overview of the use of treatability tests in confirming the selection of thermal desorption as the technology remedy under CERCLA. It also provides a decision tree that defines the tiered approach to the overall treatability study program with examples of the application of treatability studies to the RI/FS and remedy selection process. Subsection 3.1 presents an overview of the general process of conducting treatability tests. Subsection 3.2 defines the tiered approach to conducting treatability studies and the applicability of each tier of testing, based on the information obtained, to assess, evaluate, and confirm thermal desorption technology as the selected remedy.

3.1 PROCESS OF TREATABILITY TESTING IN SELECTING A REMEDY

Treatability studies should be performed in a systematic fashion to ensure that the data generated can support the remedy evaluation process. This section describes a general approach that should be followed by RPMs, PRPs, and contractors during all levels of treatability testing. This approach includes:

- Establishing data quality objectives
- Selecting a contracting mechanism
- Issuing the Work Assignment
- Preparing the Work Plan
- Preparing the Sampling and Analysis Plan
- Preparing the Health and Safety Plan
- Conducting community relations activities
- Complying with regulatory requirements
- Executing the study
- Analyzing and interpreting the data
- Reporting the results
- Developing cleanup criteria

These elements are described in detail in the generic guide.[28] That document gives information applicable to all treatability studies. It also presents information specific to remedy screening, remedy selection testing, and remedy design testing.

Treatability studies for a particular site will often entail multiple tiers of testing. Duplication of effort can be avoided by recognizing this possibility in the early planning phases of the project. The Work Assignment, Work Plan, and other supporting documents should include all anticipated activities.

There are three levels or tiers of treatability studies: remedy screening, remedy selection, and remedy design. Some or all of the levels may be needed on a case-by-case basis. The need for and the level of treatability testing required are management decisions in which the time and cost necessary to perform the testing are balanced against the risks inherent in the decision (e.g., selection of an inappropriate treatment alternative). These decisions are based on the quantity and quality of data available and on other decision factors (e.g., state and community acceptance of the remedy, new site data, or experience with the technology). The flow diagram for the tiered approach in Figure 3-1 traces the stepwise review of study data and the decision points and factors to be considered.

Technologies generally are evaluated first at the remedy screening level and progress through remedy selection to remedy design. A technology may enter the selection process, however, at whatever level is appropriate based on available data on the technology and site-specific factors. For example, a technology that has been successfully applied at a site with similar conditions and contaminants may not require remedy screening to determine whether it has the potential to work. Rather, it may go directly to remedy selection to verify that performance standards can be met. Treatability studies, at some level, will normally be needed even if previous studies or actual implementation have encompassed similar site conditions to assure that the site-specific target cleanup goals are going to be achieved. Figure 3-2 shows the relationship of the three levels of treatability study to each other and to the RI/FS process.

3.2 APPLICATION OF TREATABILITY TESTS

Before conducting treatability studies, the objectives of each tier of testing must be established. Thermal desorption

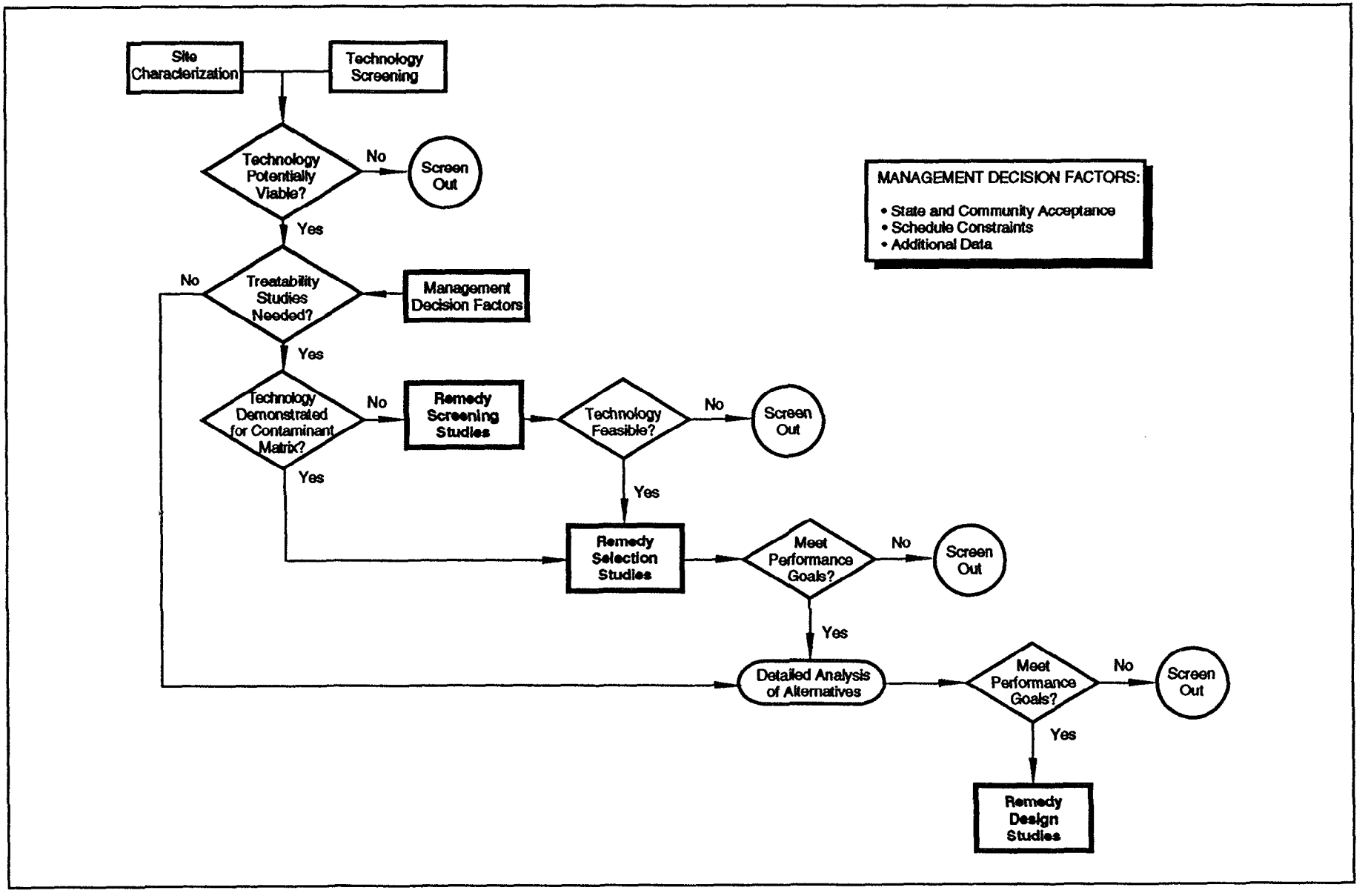

Figure 3-1. Flow diagram of the tiered approach.

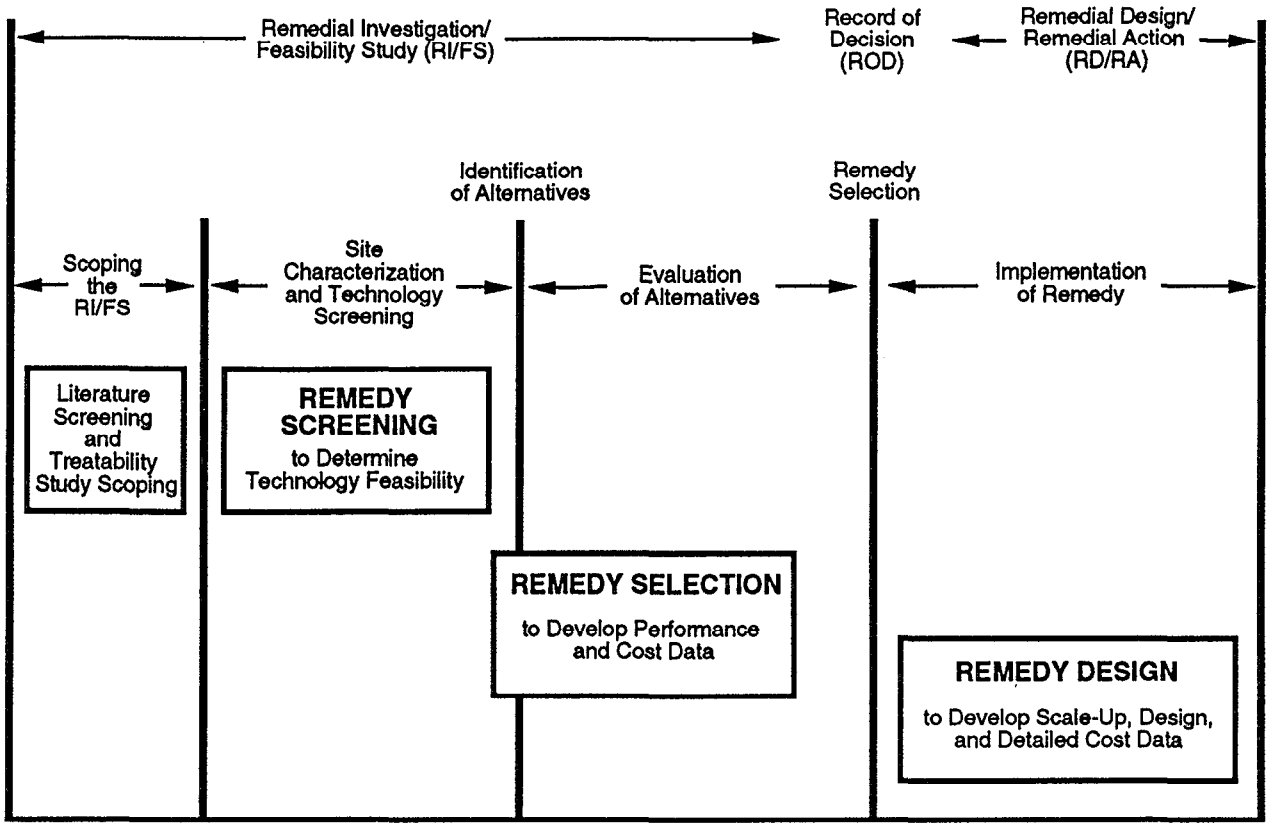

Figure 3-2. The role of treatability studies in the RI/FS and RD/RA process.

treatability study objectives are based upon the specific needs of the RI/FS. There are nine evaluation criteria specified in the document, Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA (Interim Final);[27] the treatability studies provide data for up to seven of these criteria. These seven criteria are:

- Overall protection of human health and environment
- Compliance with applicable or relevant and appropriate requirements (ARARs)
- Reduction of toxicity, mobility, or volume through treatment
- Short-term effectiveness
- Implementability
- Long-term effectiveness and permanence
- Cost

The first four of these evaluation criteria deal with the degree of contaminant reduction achieved by the thermal desorption process. What will be the remaining contaminant concentrations? Will new contaminants be produced? Will the residual contaminant levels be sufficiently low to meet the established ARARs and the risk-based contaminant cleanup levels? What are the contaminant concentration and physical and chemical differences between the untreated and the treated solids fractions (e.g., has contaminant toxicity, mobility, and volume been reduced)? The fourth criterion, short-term effectiveness, also addresses the effects of the treatment technology during construction and implementation of a remedy. This evaluation is concerned not only with contaminant concentration and toxicity, but also with the potential for exposure to offgases or residuals which may be harmful.

The implementability assessment evaluates the technical and administrative feasibility of the technology and the availability of required goods and services. The following questions must be answered in order to address the implementability of thermal desorption:

- Will ambient releases of volatile contaminants that occur during excavation and classification require controls?
- Is there a need for a blending program to ensure hot spots can be accommodated by the thermal desorption system?
- Is the water content of the waste/sludge too high or highly variable?
- Has the degree of particulate entrainment been determined, and will the particulate need to be recycled?
- Have the volumes and characteristics of residuals been approximated, and are residuals treatment and disposal options established (e.g., do metals in the treated medium need further treatment)?

- Are there appropriate air emission controls for process emissions?

Long-term effectiveness assesses how effective treatment technologies are in maintaining protection of human health and the environment after response objectives have been met. The magnitude of any residual risk and the adequacy and reliability of controls must be evaluated. Residual risk, as applied to thermal desorption, assesses the risks associated with the treatment residuals at the conclusion of all remedial activities. Analysis of residual risk from other treatment train processes should be included in this step. An evaluation of the reliability of treatment process controls assesses the adequacy and suitability of any long-term controls (such as site access restrictions and deed limitations on land use) that are necessary to manage treatment residuals at the site. Such assessments are usually beyond the scope of a remedy selection treatability study, but may be addressed conceptually based on remedy selection results. Performance objectives must consider the existing site contaminant levels and relative cleanup goals for soils, sludges, and sediments at the site. In previous years, cleanup goals often reflected background site conditions. Attaining background cleanup levels through treatment has proved impractical in many situations. The present trend is toward the development of site-specific cleanup target levels that are risk- based rather than background-based.

The final EPA evaluation criterion which can specifically be addressed during a treatability study is cost. Remedy selection treatability studies can provide data to estimate the following important cost factors:

- The ultimate cleanup level that can be achieved
- The volume and characteristics of residuals which require treatment or disposal
- The degree to which medium pretreatment or process modifications can enhance the efficiency of the process
- The amount of energy required to heat and clean the medium and approximate fuel costs

The first three factors provide information about the costs of downstream treatments by determining the amount and character of the contaminated residuals. The last factor helps estimate the costs of supplies and utilities.

3.2.1 Remedy Screening

Remedy screening is the first level of testing. It is used to establish the ability of a technology to treat a waste. Remedy screening is generally low cost (e.g., $8,000 to $30,000) and requires several days to three months to complete. Time must be allowed for project planning, chemical analyses, interpretation of test data, and report writing. Limited quality control is required for remedy screening studies. They yield data indicating a technology's potential to meet performance goals and applicability to the specific waste sample. Remedy screening tests can identify operating parameters for investigation during remedy selection or remedy design. They generate little, if any, design or cost data and should not be used as the sole basis for selection of a remedy.

In some instances, thermal desorption remedy screening treatability studies can be skipped, if enough information about the physical and chemical characteristics of the contaminants and medium would allow for evaluation of the potential success of thermal desorption at a site. In such cases, remedy selection tests are normally the first level of treatability study executed. Screening tests are conducted using laboratory-scale equipment. These tests are generic, not vendor-specific, and can be performed at laboratories with the proper equipment and qualified personnel.

3.2.2 Remedy Selection

Remedy selection is the second level of testing. Remedy selection studies identify the technology's performance at a site. These studies have a moderate to high cost (e.g., $10,000 to $100,000) and require several months to plan, obtain samples, and execute.[24] Remedy selection studies yield data that verify that the technology can meet expected cleanup goals, provide information in support of the detailed analysis of alternatives, and give indications of optimal operating conditions.

The remedy selection tier of thermal desorption testing consists of either bench-scale tests or pilot tests. Frequently, these tests will be technology-specific. The key question to be answered during remedy selection testing is whether the treated medium will meet the cleanup goals for this site. The exact removal efficiency or acceptable residual contaminant level specified as the goal for the remedy selection test is site-specific. A remedy design study would follow a successful remedy selection study, although they are usually not conducted until after a Record of Decision (ROD) has been issued.

3.2.3 Remedy Design

Remedy design is the third level of testing. It provides quantitative performance, cost, and design information for an operable unit. This testing also produces the remaining data required to optimize performance. These studies are of moderate to high cost (e.g., $50,000 to $200,000) and require several months to complete.[24] For complex sites (e.g., sites with different types or concentration of contaminants in different media such as soil, sludges, and sediments), longer testing periods may be required, and costs will be higher. Remedy design tests yield data that verify performance to a higher degree than the remedy selection and provide detailed design information. They are most often performed during the remedy design phase of a site cleanup.

Remedy design tests usually consist of bringing a mobile pilot-scale treatment unit to the site, or constructing a small-scale unit for non-mobile technologies. Remedy design tests can also be conducted using vendor-specific pilot-scale equipment at the vendor's site which is generally much cheaper than onsite mobilization or construction. Applicable permits would have to be obtained for onsite testing; however, waivers may be available under certain conditions. The goal of this tier of testing is to confirm the cleanup levels and operating conditions specified in the Work Plan (see subsection 4.1.1). This is best achieved by operating a field unit under conditions similar to those expected in the full-

scale remediation project.

Data obtained from the remedy design tests are used to:

- Specify equipment type for a full-scale unit
- Determine feasibility of thermal desorption based on target cleanup goals
- Refine cleanup time estimates
- Refine cost predictions

If remedy selection testing was performed using pilot-scale equipment, this may provide sufficient data to make any further remedy design testing unnecessary. Given the limited amount of full-scale experience with innovative technologies, such as thermal desorption, remedy design testing will generally be necessary in support of the final process selection and implementation of a remedy. As technologies mature, the need for remedy design testing will decrease.

SECTION 4
TREATABILITY STUDY WORK PLAN

This chapter focuses on specific elements of the Work Plan for thermal desorption treatability studies. These include test goals, experimental design, equipment and materials, sampling and analysis, data analysis and interpretation, reports, schedule, management and staffing, and budget. These elements are described in subsections 4.1 through 4.9. Complementing the above subsections are section 5, Sampling and Analysis Plan and Quality Assurance Project Plan, and section 6, Treatability Data Interpretation. Table 4-1 lists all of the Work Plan elements.

Table 4-1. Suggested Organization of Thermal Desorption Treatability Study Work Plan

No.	Work Plan Elements	Subsection
1.	Project Description	
2.	Remedial Technology Description	
3.	Test Goals	4.1
4.	Experimental Design	4.2
5.	Equipment and Materials	4.3
6.	Sampling and Analysis	4.4
7.	Data Management	
8.	Data Analysis and Interpretation	4.5
9.	Health and Safety	
10.	Residuals Management	
11.	Community Relations	
12.	Reports	4.6
13.	Schedule	4.7
14.	Management and Staffing	4.8
15.	Budget	4.9

Carefully planned treatability studies are necessary to ensure the data generated are useful for evaluating the applicability or performance of a technology. The Work Plan, usually prepared by a contractor when the Work Assignment is in place, sets forth the contractor's proposed technical approach for completing the tasks outlined in the Work Assignment. It assigns responsibilities and establishes the project schedule and costs. The Work Plan must be approved by the RPM before initiating subsequent tasks. For more information on each of these sections, refer to the generic guide.[28]

4.1 TEST GOALS

Setting goals for the treatability study is critical to the ultimate usefulness of the data generated. Objectives must be defined before starting the treatability study. Each tier of the treatability study needs performance goals appropriate to that tier. For example, remedy selection tests are used to answer the question, "Will thermal desorption work on this medium/contaminant matrix?" It is necessary to define "work" (e.g., set the goal of the study). The remedy selection test measures whether the process has the potential to reduce contamination to below the anticipated performance criteria to be specified in the ROD. This would indicate that further testing for remedy design is appropriate.

The ideal technology performance goals are the same as the anticipated cleanup criteria for the site. For several reasons, such as ongoing waste analysis and ARARs determination, cleanup criteria are sometimes not finalized until the ROD is signed, long after treatability studies must be initiated. Nevertheless, treatability study goals need to be established before the study is performed so that the success of the treatability study can be assessed. In many instances, this may entail an educated guess as to what the final cleanup levels may be. In the absence of final cleanup levels, the RPM can estimate performance goals for the treatability studies based on the first two criteria listed in subsection 3.2 of this guide. Existing treatability study results from other sites may provide the basis for an estimate of the treatability study goals for a specific case.

4.1.1 Remedy Screening Goals

When remedy screening tests are performed, determining the minimum temperature of the medium and residence time needed to achieve the required cleanup criteria are the desired goals. The remedy screening treatability study goals must be determined on a site-specific basis. Typically, 75 percent or higher separation efficiencies are achieved in the remedy screening tier. RREL's Remedy Screening Lab has used 50 percent as a goal in the past. Since thermal desorption remedy screening tests may be

a simple test, such as the use of a flat tray of contaminated medium inserted into a small lab furnace, the level of volatilization efficiency achieved should not be used as the sole criteria for conducting further treatability testing.

Example 2 describes a series of remedy screening tests conducted at a Superfund site introduced in Example 1. The example illustrates how to decide whether the remedy selection treatability studies using thermal desorption should be performed.

4.1.2 Remedy Selection Treatability Study Goals

The main goals of this tier of testing are to obtain information on operating parameters relevant to a full-scale thermal desorption system. Inclusive in these goals are determining actual contaminant concentrations achieved after treatment, definition of the heat input requirements, and average bed temperatures achieved, as well as limited performance data for the offgas treatment system(s) thought to be applicable to the medium/contaminant matrix. The actual goal for separation efficiency must be based on site- and process-specific characteristics. Typical separation efficiencies are 90 percent and higher. The specified separation efficiency must meet site-specific cleanup goals, which are based on a site risk assessment.

Example 3 continues from Example 2 and illustrates the goal of a remedy selection treatability study at the Superfund site. In this example, the remedy selection treatability studies show that pilot-scale testing should be conducted.

4.2 EXPERIMENTAL DESIGN

4.2.1 Remedy Screening Tier

Remedy screening tests can be rapidly performed in a laboratory to evaluate the potential performance of thermal desorption. When assessing the need for remedy screening tests, the investigator should use available knowledge of the site and any preliminary analytical data on the type and concentration of contaminants present. If it is confirmed that the concentration of metals is low, the

Example 2. Remedy Screening

BACKGROUND

In Example 1, recommendations were made to proceed with remedy screening treatability tests to check the potential feasibility of thermal desorption. Pyrene, arsenic, and toluene were chosen as the indicator contaminants.

RESULTS OF TESTING

Static tray muffle furnace tests were conducted by a thermal desorption contractor in accordance with the procedures described in Section 4.0 of this document. Tests were conducted at soil temperatures of 400°F, 800°F, and 1,000°F and a residence time at temperature of 10 minutes for each test. Tests at all conditions showed that the concentration of toluene could be reduced to less than 0.5 mg/kg (>96 percent). The concentration of pyrene was reduced by 50 percent, 85 percent, and 95 percent, respectively in the three tests. The concentration of arsenic in the soil was not appreciably reduced at the two lower temperature conditions. At the test temperature of 1,000°F, the concentration of arsenic in the treated material was approximately 30 percent less than the concentration in the untreated sample.

RPM'S DECISION

The remedy screening tests indicate that the VOCs can be removed to acceptable residual concentrations over a broad range of thermal desorption operating temperatures. Removal of base/neutral compounds at greater than 90 percent efficiency will require operating near the upper temperature limits of a thermal desorption system. However, at this condition, some of the arsenic apparently volatilizes to the gas phase. The RPM decides to conduct further treatability testing (remedy selection) to refine operating conditions required to achieve target residual concentrations for pyrene and to determine the fate of arsenic at these operating conditions.

Example 3. Remedy Selection Treatability Test Using Rotary Thermal Apparatus

BACKGROUND

In Example 2, recommendations were made to proceed with remedy selection treatability tests to bracket operating conditions for thermal desorption and determine the fate of arsenic at these conditions. Pyrene and arsenic were chosen as the indicator contaminants.

RESULTS OF TESTING

Rotary thermal apparatus tests were conducted by a thermal desorption contractor in accordance with the procedures described in Section 4.0 of this document. Tests were conducted at soil temperatures of 800°F, 900°F, and 1,000°F and a time-at-temperature of 10 minutes for each test. Tests showed that the concentration of pyrene in the treated soil sample could be reduced to 25 mg/kg, 10 mg/kg, and 7 mg/kg at soil temperatures of 800°F, 900°F, and 1,000°F, respectively. Tests at all conditions confirmed that the residual concentration of toluene in the treated soil was less that 0.5 mg/kg.

Samples of offgas from the rotary thermal apparatus were passed through a condenser. Gas samples were collected both upstream and downstream of the condenser. A material balance was performed for arsenic for each test. Tests at both 900°F and 1,000°F indicated that greater than 10 to 20 percent of the arsenic in the sample partitioned to the gas phase and was not appreciably removed by passing the gas through a condenser.

RPM'S DECISION

The remedy selection treatability tests indicated that a thermal desorption system that operates at a soil temperature of up to 900°F will be required to meet the treatment criteria for the base/neutral compounds. Approximately 10 to 20 percent of the arsenic is partitioned to the offgas and is not removed in a condensation system. The RPM believes that the arsenic in the offgas is attributable both to particulate carryover and volatilization of arsenic. The volatilized fraction may condense to a fine fume and would require a sophisticated air pollution control system.

The RPM decides to conduct a remedy design treatability test of a thermal desorption process and associated gas treatment system to confirm removal efficiency projections for base/neutral compounds and to obtain an estimate of arsenic emissions from a full-scale system. A pilot thermal desorption system that includes a venturi scrubber to treat offgas is recommended as the test equipment.

contaminants are generally represented in the classes of contaminants shown in Table 2-1, and the general limitations described in section 2 are met, then the remedy screening tier may be precluded. Remedy selection studies would yield more valuable data and save time and money in this case.

When considering remedy screening testing, a number of systems can be used, such as a static tray or differential bed reactor (DBR). In the tray test, contaminated medium is heated in a muffle furnace equipped with an electronic temperature controller. The furnace should be capable of achieving an internal temperature up to 1,400°F with a relatively fast heat-up rate. The depth of the soil should be kept at a minimum to eliminate temperature and concentration gradients within the soil bed. The temperature of the medium should be monitored very closely, and care should be taken that the thermocouple(s) are completely immersed in the solid material. The time to reach the target treatment temperature should be minimized to a practical laboratory timeframe such as 5 to 10 minutes. Longer time may be required depending on the specific contaminants present in the soil. Figure 4-1 shows a schematic of a static tray test oven.[4]

In a DBR, a thin bed of medium is placed in a furnace between two screens. Preheated gas passes through the bed which eliminates concentration and temperature

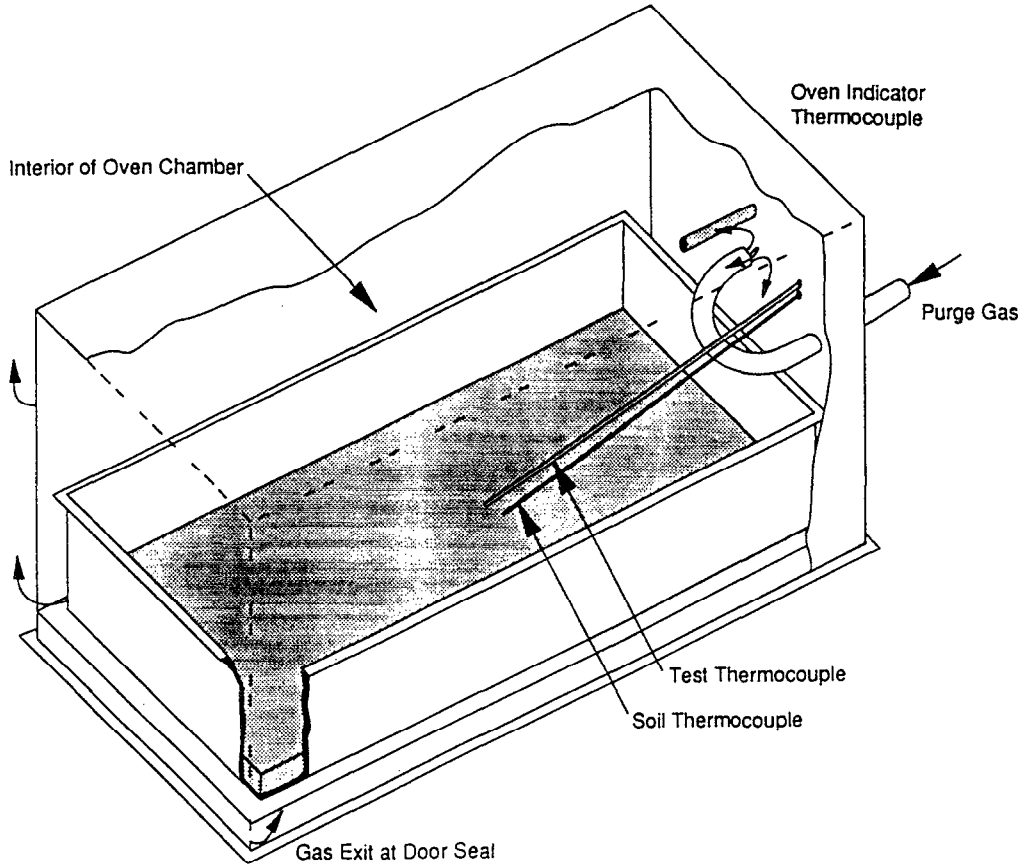

Figure 4-1. Cut-a-way view of static tray test oven with the tray insert.

gradients within the bed. In this reactor, the temperature of the medium should also be monitored and the bed should reach its target temperature within 5 to 10 minutes. Figure 4-2 shows a schematic of the DBR.[8]

In remedy screening tests, the offgas may be analyzed for volatiles and semivolatiles; however, particulate control equipment is not necessary. Remedy screening tests alone do not produce enough information to perform an economic analysis of a thermal desorption process, but do generate data on time-at-temperature requirements.

To reduce analytical costs during the remedy screening tier, the list of known contaminants must be reduced to a few key compounds selected as indicators of performance. The selection of indicator chemicals for remedy screening testing should be based on the following:

1) Select one or two contaminants that have low volatility.

2) Select one or two contaminants present in the medium that are most toxic or most prevalent.

3) Select indicator compounds to represent other compounds within those groups (e.g., TCE for chlorinated volatiles, benzene for nonchlorinated volatiles).

4) Select a representative sample either composite or hot spot (for worst case, see subsection 4.4.1).

5) Select polar contaminants since they tend to adsorb strongly to some media.

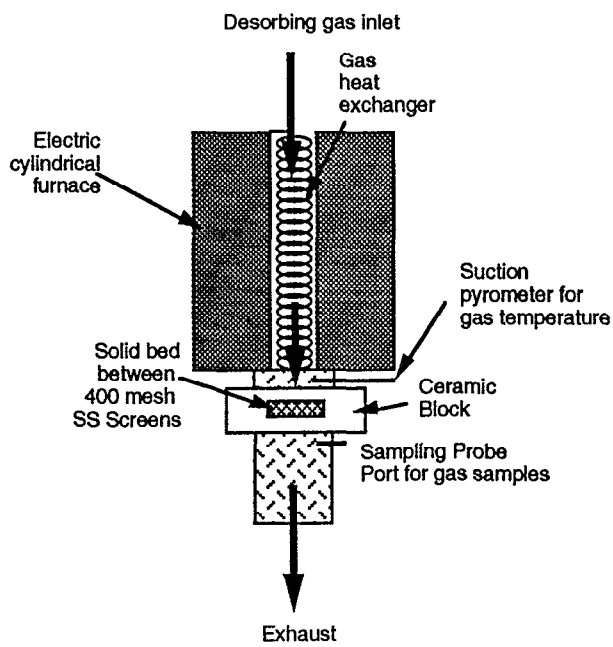

Figure 4-2. Cut-a-way view of the Differential Bed Reactor (DBR).

Mass balance calculations are usually limited by analytical results on solids and liquid feed and discharge streams during remedy screening. Normally, gaseous emissions are not tested at this tier.

4.2.2 Remedy Selection Tier

Remedy selection testing is intended to more accurately estimate the performance of a full-scale thermal desorption system. The tests may be conducted in either batch or continuous treatment systems that simulate the heat and mass transfer characteristics of specific full-scale thermal desorption processes. Data collected at this level can be used to model thermal desorption under various experimental conditions. Information from modeling can then be used to predict time and temperature requirements in full-scale operating systems. Remedy selection treatment systems are available to simulate the performance characteristics of the various desorption systems.

Remedy selection testing should define the time-at-temperature and residual contaminant concentrations as a function of heat input and bed-mixing characteristics for a thermal desorption device. Under certain conditions remedy selection testing can be conducted using a static tray or DBR. After conducting the tray tests, remedy selection usually will lead to a vendor pilot-scale unit that generates data applicable to that vendor's full-scale unit. Currently, there is no remedy selection system available that permits concurrent evaluation of the specific full-scale thermal desorption processes.

More precision is used in weighing and mixing of the sample, with an associated increase in QA/QC costs. Further care must be taken to ensure homogeneity of the sample(s) being treated. Holding time of the medium and offgas samples in the lab before extraction and analysis can be an important consideration for some contaminants. At this phase of remedy selection, it is recommended that duplicate (or triplicate) test runs are completed to ensure reproducibility of the results. This is extremely important when non-vendor (generic) tests are performed (i.e., DBR or static tray). This series of tests is considerably more costly than remedy screening tests, so only sites with contaminated media that show promise in the remedy screening phase should be carried forward into the remedy selection tier. If sufficient data are available in the prescreening step, the remedy screening step may be skipped. The objective of the remedy selection thermal desorption design is to meet the goals discussed in subsection 4.1.2.

Variables that should be documented and/or controlled during this level of treatability testing include:

- moisture content of medium
- contaminant concentration in medium
- particle size of medium
- treatment temperature or minimum solids temperature
- time-at-temperature or total residence time
- medium physical and chemical characteristics
- thermal properties of contaminated medium
- degree of agitation (solid/gas mixing)
- purge gas flow, composition, and temperature

The moisture content of the medium affects the throughput rate due to the energy requirements for drying. A high water concentration delays contaminant volatilization or requires larger heat input to remove contaminants from the medium, if the same throughput rate is to be maintained. Data exist, however, that suggest that some contaminants may be removed at lower temperatures by the physical action of steam stripping as water boils off.[15] Treatability testing should be performed with medium samples that represent the average moisture content expected during full-scale thermal desorption operations.

Samples should be representative of site conditions for the range of concentration of contaminants. Some variability in contaminant concentration should be expected in individual samples which are used to characterize the extent of contamination at the site. Blending waste material into a more homogeneous mixture can lessen this variability.

The particle size distribution of the medium should approximate that expected for the contaminated volume to be treated. If a significant amount of foreign objects; large, consolidated chunks of medium; or significant media heterogeneity exist at the site, this may impact the selection. This may also indicate the need for additional material handling equipment if the next tier of testing is conducted.

Thermal desorption treatability tests are normally conducted at temperatures within the operating ranges of full-scale thermal desorption systems. This temperature range is normally between 200°F and 1,000°F for the medium.

Example 4 shows data obtained from using a vendor-specific bench-scale unit while proceeding with remedy selection testing. This shows background information, sample handling, test operating conditions, and cleanup objectives. The test results, along with estimated cleanup costs are detailed in section 6 as Example 5. These examples describe a case study and should not be considered directly transferrable to a specific site.

The decision on whether to perform remedy selection testing on hot spots or composite soil samples is difficult and must be made on a site-by-site basis. Hot spot areas should be factored into the test plan if they represent a significant portion of the waste site. However, it is more practical to test the specific waste matrix that will be fed to the full-scale system over the bulk of its operating life. If the character of the medium changes radically over the depth of contamination, then tests should be designed to separately study system performance on each media type. It may be necessary to identify extreme conditions and determine the degree of blending required. Additional guidance on soil sampling techniques and theory can be found in Soil Sampling Quality Assurance User's Guide[34] and Methods for Evaluating the Attainment of Cleanup Standards.[31]

If the contaminants and particular medium type(s) present are similar to those where the technology has been

demonstrated at full-scale applications, remedy screening and remedy selection treatability testing may be unnecessary. The RPM/OSC must carefully compare the initial conditions at the previous site and the full-scale data generated with those of the site being considered. Remedy design testing may represent a prudent step in

Example 4. Remedy Selection Using Vendor-Specific Laboratory-Scale Unit

BACKGROUND

The treatability study was conducted on soil from an abandoned facility which was used to formulate and package pesticides, herbicides, and other types of chemicals. The bench-scale unit directly reflects operating conditions of the vendor's full-scale unit. Feed rates for this test were conducted within the test unit capacity of 20 g/min. Temperature and residence time are varied within the ranges available for the full-scale unit. The practical residence time for the large unit is 45 to 120 minutes. A test series was developed to hold the material within the unit (from feed to discharge) for 85 minutes.

Thermocouples on the test unit measure temperatures at three zones on the outside shell as well as the discharge bed temperature. For this test series, the center zone shell temperature was to be held at the two conditions of 900°F and 800°F. At the conclusion of the first test, the bed temperature was noted to have fluctuated greater than the 5°F variance that the vendor requires to call the test a "steady state" test. Conditions of the first test were immediately repeated with steady state results during this second trial.

CONDITIONS OF THE TESTING

Representative sampling was performed at the site to determine quantities of soil for cleanup and areas of differing contaminant concentrations. Hot spots were characterized and composites were taken to generate an equivalent "blended" concentration sample for this treatablility test. The material was screened to less than 1/4" due to the size constraints for feeding into the test unit. A representative sample of this final material was taken to get "feed" contaminant concentrations. Table A provides contaminant concentration ranges for both the site materials and the blended sample along with proposed cleanup goals.

The function of the bench-scale unit used for this study was to provide a preliminary assessment of the vendor's capability for treating specific contaminated wastes and identification of operating parameters. If the laboratory-scale testing met the treatment goals, the operating data could be used to estimate preliminary costs for a full-scale remediation. Prior experience had shown a close correlation between this laboratory unit and the vendor's full-scale system removal efficiencies. The most significant variables affecting removal efficiency were the temperature and residence time.

Table A. Site Contamination Levels and Clean-up Goals

Contaminant	Concentration Range (mg/kg)	Blended Average Concentration (mg/kg)	Proposed Clean-up Goals (mg/kg)
Chlordane	10 – 31	15 – 22	<10
Edrin	15 – 70	20 – 40	< 5
Heptachlor	5 – 92	38 – 72	< 3
Pentachlorophenol	4 – 33	6 – 24	< 5

Example 4. (continued)

OPERATING DATA SUMMARY

The bench unit was operated at three test conditions defined by the Zone 2 outside shell temperature and solids residence time as follows:

Condition 1: 900°F/85 min.
Condition 2: 900°F/85 min.
Condition 3: 800°F/85 min.

Conditions 1 & 2 are similar, but the treated material exit temperature increased from 831°F to 842°F for an average of 837°F during the first condition. The steady state condition was maintained in Condition 2 with a bed temperature of 841°F. Table B summarizes the results from the operating conditions.

Table B. Summary of Operating Conditions

Cond. No.	Average Feed Rate (g/min)	Dryer Fill Volume* (%)	Total Residence Time (min)	Temperature (F°)			
				Zone 1	Zone 2	Zone 3	Treated Material Exit
1	13.1	6.2	85	861	900	926	837
2	13.9	6.6	85	860	900	925	841
3	14.5	6.9	85	763	800	820	747

* Fill volume = percentage of dryer cylinder cross section filled with solids, based on measured products loose density of 1.09 g/cc

DISCUSSION OF TEST

This remedy selection test was designed to mimic full-scale conditions in terms of operating temperature, residence time, and (scaled-down) throughput. The sample concentrations were representative of average contaminant loadings, and preliminary cleanup standards were used to structure the design and assess the success of the test (See Section 6, Example 5).

This particular remedy selection equipment was an indirect fired rotary kiln. Obviously, the operating parameters collected (i.e., temperatures from three shell zones) would not be applicable to the operating parameters necessary to evaluate a thermal screw remedy selection unit.

detailing the site-specific requirements posed by thermal desorption, and assuring compliance with the cleanup requirements.

4.3 EQUIPMENT AND MATERIALS

The Work Plan should specify the equipment and materials needed for the treatability test. Standard laboratory methods normally dictate the types of sampling containers which can be used with various contaminant groups. Appropriate methods for preserving samples and specified holding times for those samples should be used.

The following equipment is typically needed for remedy screening thermal desorption tests:

- muffle furnace, vapor extractor, DBR, or similar devices
- exhaust hood (for control of fugitive dust and volatilized compounds)
- tray or some other device to hold contaminated media
- thermocouples (to record medium and gas temperature)
- rotameter (to regulate purge gas flow rate)

Equipment for remedy selection testing is typically vendor-specific and may include the following systems:

- Rotary dryer
- Thermal screw
- Vapor extractor
- Distillation chamber
- Associated offgas controls for each

A number of vendors have bench-scale to pilot-scale size systems available.

4.4 SAMPLING AND ANALYSIS

The Work Plan should describe the procedures to be used in field and treatability study sampling. The procedures to be used will be site-specific.

4.4.1 Field Sampling

A sampling plan should be developed for the collection of representative samples from the site for the treatability test. The sampling plan is site-specific. It describes the number, location, and volume of samples. If the objective of the testing is to investigate the performance of thermal desorption at the highest contaminant concentration, the sample collection must be conducted at a "hot spot". This will require conducting a preliminary site sampling program or analyzing existing data to identify the locations of highest contaminant concentration. (This information is generated early in the RI process.) If the medium and types of contaminants vary throughout the site, extensive sampling may be required. If thermal desorption is being considered only for certain areas of the site, the sampling program may be simplified by concentrating on those areas.

If the objective of the testing is to investigate the use of the technology for a more homogenous waste, an "average" sample for the entire site must be obtained. This will require a statistically-based program of mapping the site and selecting sampling locations that represent the variety of waste characteristics and contaminant concentrations present. The selection of sampling locations should be based on knowledge of the site. Information from previous samples, obvious odors, or residues are examples of information which can be used to specify sample locations. Table 4-2 lists the type of analyses required for samples in remedy selection testing.

These analyses are typically required for any thermal desorption system. Additional analyses for total metals, TCLP parameters, PCBs, PAHs, dioxins, or furans may also be required depending on the site.

Chapter 9 of Test Methods for Evaluating Solid Waste[36] presents a detailed discussion of representative samples and statistical sampling methods. Additional sources of information on field sampling procedures can be found in Annual Book of ASTM Standards, [3] NIOSH Manual of Analytical Methods (February 1984),[17] and EPA publications Soil Sampling Quality Assurance User's Guide[34] and Methods for Evaluating the Attainment of Cleanup Standards.[31] These documents should be consulted to plan effective sampling programs for either simple or complex sites.

4.4.2 Waste Analysis

Subsection 2.2.3 detailed the physical tests that are useful in characterizing the contaminated medium during the prescreening step. The key for successful thermal desorption treatability studies is to properly select the medium samples based on the initial prescreening and

Table 4-2. Analyses Required in Remedy Selection Testing

	Parameter						
Sample	VOC	SVOC	pH	Moisture	Ash	Oil/Grease	Particle Size
Feed Stream	X	X	X	X	X	X	X
Treated Stream	X	X	X	X	X	X	X
Offgas/Condensate	X	X	X				

additional medium characterizations. Analyses conducted during the RI/FS for contaminants at Superfund sites should identify the contaminants of concern. The spatial distribution and variations in the concentrations of contaminants will be important for the design of treatability studies. If the site contains complex mixtures of contaminants, it may be difficult to treat economically. In some instances, frequent changes in contaminant composition can cause dramatic changes in thermal desorption performance.

4.4.3 Process Control Measurements

Process control and monitoring measurements are essential for remedy screening and remedy selection tests. Placement of thermocouples is dependent on the type of equipment used. They generally are placed within the various zones of the desorption unit to measure medium temperature throughout the test run. Mass flow rates in and out of the desorber are measured. Treatment times (i.e., time-at-temperature for the bed or total residence time) are also recorded.

4.4.4 Residual Sampling and Analysis

The complement of tiers of treatability studies seeks to characterize the performance of the desorption unit in separating organic contaminants from the medium, and approximate the full-scale equipment needs and throughputs. Residuals from thermal desorption requiring sampling and analysis include treated medium, condensate, and particulate control system dust.

Thermal desorption is not a stand-alone process (see subsection 2.1.1), but a separation process that can leave the bulk of the clean solid media onsite. It generates small quantities of residuals which must be disposed of properly. The primary residuals are the concentrated contaminants which are typically removed from the offgas. Sometimes, a useable oil may be produced from condensation of the offgas. Because the nature of thermal desorption equipment and processes varies greatly between vendors, remedy design testing is frequently necessary to evaluate the type, quantity, and properties of residuals. The remedy design treatability testing tier will not be discussed in detail in this document.

Process residuals should be analyzed for the contaminants identified in the original soil analyses as well as any by-products that may have been formed. In many cases, indicator contaminants, which are representative of a larger group of contaminants, can be analyzed in place of a full scan. Caution must be exercised in using indicator contaminants since thermal desorption efficiencies can vary from one contaminant to another. The process efficiency may be either understated or overstated when analyzing for indicator compounds.

4.4.5 Sampling and Analysis Plan (SAP) and Quality Assurance Project Plan (QAPP)

A SAP is required for all field activities conducted during the RI/FS. The SAP consists of the Field Sampling Plan and the QAPP. This section of the Work Plan describes how the RI/FS SAP is modified to address field sampling, medium characterization, and sampling activities supporting treatability studies. It describes the samples to be collected and specifies the level of QA/QC required. See section 5 for additional information on the SAP.

4.5 DATA ANALYSIS AND INTERPRETATION

The Work Plan should discuss the techniques to be used in analyzing and interpreting the data. The objective of data analysis and interpretation is to provide sufficient information to the RPM and EPA management to assess the feasibility of thermal desorption as a remediation technology. After remedy selection testing is complete, the decision must be made whether to proceed to the remedy design tier or full-scale thermal desorption remediation, or to rule out thermal desorption as an alternative. The data analysis and interpretation are a critical part of the remedy selection process. When comparing contaminant concentrations in the feed material versus levels in product streams it is always necessary to use the same basis. Laboratories normally report concentrations on a dry-weight basis; this should be required to eliminate any dilution effects of adding water to the treated medium.

Temperature, treatment times, and residual contamination can be used for screening thermal desorption systems to determine if they can meet specific cleanup criteria. The key results from a remedy screening test usually include:

- temperature (continuous measurement)
- treatment times (continuous measurement)
- initial contaminant concentration
- treated medium contaminant concentration
- residuals

Remedy screening tests are normally conducted by fixing all but one test parameter (independent variable) and running a series of tests while varying the independent variable. The independent variable is generally a parameter that directly affects the thermal desorption performance. Parameters that have a direct affect on thermal desorption performance include temperature, soil classification, contaminant type, treatment time, moisture content, and solid/gas mixing.

Remedy selection testing is nearly always required in the absence of relevant full-scale performance data. Temperature, treatment times, and residual concentration data from remedy screening tests can be used to establish target operating temperatures. One or more of the following performance criteria may also be addressed during this tier of testing:

- Throughput rate expected for the applicable remedy design or full-scale thermal desorption device (including energy input)
- Material handling system design requirements (pre- and post-treatment)
- Air pollution control system design requirements

- Need for air pollution control measures during excavation, transport, and feeding

4.6 REPORTS

The last step of the treatability study is reporting the results. The Work Plan discusses the organization and content of interim and final reports. Complete, accurate reporting is critical because decisions about implementability will be partly based upon the outcome of the study. However, the RPM may not require formal reports at each thermal desorption study tier. Interim reports should be prepared after each tier. Project briefings should be provided to determine the need and scope of the next tier of testing. To facilitate the reporting of results and comparisons between treatment alternatives, a suggested table of contents is presented in the generic guide.[28] At the completion of the study, a formal report is always required.

OERR requires that a copy of all treatability study reports be submitted to the Agency's Superfund Treatability Database repository. One copy of each treatability study report must be sent to:

U.S. Environmental Protection Agency
Superfund Treatability Database
ORD/RREL
26 West Martin Luther King Dr.
Cincinnati, Ohio 45268
Attention: Glenn Shaul, MS-445

4.7 SCHEDULE

The Work Plan includes a schedule for completing the treatability study. The schedule gives the anticipated starting date and ending date for each of the tasks described in the Work Plan and shows how the various tasks interface. The time span for each task accounts for the time required to obtain the Work Plan, subcontractor, and other approvals [e.g., disposal approval from a commercial Treatment, Storage, and Disposal Facility (TSDF)]; analytical turnaround time; and review and comment period for reports and other project deliverables. Some slack time should also be built into the schedule to accommodate unexpected delays (e.g., bad weather, equipment downtime) without affecting the project completion date.

The schedule is usually displayed in the form of a bar chart (Figure 4-3). If the study involves multiple tiers of

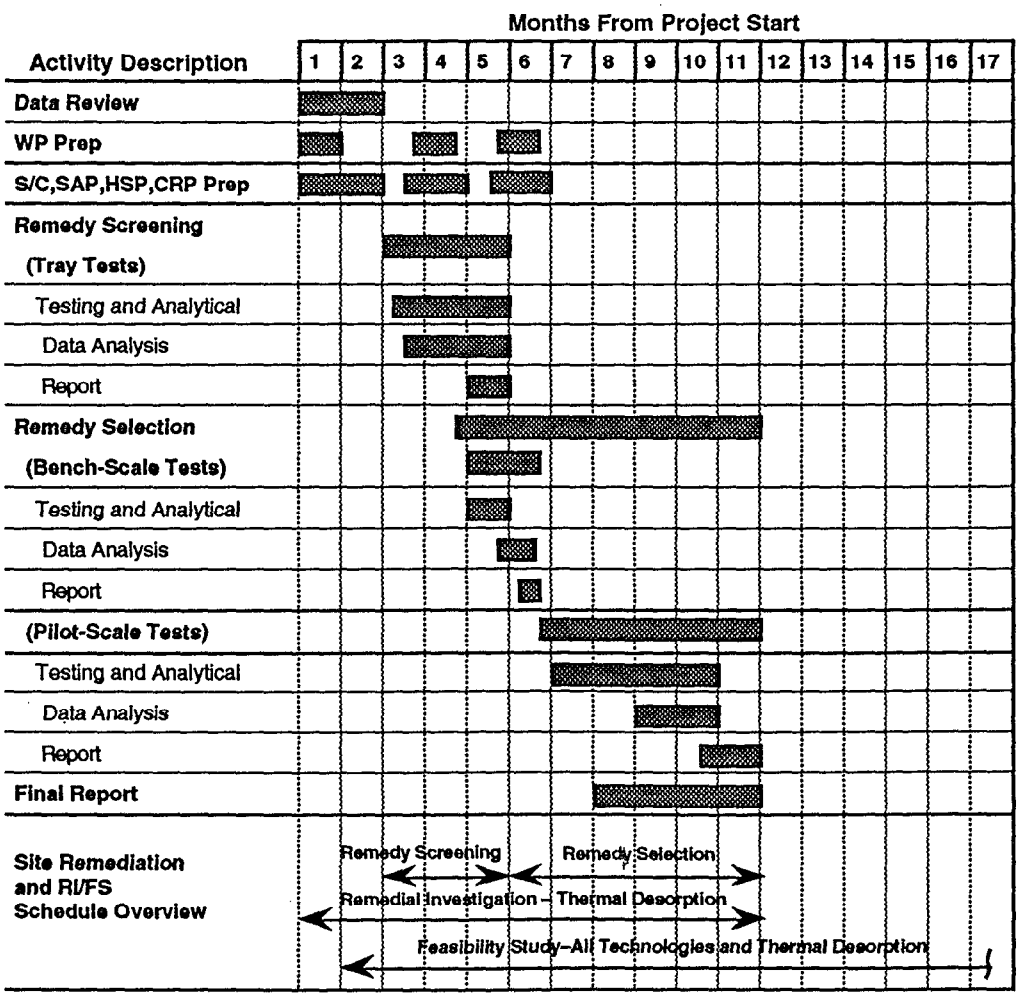

Figure 4-3. Example project schedule for a thermal desorption treatability study program.

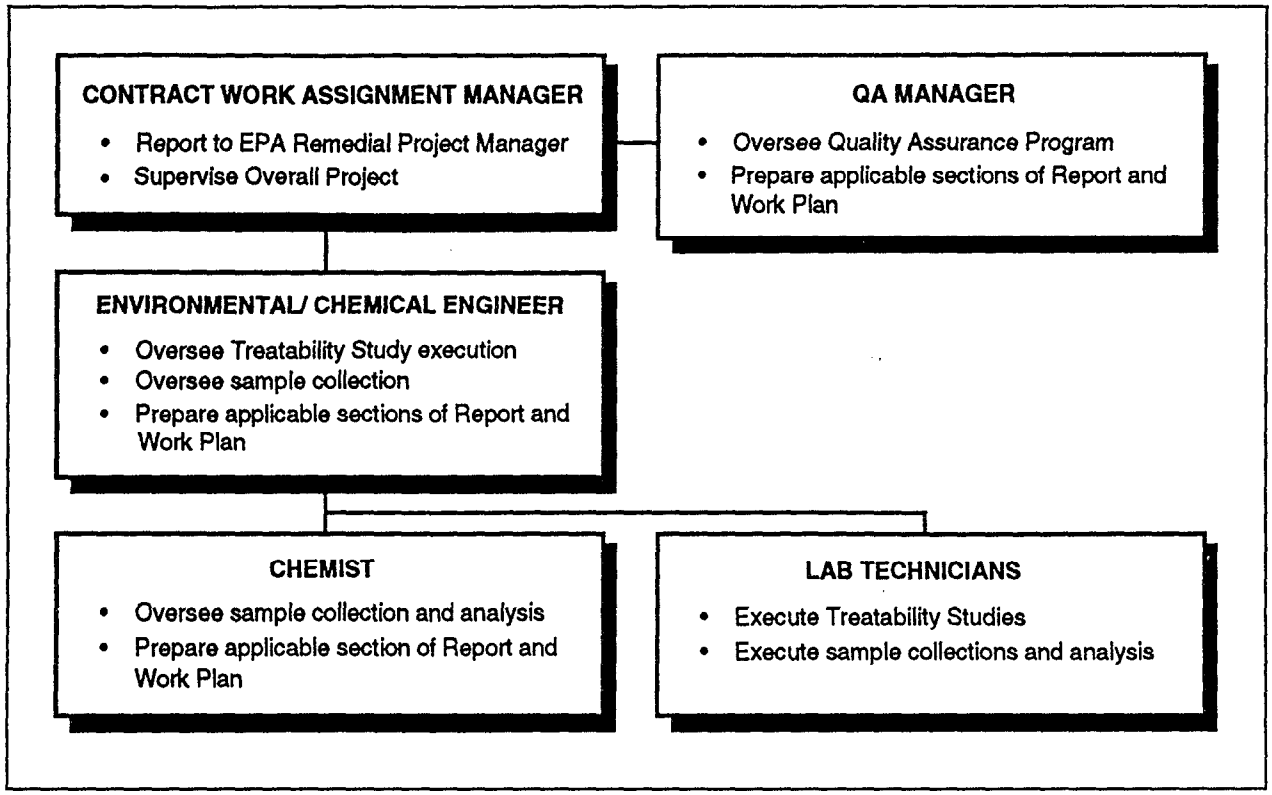

Figure 4-4. Organization chart.

testing, all tiers should be shown on one schedule. Careful planning before the start of the tests is essential. Depending on the review and approval process, planning can take up to several months. Remedy screening tests typically take up to three months. It is not unusual for the remedy selection thermal desorption treatability test to be a several-month project.

Barring any difficulties such as acquiring sampling equipment and site access, the sampling and analysis phase can generally be accomplished in several months. Contracting with an external lab for treatability study analysis may take a month. Laboratory results can often be available in less than 30 days. Shorter analytical turnaround time can be requested, but this will normally increase the costs. Compounds such as pesticides and PCBs may require longer turnaround times due to the extractions and analyses involved. Interpretation of the results and final report writing may take up to 3 months, but this is highly dependent on the length of time for the review process.

4.8 MANAGEMENT AND STAFFING

The Work Plan discusses the management and staffing of a treatability study. The Work Plan specifically identifies the personnel responsible for executing the treatability study by name and qualifications. Generally, the following typical expertise is needed for the successful completion of the treatability study:

- Project Manager (Work Assignment Manager)
- QA Manager
- Environmental / Chemical Engineer
- Chemist
- Lab Technician

Responsibility for various aspects of the project is typically shown in an organizational chart such as the one in Figure 4-4.

4.9 BUDGET

The Work Plan discusses the budget for completion of a treatability study. Remedy screening, with its associated lack of replication and detailed testing, can range from $8,000 to $30,000. These estimates are highly dependent on the factors discussed in Section 4. Not included in these costs are the cost of governmental procurement procedures, including soliciting for bids, awarding contracts, etc.

Costs for remedy selection depend on a variety of factors. Table 4-3 provides a list of potential major cost estimate components for this tier. Sites where the medium, contaminant types, and contaminant concentration vary widely will usually require more samples than sites where the medium and contamination is more homogeneous. It is not unusual for the sampling, analysis, and QA activities

Table 4-3. Major Cost Elements Associated with Remedy Selection Thermal Desorption Studies

Cost Element	Cost Range ($)
Initial Data Review	1,000 – 10,000
Work Plan Preparation	1,000 – 5,000
Sampling & Testing	3,000 – 60,000
Analysis, QA/QC Activities	3,000 – 20,000
Data Presentation/Report	2,000 – 5,000
TOTAL COST RANGE	$10,000 – $100,000

to represent over 50 percent of the total study cost. In general, the costs for analyzing organics are greater than for metals. Actual costs will vary according to individual laboratories, required turnaround times, volume discounts, and any customized analytical requirements.

Sampling costs will be influenced by the contaminant types and depth of contamination found in the medium. The health and safety considerations during sampling activities are more extensive when certain contaminants, (e.g., volatile organics), are present in the medium. Level B personal protective equipment (PPE) rather than Level D PPE can increase this cost component an order of magnitude. Sampling equipment requirements for surface samples are much less complicated than those for depth samples. Residuals from treatability testing require proper treatment and/or disposal. If the residuals are considered hazardous wastes, treatment and disposal of them will increase costs significantly. It is common to return the test residuals to the site for storage until remedial actions are started. This includes contaminated PPE from sampling, testing, and analysis.

Other factors to consider include report preparation and the availability of vital equipment and laboratory supplies. Generally, an initial draft of the report under goes internal review prior to the final draft. Depending on the process, final report preparation can be time-consuming as well as costly. Procurement of testing equipment and laboratory supplies will also increase the costs.

SECTION 5
SAMPLING AND ANALYSIS PLAN

The Sampling and Analysis Plan (SAP) consists of two parts, the Field Sampling Plan (FSP) and the Quality Assurance Project Plan (QAPP). The purpose of this section is to identify the contents and aid in the preparation of these plans. The RI/FS requires a SAP for all field activities. The SAP ensures that samples obtained for characterization and testing are representative and that the quality of the analytical data generated is known and appropriate. The SAP addresses field sampling, medium characterization, and sampling and analysis of the treated medium and residuals from the testing apparatus or treatment unit. The SAP is usually prepared after Work Plan approval.

5.1 FIELD SAMPLING PLAN

The FSP component of the SAP describes the sampling objectives; the type, location, and number of samples to be collected; the sample numbering system; the equipment and procedures for collecting the samples; the sample chain-of-custody procedures; and the required packaging, labeling, and shipping procedures.

Field samples are taken to provide baseline contaminant concentrations and contaminated material characteristics for treatability studies. The sampling objectives must be consistent with the treatability test objectives.

The primary objectives of remedy selection treatability studies are to evaluate the extent to which specific chemicals can be removed from soils, sediments, or sludges. The primary objectives for collecting samples to be used in treatability testing include:

- Acquisition of representative samples. In some cases statistically designed field sampling plans may be required to ensure samples taken are representative of the entire site. However, professional judgment regarding the sampling locations may be exercised to select sampling sites that are typical of the area (pit, lagoon, etc.) or appear above the average concentration of contaminants in the area being considered for the treatability test. This may be difficult because reliable site characterization data may not be available early in the RI stage.
- Acquisition of sufficient sample volumes necessary for testing, analysis, and quality assurance and quality control.

From these two primary objectives, more specific objectives/goals are developed. When developing the more detailed objectives, the following types of questions should be considered:

- Are there adequate data to determine sampling locations indicative of the more contaminated areas of the site? Have soil gas surveys been conducted? Contaminants may be widespread or isolated in small areas (hot spots). Contaminants may be mixed with other contaminants in one location and appear alone in others. Concentration profiles may vary significantly with depth.
- Are the soils homogeneous or heterogeneous? Soil types can vary across a site and will vary with depth. Depending on professional judgement, contaminated samples for various soil types may have to be taken to conduct treatability tests.
- Are contaminants present in sediments or sludges? Different sampling methods must be used for these media.
- Is sampling of a "worst-case" scenario warranted? Assessment of this question must be made on a site-by-site basis. Hot spots and contaminants in different media may be difficult to treat. These should be factored into the test plan if they represent a significant portion of the site.

After identifying the sampling objectives, an appropriate sampling strategy is described. Specific items that should be briefly discussed and included are listed in Table 5-1.

5.2 QUALITY ASSURANCE PROJECT PLAN

The QAPP consists of 11 sections. Since many of these sections are generic, applicable to any QAPP, and covered in available documents,[25][32] this guide will discuss only those aspects of the QAPP that are affected by the treatability testing of thermal desorption.

5.2.1 Experimental Description

Section 1 of the QAPP must include an experimental project description that clearly defines the experimental design, the experimental sequence of events, each type of critical measurement to be made, each type of matrix

(experimental setup) to be sampled, and each type of system to be monitored. This section may reference section 4 of the Work Plan. All details of the experimental design not finalized in the Work Plan should be defined in this section.

Table 5-1. Suggested Organization of Sampling and Analysis Plan

Field Sampling Plan

1. Site Background
2. Sampling Objectives
3. Sample Location and Frequency
   - Selection
   - Medium Type
   - Sampling Strategy
   - Location Map
4. Sample Designation
   - Recording Procedures
5. Sample Equipment and Procedures
   - Equipment
   - Calibration
   - Sampling Procedures
6. Sample Handling and Analysis
   - Preservation and Holding Times
   - Chain-of-Custody
   - Transportation

Quality Assurance Project Plan

1. Project Description
   - Test Goals
   - Critical Variables
   - Test Matrix
2. Project Organization and Responsibility
3. QA Objectives
   - Precision, Accuracy, Completeness
   - Representativeness and Comparability
   - Method Detection Limits
4. Sampling Procedures
5. Sample Custody
6. Calibration Procedures and Frequency
7. Analytical Procedures
8. Data Reduction, Validation, and Reporting
9. Internal QC Checks
10. Performance and System Audits
11. Preventive Maintenance
12. Calculation of Data Quality Indicators
13. Corrective Action
14. QC Reports to Management
15. References
16. Other Items

Items in this section include, but are not limited to the following:

- Number of samples (areas) to be studied
- Identification of treatment conditions (variables) to be studied for each sample
- Target compounds for each sample
- Number of replicates per treatment condition
- Criteria for technology retention or rejection for each type of remedy evaluation test

The Project Description clearly defines and distinguishes the critical measurements from other observations and system conditions (e.g., process controls, operating parameters, etc.) routinely monitored. Critical measurements are those measurements, data gathering, or data generating activities that directly impact the technical objectives of a project. At a minimum, the determination of the target compound in the initial and treated solid samples, bed temperature, and time-at-temperature will be critical measurements for remedy selection tests. Concentration of target compounds in all fractions will be critical measurements for remedy design tests.

5.2.2 Quality Assurance Objectives

Section 2 of the QAPP lists the QA objectives for each critical measurement and sample matrix defined in section 1. These objectives are presented in terms of the six data quality indicators: precision, accuracy, completeness, representativeness, comparability, and, where applicable, method detection limit.

5.2.3 Sampling Procedures

The procedures used to obtain field samples for the treatability study are described in the FSP. They need not be repeated in this section, but should be incorporated by reference.

Section 3 of the QAPP contains a description of a credible plan for subsampling the material delivered to the laboratory for the treatability study. The methods for aliquoting the material for determination of chemical and physical characteristics such as bulk density or specific gravity, moisture content, contaminant concentration, etc. must be described.

5.2.4 Analytical Procedures and Calibration

Section 4 describes or references appropriate analytical methods and standard operating procedures for the analytical method for each critical measurement made. In addition, the calibration procedures and frequency of calibration are discussed or referenced for each analytical system, instrument, device, or technique for each critical measurement.

The methods for analyzing the treatability study samples are the same as those for chemical characterization of field

samples. Preference is given to methods in "Test Methods for Evaluating Solid Waste, SW-846, 3rd. Ed.," November 1986.[36] Other standard methods may be used, as appropriate.[2][3][30] Methods other than gas chromatography/mass spectroscopy (GC/MS) techniques are recommended to conserve costs when possible.

5.2.5 Data Reduction, Validation and Reporting

Section 5 includes, for each critical measurement and each sample matrix, specific presentation of the requirements for data reduction, validation, and reporting. Aspects of these requirements are covered in subsections 4.5, 4.6, and 6.1 of this guide.

5.2.6 Quality Control Reports

Section 10 describes the QA/QC information that will be included in the final project report. As a minimum, reports include:

- Changes to the QA Project Plan
- Limitations or constraints on the applicability of the data
- The status of QA/QC programs, accomplishments, and corrective actions
- Results of technical systems and performance evaluation QC audits
- Assessments of data quality in terms of precision, accuracy, completeness, method detection limits, representativeness, and comparability

The final report contains all the QA/QC information to support the credibility of the data and the validity of the conclusions. This information may be presented in an Appendix to the report. Additional information on data quality objectives[25] and preparation of QAPPs[32] is available in EPA guidance documents.

SECTION 6
TREATABILITY DATA INTERPRETATION

The remedy screening tier establishes the general applicability of the technology. The remedy selection tier demonstrates the applicability of the technology to a specific site. The remedy design tier provides information in support of the evaluation criteria after the ROD. The test goals for each tier are based on established cleanup goals or other performance-based specifications. Proper evaluation of the potential of thermal desorption for remediating a site must compare the test results (described in subsection 4.5) to the test goals (described in subsection 4.1) for the remedy selection tier. The evaluation is interpreted in relation to seven of the nine RI/FS evaluation criteria, as appropriate.

Subsection 4.6 of this guide discusses the need for the preparation of interim and final reports and refers to a suggested format. In addition to the raw and summary data for the treatability study and associated QA/QC, the treatability report should describe what the results mean and how to use them in the feasibility study in screening/selecting alternatives. The report must evaluate the expected performance of the technology and give an estimate of the costs of further treatability studies and final remediation with the technology.

6.1 TECHNOLOGY EVALUATION

Remedy screening treatability studies are designed to gain fundamental information regarding the proof of concept for the technology. Tests are typically conducted using laboratory equipment such as a static tray, DBR, or other screening devices. The contaminant concentration in the medium before treatment is compared to the contaminant concentration after treatment. If the measured separation efficiency is sufficient, additional treatability studies are warranted. If the operating parameters are properly selected, separation efficiency can be high. This would indicate success on the screening level, and testing should proceed to remedy selection. If remedy screening tests are conducted at lower temperatures and/or shorter treatment times than those discussed in subsection 4.2, removal efficiencies may be lower. It may not be appropriate to eliminate thermal desorption as a treatment alternative under such cases, since screening tests may be redesigned under different conditions to demonstrate higher removal efficiencies. At certain sites, removal efficiencies less than 90 percent may be acceptable in meeting expected cleanup goals and testing can proceed to remedy selection. Before and after concentrations can normally be based on duplicate samples for each test run. The mean values from these analyses are compared to assess the success of the study. A number of statistical texts are available if more information is needed.[5][12]

The remainder of this section discusses the interpretation of data from remedy selection treatability studies. Subsections 4.1 and 4.2 of this guide discussed the goals and design of remedy selection treatability studies, respectively. The goals of remedy selection are:

- to address general medium pretreatment and materials handling requirements
- to estimate performance and cost data of full-scale systems
- to verify that thermal desorption can meet cleanup levels at normal operating conditions
- to define heat input requirements
- to address general offgas treatment and residuals disposal requirements

Data obtained from remedy selection need to be interpreted with a scale-up tool (i.e. past experience or computer simulation). Vendors use past experience to scale up to their own systems. A properly validated computer simulation can be another scale-up tool.

One such computer simulation is the GRI/NSF Thermal Treatment Model[18] being developed at the University of Utah to describe the decontamination of a solid medium when heated in a rotary dryer. The model describes the heat transfer to the contaminated medium, the desorption of the contaminant from the medium, and its subsequent fate in the gas phase. The model consists of two major submodels:

1. A heat transfer model which predicts the medium temperature as a function of kiln residence time for both direct and indirect heated systems which may be cocurrent or countercurrent. The model accounts for heating the medium by convection, radiation, and conduction in a series of perfectly mixed axial zones. Heat can be transferred to the medium from hot gases or from the heated shell.
2. A mass transfer model which predicts organic desorption. This requires data from laboratory tests to define a series of adjustable parameters which are contaminant and medium dependent.[14]

The model, which is not vendor-specific, has been used to predict the performance of full-scale systems from data generated in treatability studies. It provides an ideal method for the interpretation of both remedy selection and remedy design data, but it is relevant to rotary dryer desorption systems only.[14]

Example 5 continues from Example 4 and illustrates typical results presented from remedy selection treatability tests. This example goes on to give the vendor's estimated costs for the full-scale remediation. Costing is described further in subsection 6.2 of this guide.

Example 5. Remedy Selection Treatability Test Results

BACKGROUND

In Example 4, the site history, equipment used, and test conditions were reviewed. The same vendor-specific treatability test is continued to show how results could be presented and interpreted.

RESULTS OF TESTING

The mass balance is based on the total time that solids were fed to and discharged from the system. All solid products recovered are assumed to be the average of the three product samples analyzed. Contaminant concentrations were measured in the solid and liquid streams only. Analysis of the contaminants in the gas phase was not within the scope of this test series. The component recovery calculations are based on the mass of the contaminant in the untreated soil feed. The major component recoveries for this study are summarized in Table C.

Table C. Major Component Material Balance

Component	Total Mass In (g)	Total Mass Out (g)	% Recovery
Solids	9,363	8,912	95.2
Water*	1,783	2,057	115
Oil and Grease	1.07	0.177	16.5

*Based on water content of feed only

The removal efficiencies of the POHCs are shown in Table D. The analytical results indicate the concentrations were significantly reduced.

Table D. POHC Removal Efficiency

Contaminant	Run Feed (mg/kg)	Product (mg/kg)	% Removal	Proposed Cleanup Standard (mg/kg)
Chlordane (total)	20.2	0.86	95.7	10
Endrin	35.7	0.86	97.6	5
Heptachlor	63.1	<0.33	>99.5	3
Pentachlorophenol	18.8	<0.63	>96.6	5

Example 5. (continued)

Based on the test results available versus proposed treatments goals, the vendor process is a suitable alternative treatment technology for the pesticide-contaminated soils at the site. For this type of clayey soil with a moisture content between 15 and 20 percent, the vendor could process 100 to 130 tons per day. To estimate the total amount of material requiring treatment, the site soil volume estimates were converted to mass using a calculated in situ density of 1.5 ton/yd^3. Table E shows the vendor estimated treatment costs, using the Remedy Selection test results and the vendor's experience as a scale-up tool.

Table E. Vendor's Treatment Cost Estimate From Remedy Selection Test Results

Item	($/ton)
Mobilization/Demobilization	15.0
Operating Labor	24.5
Maintenance	22.5
Capital Charge	44.0
Utilities	
Electricity	12.0
Propane	21.5
Consumables	
Nitrogen	9.5
Carbon	6.0
Miscellaneous	3.5
Residual Management	
Condensed Water	6.0
Condensed Organics	2.5
Filter Cake Recycle	6.5
Total Treatment Cost	**172.5**

Assumptions:
1) Soil Density = 1.5 tons/yd^3 (111 lb/ft^3)
2) Feed Rate = 106 tons/day
3) Soil Moisture = 20 percent
4) Total Volume for Treatment = 24,000 yd^3

CONCLUSIONS

Using a representative sample and a vendor's bench-size, scaled model of their production unit, the efficiency of contaminant removal is estimated. This vendor predicted feed rates, organic removal rates, and operating costs for the full-scale production unit.

Wtih this data available, the RPM can decide if the cleanup levels achieved are acceptable, the economics are justifiable, and whether thermal desorption is a viable alternative. If efficiencies are low and/or cost data can't be provided, the decision could be to move to remedy design testing for detailed information.

6.2 ESTIMATION OF COSTS

Reasonable preliminary cost estimates are crucial to the feasibility study process. Comparisons of various technologies must be based on the most complete and accurate estimates available. Remedy screening treatability studies cannot provide this type of information. Preliminary cost estimates for full-scale remediation are generally possible from remedy selection data. Such estimates may be good enough for comparisons to other technologies at the same tier of testing. On this basis, the estimates can form the basis of the ROD. Remedy design studies, which are conducted after the ROD has been signed, may be necessary to provide a more accurate estimate of the eventual cost of full-scale thermal desorption remediation. This is especially true since thermal desorption will form only one component of a treatment train.

6.2.1 Thermal Desorption Remedy Selection Cost Estimates

Remedy selection tests can be used to obtain preliminary cost estimates for full-scale systems.

Data obtained from remedy selection which are needed to estimate full-scale costs include:

- medium pretreatment and materials handling
- moisture content
- contaminant identification and concentration
- operating temperature
- treatment time
- residual contaminants and contaminant concentrations in the treated medium
- offgas treatment

Medium characterization (i.e., moisture content and contaminant concentration) is needed to determine the size and throughput of the thermal desorption unit. Moisture content not only determines the heat input that is required but also the time required to dry soil. If soil moisture is low or minimized through pretreatment, increased throughput rates should be realized. (Pretreatment costs must be factored into the cost estimate.) Although moisture and concentration levels may vary throughout the site, average values are needed to make some sort of throughput determination. Operating temperature and treatment time, which are dependent on moisture content and contaminant identification and concentration, are needed as part of the thermal desorption unit size determination.

The presence of metals or other inorganic contaminants, which may indicate additional treatment is necessary, needs to be determined. Residual contaminant concentrations from treatability testing are generally not the same as residual levels from full-scale cleanups. However, they are needed to make preliminary cost estimates for full-scale systems; any existing or even empirical full-scale data should be evaluated with treatability test data to help compensate for inherent scale-up uncertainties. Offgas treatment and material handling are important cost considerations in any thermal desorption system. Preliminary cost estimates for material handling cannot be determined directly from most remedy selection tests but can be derived from site characterization data. The total volume of medium, moisture content, particle size distribution, and the presence of any debris are important factors in determining material handling costs. Offgas treatment cost estimates can be derived from offgas analysis conducted in the treatability study, although they should only be considered order of magnitude.

6.2.2 Full-Scale Thermal Desorption Cost Estimates

Various thermal desorption systems are operating at several Superfund sites. Vendors have documented processing costs per ton of feed processed. The overall range varies from $80 to $350/ton of medium processed. Caution is recommended in using costs out of context because the scope of work may vary from site to site. It is important to know what costs are included (e.g., engineering design, excavation, pretreatment, residual disposal) and what is the base year. Costs also are highly variable due to the quantity of medium to be processed, throughput rate (the capacity of the thermal desorption unit), term of the remediation contract, moisture content, organic constituent variation of the contaminated medium, and cleanup standard to be achieved. Similarly, cost estimates should include such items as preparation of Work Plans, permitting, testing, excavation, processing, sampling and analysis, QA/QC verification of treatment performance, and reporting of data.

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