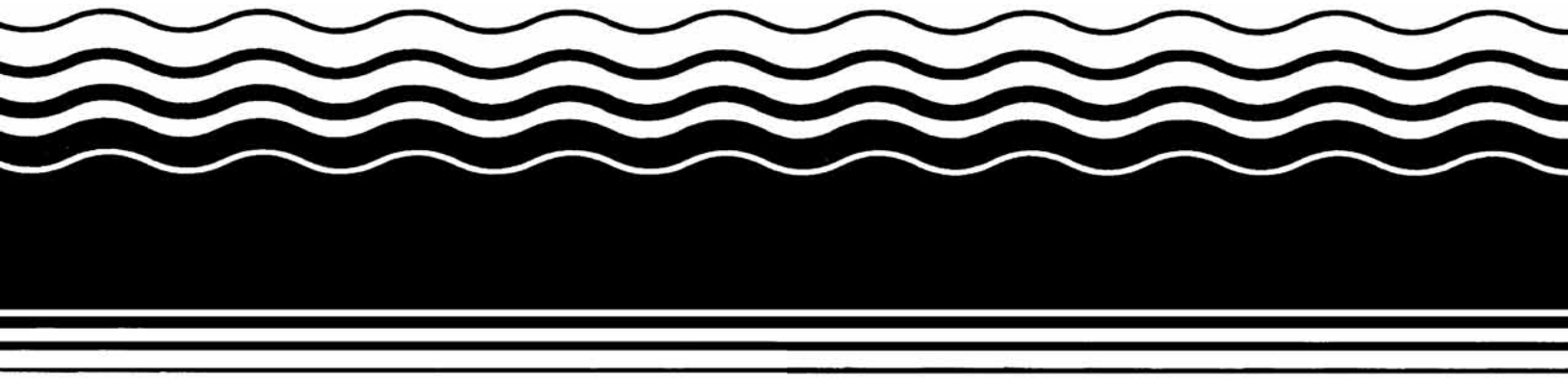
United States Environmental Protection Agency | Office of Research and Development Washington DC 20460 | Office of Solid Waste and Emergency Response Washington, DC 20460

Superfund | EPA/540/R-92/071a | October 1992

Guidance for Conducting Treatability Studies under CERCLA

Final



Word-searchable Version – Not a true copy

EPA/540/R-92/071a
OSWER Directive No. 9380.3-10
November 1992

GUIDE FOR CONDUCTING TREATABILITY STUDIES UNDER CERCLA

FINAL

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, DC 20460

NOTICE

The information in this document has been funded wholly or in part by the U.S. Environmental Protection Agency (EPA) under Contract No. 68-C9-0036. It has been subjected to the Agency's review process and approved for publication as an EPA document.

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 (EPA) 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 purpose of this guide is to provide information on conducting treatability studies. It describes a three-tiered approach that consists of 1) remedy screening, 2) remedy-selection testing, and 3) remedial design/remedial action testing. It also presents a protocol for conducting treatability studies in a systematic and stepwise fashion for determination of the effectiveness of a technology (or combination of technologies) in remediating a CERCLA site.

E. Timothy Oppelt, Director
Risk Reduction Engineering Laboratory

ABSTRACT

Systematically conducted, well-documented treatability studies are an important component of the removal process, 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 screening, selection, and implementation of the site remedies. This guide focuses on both treatability studies conducted in support of remedy screening and selection [i.e., pre-Record of Decision (ROD)] and treatability studies in support of remedy implementation (i.e., post-ROD).

The guide describes a three-tiered approach for conducting treatability studies that consists of 1) remedy screening, 2) remedy-selection testing, and 3) RD/RA testing. Depending on the technology information gathered during RI/FS scoping, pre-ROD treatability studies may begin at either the remedy-screening or remedy-selection tier. Remedial design/remedial action treatability testing is performed post-ROD.

The guide also presents an 11-step generic protocol for conducting treatability studies. The steps include:

- Establishing data quality objectives
- Identifying sources for treatability studies
- 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

The intended audience for this guide comprises Remedial Project Managers, On-Scene Coordinators, Federal facility environmental coordinators, potentially responsible parties, contractors, and technology vendors. Although Resource Conservation and Recovery Act (RCRA) program officials may find many sections of this guide useful, the RCRA program is not expressly addressed in the guide.

TABLE OF CONTENTS

FIGURES

Figure **Page**

TABLES

ACRONYMS

AOC	Administrative Order on Consent
ARAR	applicable or relevant and appropriate requirement
ARCS	Alternative Remedial Contracts Strategy
ATTIC	Alternative Treatment Technology Information Center
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Action of 1980 (aka Superfund)
CFR	Code of Federal Regulations
COLIS	Computerized On-Line Information Service
COE	U.S. Army of Corps of Engineers
CRP	Community Relations Plan
DOD	Department of Defense
DOE	Department of Energy
DOT	Department of Transportation
DQO	Data quality objective
EPA	U.S. Environmental Protection Agency
ERCS	Emergency Response Cleanup Services
ERT	Emergency Response Team
ETSC	Engineering Technical Support Center
FAR	Federal Acquisition Regulations
FR	Federal Register
FS	feasibility study
FSP	Field Sampling Plan
HSP	Health and Safety Plan
HSWA	Hazardous and Solid Waste Amendments of 1984
ITSV	Inventory of Treatability Study Vendors
LDRs	Land Disposal Restrictions
MCLs	Maximum Contaminant Levels
MSDS	Material Safety Data Sheet
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NIOSH	National Institute of Occupational Safety and Health
NPL	National Priorities List
O&M	Operations and Maintenance
OERR	Office of Emergency and Remedial Response
ORD	Office of Research and Development
OSC	On-Scene Coordinator
OSHA	Occupational Safety and Health Administration
OSWER	Office of Solid Waste and Emergency Response
PARCC	Precision, Accuracy, Representativeness, Completeness, and Comparability
PAH	Polynuclear Aromatic Hydrocarbon
PCB	Polychlorinated biphenyl
PRP	Potentially responsible party
QAPP	Quality Assurance Project Plan
QA/QC	quality assurance/quality control
RA	remedial action
RCRA	Resource Conservation and Recovery Act of 1976
RD	remedial design
RD&D	research, development, and demonstration
RFP	request for proposal
RI	remedial investigation
ROD	Record of Decision
RPM	Remedial Project Manager
RREL	Risk Reduction Engineering Laboratory
SAP	Sampling and Analysis Plan
SARA	Superfund Amendments and Reauthorization Act of 1986
SCAP	Superfund Comprehensive Accomplishments Plan
SITE	Superfund Innovative Technology Evaluation
SOP	standard operating procedure
SOW	Statement of Work
START	Superfund Technical Assistance Response Team
TAT	Technical Assistance Team
TCLP	toxicity characteristic leaching procedure
TIX	Technical Information Exchange
TOC	total organic carbon
TOX	total organic halogen
TSDF	treatment, storage, or disposal facility
TSC	Technical Support Center
TSP	Technical Support Project
TST	Technical Support Team
USCG	United States Coast Guard
USPS	United States Postal Service
UST	Underground Storage Tank

ACKNOWLEDGMENTS

This guide was prepared for the U.S. Environmental Protection Agency, Office of Research and Development, Risk Reduction Engineering Laboratory (RREL), Cincinnati, Ohio, by IT Corporation. Mr. Eugene F. Harris and Mr. David L. Smith served as the EPA Technical Project Monitors, assisted by Ms. Robin M. Anderson, Office of Emergency and Remedial Response, and Mr. Johnathan Herrmann, RREL. Mr. Gregory D. McNelly was IT's Work Assignment Manager. The project team included Jeffrey S. Davis, Mary Beth Foerst, E. Radha Krishnan, Jennifer Platt, Michael Taylor, and Julie Van Deuren. Ms. Judy L. Hessling served as IT's Senior Reviewer, and Ms. Martha H. Phillips served as the Technical Editor. Document layout was provided by Mr. James I. Scott, III.

The following personnel have contributed their time and comments by participating in the Guide for Conducting Treatability Studies Under CERCLA workshop:

Lisa Askari	U.S. EPA, Office of Solid Waste
John Barich	U.S. EPA, Region X
Edward Bates	U.S. EPA, Risk Reduction Engineering Laboratory
Benjamin Blaney	U.S. EPA, Risk Reduction Engineering Laboratory
John Blevins	U.S. EPA, Region IX
Randall Breeden	U.S. EPA, Office of Emergency and Remedial Response
JoAnn Camacho	U.S. EPA, Environmental Response Team
Jose Cisneros	U.S. EPA, Region V Emergency Response
Paul Flathman	OHM Remediation Services Corporation
Vance Fong	U.S. EPA, Region IX
Frank Freestone	U.S. EPA, Risk Reduction Engineering Laboratory
Tom Greengard	EG&G Rocky Flats
Eugene Harris	U.S. EPA, Risk Reduction Engineering Laboratory
Sarah Hokanson	Clean Sites, Inc.
Norm Kulujian	U.S. EPA, Region III
Donna Kuroda	U.S. Army Corps of Engineers
John Quander	U.S. EPA, Technology Innovation Office
Jim Rawe	Science Applications International Corporation
Ron Turner	U.S. EPA, Risk Reduction Engineering Laboratory

SECTION 1
INTRODUCTION

1.1 Background

Under the Superfund Amendments and Reauthorization Act of 1986 (SARA), the U.S. Environmental Protection Agency (EPA) is required to select remedial actions involving treatment that "permanently and significantly reduces the volume, toxicity, or mobility of the hazardous substances, pollutants, and contaminants" [Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), Section 121(b)].

Selection of remedial actions involves several risk management decisions. Uncertainties with respect to performance, reliability, and cost of treatment alternatives underscore the need for well-planned, well-conducted, and well-documented treatability studies, as evident in the following quote from *Management Review of the Superfund Program* (EPA 1989a):

> "To evaluate the application of treatment technologies to particular sites, it is essential to conduct laboratory or pilot-scale tests on actual wastes from the site, including, if needed and feasible, tests of actual operating units prior to remedy selection. These 'treatability tests' are not currently being performed at many sites to the necessary extent, or their quality is not adequate to support reliable decisions."

Treatability studies provide valuable site-specific data necessary to support Superfund remedial actions. They serve two primary purposes: 1) to aid in the *selection* of the remedy, and 2) to aid in the *implementation* of the Selected remedy. Treatability studies conducted during a remedial investigation/feasibility study (RI/FS) indicate whether a given technology can meet the expected cleanup goals for the site and provide important information to aid in remedy selection, whereas treatability studies conducted during remedial design/remedial action (RD/RA) establish the design and operating parameters necessary for optimization of technology performance and implementation of a sound, cost-effective remedy. Although the purpose and scope of these studies differ, they complement one another because information obtained in support of remedy selection may also be used to support the remedy design and implementation. Treatability studies also may be conducted under the CERCLA Removal Program to support removal actions that involve treatment.

Historically, treatability studies have been delayed until after the Record of Decision (ROD) has been signed. Although certain post-ROD treatability studies are appropriate, conducting treatability studies during the RI/FS (i.e., pre-ROD) should reduce the uncertainties associated with selecting the remedy, provide a sounder basis for the ROD, and possibly facilitate negotiations with potentially responsible parties without lengthening the overall cleanup schedule for the site. Because treatability studies may be expensive and time-consuming, however, the economics of cost and time must be taken into consideration when planning treatability studies in support of the various phases of the Superfund program.

1.2 Purpose

This document presents guidance on conducting treatability studies under CERCLA. Its purpose is to facilitate efficient planning, execution, and evaluation of treatability studies and to ensure that the data generated can support remedy selection and implementation.

1.3 Intended Audience

This document is intended for use by EPA Remedial Project Managers (RPMs), EPA On-Scene Coordinators (OSCs), potentially responsible parties (PRPs), Federal facility environmental coordinators, treatability study contractors, and technology vendors. As described here, each of these persons plays a different role in conducting treatability studies under CERCLA. Although the Resource Conservation and Recovery Act (RCRA) program is not expressly

addressed, many sections of the guide may be useful in the planning of treatability studies in support of corrective action. Some parts may also be applicable in the Underground Storage Tank (UST) program.

1.3.1 Remedial Project Managers

Remedial Project Managers are EPA or State officials responsible for remediation planning and oversight at a site. Their role in treatability investigations depends on the designated lead agency (Federal, State, or private) and whether the site is a fund-financed or enforcement-lead site. Their activities generally include scoping the treatability study, establishing the data quality objectives, selecting a contractor, and issuing a work assignment, or obtaining EPA sponsored treatability study support, overseeing the execution of the study, informing or involving the public as appropriate, reviewing project deliverables, and using treatability study data in decision making.

1.3.2 On-Scene Coordinators

On-Scene Coordinators are Federal officials predesignated by the EPA or U.S. Coast Guard (USCG) to coordinate and direct removal actions at both National Priorities List (NPL) and non-NPL sites. Their role in treatability studies is similar to that of the RPM.

1.3.3 Potentially Responsible Parties

Under CERCLA Sections 104(a) and 122(a), EPA has the discretion to allow PRPs to perform certain RI/FS activities, including treatability studies. The EPA or an authorized State agency oversees the conduct of PRP-led treatability studies, but the PRP is responsible for project planning, execution, and evaluation.

1.3.4 Federal Facility Environmental Coordinators

Environmental coordinators at Federal facilities may conduct treatability studies under CERCLA or agency-specific programs such as the Department of Defense (DOD) Installation Restoration Program and the Department of Energy (DOE) Environmental Restoration and Waste Management Program. The roles and responsibilities of these personnel will vary by agency and program; however, for treatability studies they will be similar to those of the EPA RPM.

1.3.5 Contractors/Technology Vendors

Treatability studies are generally performed by remedial contractors or technology vendors. Their roles in treatability investigations include preparing the Work Plan and other supporting documents, complying with regulatory requirements, executing the study, analyzing and interpreting the data, and reporting the results.

1.4 History of the Guide

In December 1989, EPA published the interim final *Guide for Conducting Treatability Studies Under CERCLA* (EPA 1989b). This generic treatability guidance was one component of the EPA's Office of Research and Development (ORD) treatability study initiative to identify treatability capabilities, to consolidate treatability data, and to develop standard operating protocols. The objectives of the guide were threefold:

1) To provide guidance to RPMs and Superfund remedial contractors for conducting treatability studies in support of remedy selection (i.e., pre-ROD).

2) To serve as a framework for developing technology-specific protocols.

3) To be a dynamic document that evolves as the Agency gains treatability study experience.

As part of the development of the generic treatability guidance, EPA sponsored a treatability protocol workshop in July 1989, which was attended by more than 60 representatives from EPA Headquarters and Regional offices, contractors/technology vendors, and academia. The tiered approach to treatability studies and the 11-step protocol that evolved during the workshop and subsequent document peer review process form the basis of the treatability guidance.

In keeping with the original objective of producing a dynamic document, comments on the utility of the interim final guidance after approximately 18 months of use were solicited through a survey of potential users (principally RPMs and their contractors) and a second workshop in August 1991. Although the general content and format have not changed, the document has been expanded to address a broader audience and updated to reflect current regulations, policy, and guidance/information sources. In addition, the "tier" terminology has been revised to reflect the intended use of the data rather than the scale of testing.

1.5 Use of the Guide

1.5.1 Organization of the Guide

The guide is organized into two principal sections: an

overview of treatability studies and a step-by-step protocol. Section 2 describes the need for treatability studies and presents a three-tiered approach consisting of 1) remedy screening, 2) remedy selection, and 3) remedial design/ remedial action. This section also describes the application of the tiered approach to innovative technologies, treatment trains, and in situ technologies; circumstances in which treatability studies can and cannot be performed generically; and PRP-conducted treatability studies.

Section 3 presents a general approach or protocol for conducting treatability studies. It contains information on planning, performing, and reporting the results of treatability studies with respect to the three tiers, Specifically, this section includes information on:

- Establishing data quality objectives.
- Identifying qualified sources for performance of treatability studies and selecting a contracting mechanism.
- Issuing the work assignment, with emphasis on writing the scope of work.
- Preparing the Work Plan, with emphasis on designing the experiment.
- Preparing the Sampling and Analysis Plan for a treatability study.
- Preparing the Health and Safety Plan for a treatability study.
- Conducting community relations activities in support of treatability studies.
- Complying with regulatory requirements for testing and residuals management.
- Executing the treatability study, with emphasis on collecting and analyzing samples.
- Analyzing and interpreting the data, including a discussion on statistical analysis techniques.
- Reporting the results in a logical and consistent format.

The text of each subsection presents general information followed (when applicable) by specific details pertaining to the three tiers of treatability testing.

Appendix A contains additional sources of treatability information. Appendix B discusses the major cost elements associated with treatability studies. Appendix C contains technology-specific waste-characterization parameters.

1.5.2 Application and Limitations of the Guide

Treatability studies are an integral part of the Superfund program. This guide is intended to supplement the information on development, screening, and analysis of alternatives contained in the interim final *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA 1988a), hereinafter referred to as the RI/FS guidance. Generic in nature, the guide encompasses all waste matrices (soils, sludges, liquids, and gases) and all categories of technologies (biological treatment, physical/chemical treatment, immobilization, thermal treatment, and in situ treatment). The guide addresses treatability studies conducted in support of remedy screening and selection (i.e., pre-ROD) and remedy design and implementation (i.e., post-ROD). Companion documents providing technology-specific treatability guidance are being prepared for soil vapor extraction, chemical dehalogenation, soil washing, solvent extraction, biodegradation, thermal desorption, and solidification/stabilization.

In an effort to be concise, supporting information in other readily available guidance documents is referenced throughout this guide rather than repeated. For example, details on the preparation of a site Sampling and Analysis Plan (which includes a Field Sampling Plan and a Quality Assurance Project Plan), a Health and Safety Plan, and a Community Relations Plan are not included herein.

Although this guidance is written to support the treatability study activities of an EPA RPM under CERCLA, it has wide applicability to many other programs. For this reason, the term "project manager" has been used, when appropriate, to signal the potential applicability of the subject covered to both the CERCLA Remedial and Removal Programs and to non-CERCLA treatability studies.

This document was drafted and reviewed by representatives from EPA's Office of Solid Waste and Emergency Response, Office of Research and Development, and the Regional offices, as well as by contractors and vendors who conduct treatability studies. Comments obtained during the course of the peer review process have been integrated or addressed throughout this guide.

SECTION 2
OVERVIEW OF TREATABILITY STUDIES

This section presents an overview of treatability studies under CERCLA and provides examples of the application of treatability studies in the RI/FS process. Subsection 2.1 outlines the role of treatability studies in the Superfund program. Subsection 2.2 provides details on the three tiers of treatability testing. Subsection 2.3 presents the methodology for applying the tiered approach. Subsection 2.4 discusses treatability study test objectives. Subsection 2.5 addresses special issues associated with CERCLA treatability studies, including examples of how the tiered approach can be applied to investigations of unit operations, treatment trains, and in situ technologies; when testing can and cannot be performed generically (i.e., without the assistance of vendors using proprietary reagents and processes); the involvement and oversight of PRPs; and the funding of treatability studies.

2.1 The Role of Treatability Studies Under CERCLA

2.1.1 Pre-ROD Treatability Studies

As discussed in the RI/FS guidance, site characterization and treatability investigations are two of the main components of the RI/FS process. As site and technology information is collected and reviewed, additional data needs for evaluating alternatives are identified. Treatability studies may be required to fill some of these data gaps.

In the absence of data in the available technical literature, treatability studies can provide the critical performance and cost information needed to evaluate and select treatment alternatives. The purpose of a pre-ROD treatability investigation is to provide the data needed for the detailed analysis of alternatives during the FS. The 1990 revised National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (55 FR 8813), Section 300.430(e), specifies nine evaluation criteria to be considered in this assessment of remedial alternatives. Treatability Studies can generally provide data to address the first seven of these nine criteria:

1) Overall protection of human health and the environment

2) Compliance with applicable or relevant and appropriate requirements (ARARs)

3) Long-term effectiveness and permanence

4) Reduction of toxicity, mobility, and volume through treatment

5) Short-term effectiveness

6) Implementability

7) Cost

8) State acceptance

9) Community acceptance

The first two criteria, which relate directly to the statutory requirements each remedial alternative must meet, are categorized as *threshold criteria*. The next five are the *primary balancing criteria* upon which the selection of the remedy is based. The final two *modifying criteria*, State acceptance and community acceptance, are addressed in the ROD when comments are received on the RI/FS and the proposed remedial plan. (The RI/FS evaluation criteria are discussed in detail in Subsection 3.11.2.)

Pre-ROD treatability studies may be needed when potentially applicable treatment technologies are being considered for which no or limited performance or cost information is available in the literature with regard to the waste

types and site conditions of concern. The general decision tree presented in Figure 1 illustrates when treatability studies are needed to support the evaluation and selection of an alternative. After the existing data on the physical and chemical characteristics of the waste have been reviewed, a literature survey is conducted to obtain any existing treatability data for the contaminants and matrices of concern. (Sources of technical support and treatability information available through EPA are discussed in Subsection 3.3 and Appendix A.) Based on the results of a review of available site data and a literature search, remedial technology types are prescreened to eliminate those that are clearly not applicable for the site. Potentially and definitely applicable technologies are assembled into alternatives and evaluated in terms of the nine RI/FS criteria to identify any data gaps. Site- and technology-specific data needs are then identified for each of the alternatives retained for investigation.

The need to conduct a treatability study on any part of an alternative is a management decision. In addition to the technical considerations, certain nontechnical management decision factors must be considered. As shown in Figure 1, these factors include the expected level of State and community acceptance of a proposed alternative; time constraints on the completion of the RI/FS and the signing of the ROD; and the appearance of new site, waste, or technology data.

If the existing data are adequate for an evaluation of the alternative for remedy selection (i.e., sufficient to perform a detailed analysis against the nine RI/FS evaluation criteria), no treatability study is required. Otherwise, a treatability study should be performed to generate the data necessary to conduct a detailed analysis of the alternative.

2.1.2 Post-ROD Treatability Studies

Although a substantial amount of data on the selected remedy may be available from the RI/FS, treatability studies may also be necessary during remedial design/remedial action if treatment is part of the remedy. Post-ROD or RD/RA treatability studies can provide the detailed design, cost, and performance data needed to optimize treatment processes and to implement full-scale treatment systems. In the process of implementing a remedy, RD/RA treatability studies can be used 1) to select among multiple vendors and processes within a prescribed remedy (pre-qualification), 2) to implement the most appropriate of the remedies prescribed in a Contingency ROD, or 3) to support preparation of the Agency's detailed design specifications and the design of treatment trains.

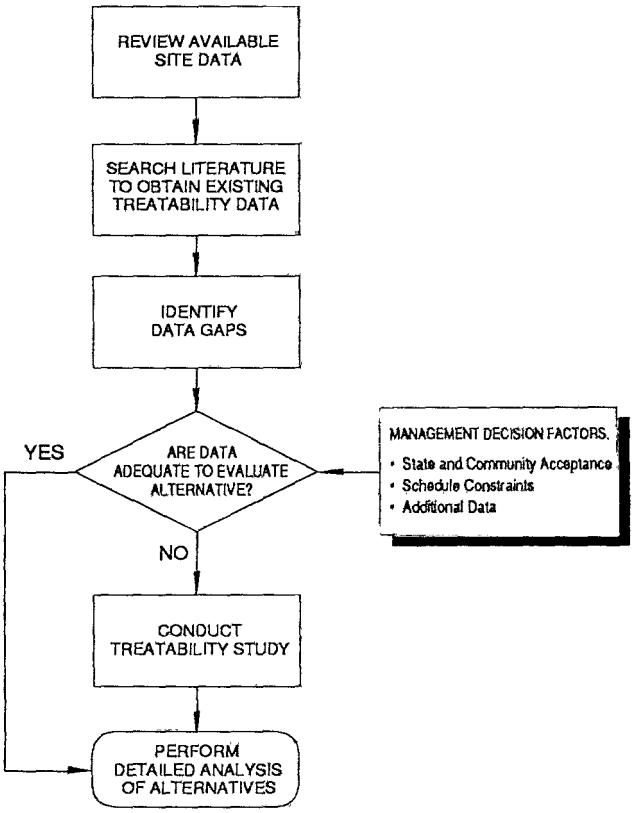


Figure 1. Decision tree showing when treatability studies are needed to support the evaluation and selection of an alternative

The need for RD/RA treatability studies may be identified by the RPM, the PRP, or the remedial designer Alternative Remedial Contracts Strategy (ARCS) contractor or U.S. Army Corps of Engineers (COE). Because the designer is ultimately responsible for the remedial design, the designer should carefully review the available site-, technology-, and waste-specific treatability data before deciding on whether an RD/RA treatability study will be needed.

Vendor/Process Prequalification

In general, a single remedy is selected in the ROD. The remedy is often identified as a technology class or family (e.g., thermal destruction) rather than as a specific process option (e.g., a rotary kiln). Selection of a treatment class affords flexibility during the remedial design to procure the most cost-effective vendor and process.

One method of selecting an appropriate vendor or process is to use RD/RA treatability study results to "prequalify" a pool of vendors. In these studies, all interested parties are

provided with a standard sample of waste. Each vendor designs and performs a treatability study based on that sample and provides treatment results to the lead agency. The lead agency uses these results to determine which vendors are qualified to bid on the RA. Generally, the vendor should achieve results equivalent to the cleanup criteria defined in the ROD to be considered for prequalification.

This prequalification approach has been used at the Selma Treating Company Superfund Site, Region 9, Selma, California. Part 9 of the Federal Acquisition Regulations (FAR) describes policies, standards, and procedures applicable to this approach.

Contingency RODs

There are situations in which additional flexibility in the ROD may be required to ensure implementation of the most appropriate technology for a site. In these cases, the selected remedy may be accompanied by a proven contingency remedy in a Contingency ROD. The Contingency ROD option was developed for two purposes: 1) to promote the use of innovative technologies, and 2) to allow different technologies offering comparable performance to be carried through to remedial design.

Although treatability studies of an innovative technology will be conducted during the RI/FS to support remedy selection, it may not be feasible to conduct sufficient testing to address all of the significant uncertainties associated with the implementation of this option. This situation, however, should not cause the option to be screened out during the detailed analysis of alternatives in the FS. If the performance potential of an innovative technology indicates this technology would provide the best balance of tradeoffs from among the options considered despite its uncertainties, CERCLA Section 121(b)(2) provides support for selecting such a technology in the ROD. Implementation of the technology, however, may be contingent upon the results of RD/RA treatability testing. When an innovative technology is selected and its performance is to be verified through additional treatability testing, a proven treatment technology may also be included in the ROD as a contingency remedy. In the event the RD/RA treatability study results indicate that the full-scale innovative remedy cannot achieve the cleanup goals at the site, the contingency remedy could then be implemented.

If two different technologies for treatment of the same contaminant/matrix emerge from the FS and each offers comparable performance with respect to the five primary balancing criteria so that either one could provide the best balance of tradeoffs, one of the alternatives may be named in the ROD as the selected remedy and the other as the contingency remedy. Based on the results of post-ROD RD/RA treatability testing, the most appropriate remedy can then be identified and implemented.

Detailed Design Specifications

To support the remedial action bid package, the lead agency may choose to develop detailed design specifications. If technical data available from the RI/FS are insufficient for design of the remedy, an RD/RA treatability study may be necessary. Post-ROD treatability studies can provide the detailed cost and performance data required for optimization of the treatment processes and the design of a full-scale treatment system.

If an RD/RA treatability study is required to support the detailed design specifications, the designer will be responsible for planning the study and defining the performance goals and objectives. Treatability study oversight will be provided by the RPM and the Oversight Assistant.

Post-ROD RD/RA treatability studies can also be performed to support the design of treatment trains. Although all parts of a treatment train may be effective for treating the wastes, matrices, and residuals of concern, issues such as unit sizing, materials handling, and systems integration must also be addressed. Treatability studies of one unit's operations can assist in identifying characteristics of the treated material that may need to be taken into consideration in the design of later units. A treatability study of the entire train can then provide data to confirm compliance with ARARs and the cleanup criteria outlined in the ROD. Because a treatment train will often involve several different technologies and vendors, the designer will coordinate treatability testing of the entire system and prepare the final treatability study report.

2.2 Three-Tiered Approach to Treatability Testing

Treatability studies are laboratory or field tests designed to provide critical data needed to evaluate and implement remedial treatment technologies at waste sites. As an aid in the planning and performance of cost-effective, on-time, scientifically sound treatability studies, a three tiered approach has been developed. The three-tiered approach applies to all treatability studies conducted in

support of Superfund site remediation. Figure 2 presents the treatability tiers and their conceptual relationship to the RI/FS and the RD/RA processes. Table 1 lists general similarities and differences among the three tiers.

2.2.1 Technology Presscreening and Treatability Study Scoping

Prescreening is an important first step in the identification of potentially applicable treatment technologies and the need for treatability testing. Because or the strict time schedules and budget constraints placed on the completion of an RI/FS, it is crucial for the planning and scoping of treatability studies to begin as early as possible. As shown in Figure 2, these efforts should be initiated during the RI/FS scoping.

Technology prescreening and treatability study scoping will include searching technology literature and treatability data bases, consulting with technology experts, determining data needs, identifying potential treatability study sources or contractors, identifying preliminary data quality objectives, and preparing a work assignment. Determination of the tier or tiers of treatability testing to be conducted will be based on the technology- and contaminant-specific data needs.

Technology experts are available within EPA to assist project managers with technology prescreening and treatability study scoping. (In-house consultation services available to EPA project managers are discussed in Subsection 3.3; additional information is presented in Appendix A.) Early consultation may save time and money by preventing the treatability testing of inappropriate technologies.

2.2.2 Remedy Screening

Remedy screening, the first step in the tiered approach, provides the gross performance data needed to determine the potential feasibility of the technology for treating the contaminants and matrix of concern. Remedy-screening treatability studies may not be necessary when the literature contains adequate data for an assessment of the feasibility of a technology. The results of a remedy-screening study are used to determine whether additional, more-detailed treatability testing should be performed at the remedy-selection tier.

Feasibility is determined by assessing how well a technology achieves the treatability study's performance goals, which are based on available knowledge of the operable unit's cleanup criteria and are set prior to the study. Typically, remedy-screening studies are conducted under conditions representative of those in the proposed full-scale system. If a technology cannot achieve the predetermined performance goals under these conditions, it should be screened out. If all technologies are rejected, the project manager should reevaluate the screening performance goals to determine if they are appropriate.

As shown in Figure 2, remedy-screening treatability studies are initiated during the pre-ROD site characterization and technology screening activities and may continue through the identification of alternatives. General characteristics of the remedy-screening tier (outlined in Table 1) are discussed here.

Study Scale

Performed in the laboratory, remedy-screening treatability studies are limited in size and scope to bench-scale tests with off-the-shelf equipment. Investigations of some technologies may require additional small-scale field tests at the screening tier.

Type of Data Generated

Remedy-screening studies provide qualitative data for use in assessing the potential feasibility of a technology for

Table 1. General Comparison of Remedy-Screening, Remedy-Selection, and RD/RA Treatability Studies

Tier	Study scale	Type of data generated	No. of replicates	Process type	Waste stream volume	Time required[a]	Cost, $
Remedy screening	Bench scale	Qualitative	Single/ duplicate	Batch	Small	Days	10,000-50,000
Remedy selection	Bench or pilot scale	Quantitative	Duplicate/ triplicate	Batch or continuous	Medium	Days/ weeks	50,000-100,000
	Pilot or full scale (onsite or offsite)	Quantitative	Duplicate/ triplicate	Batch or continuous	Large	Weeks/ months	50,000-250,000
RD/RA	Full scale (onsite)	Quantitative	Duplicate/ triplicate	Batch or continuous	Large	Weeks/ months	250,000-1,000,000

[a]Indicates duration of testing only.

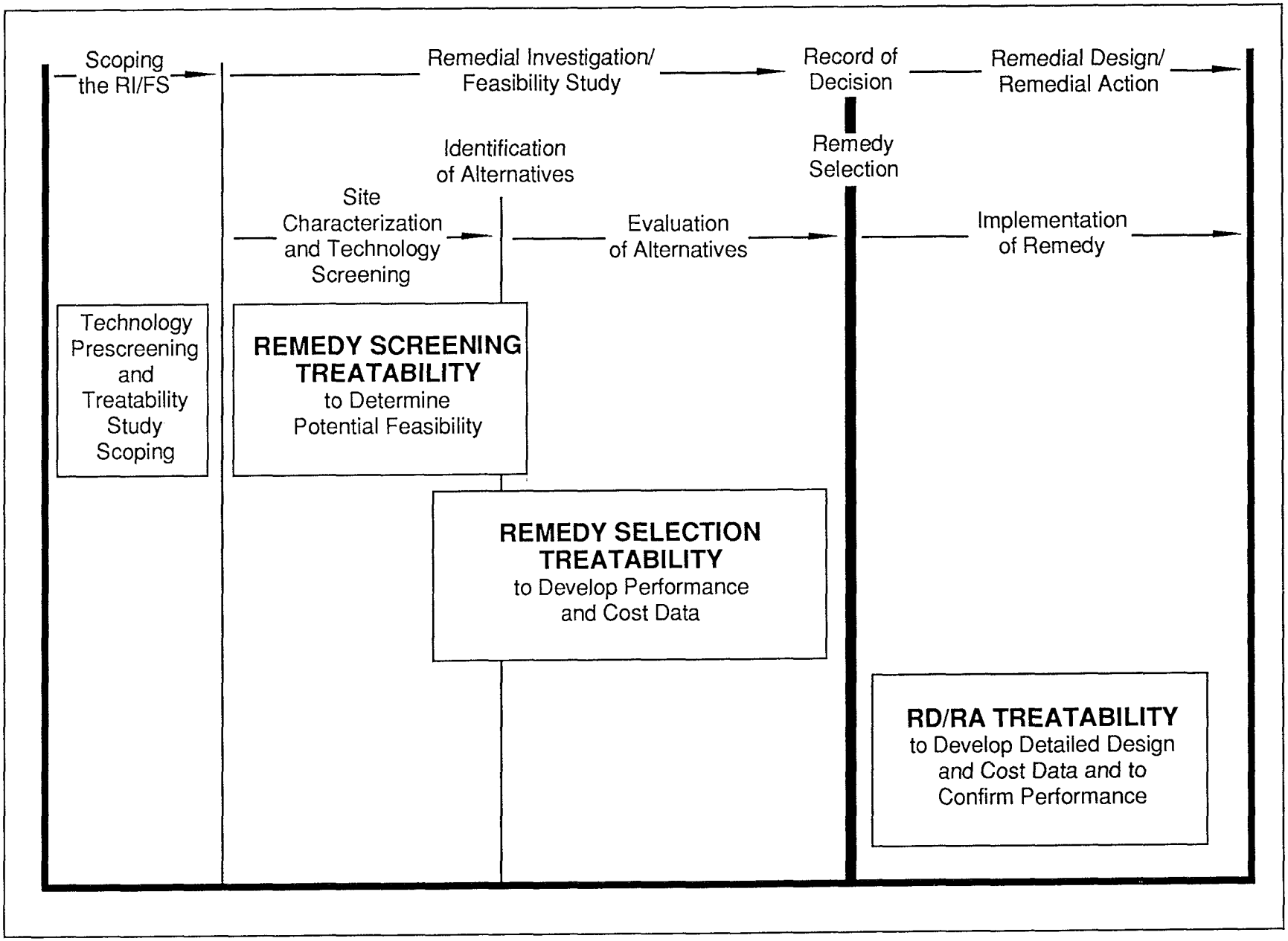


Figure 2. The role of treatability studies in the RI/FS and RD/RA process.

treating a contaminant/matrix combination. No cost or design information will be generated. The project manager must determine the overall qualitative data needs based on the intended use of the information and the availability of time and funds.

During remedy screening, a single indicator contaminant is often monitored to determine whether a reduction in toxicity, mobility, or volume is occurring. If a technology appears to meet or exceed the performance goal for that contaminant, it is considered potentially feasible and retained for further evaluation. Remedy screening is also useful for identifying critical parameters for investigation at the remedy-selection tier.

Number of Replicates

In most cases, little or no test sample replication (single or duplicate) is required at the screening tier. A less stringent level of quality assurance/quality control (QA/QC) is sufficient because a technology that is found to be feasible must still undergo remedy-selection testing before it is selected in the ROD.

Process Type/Waste Stream Volume

Screening will generally involve batch tests and the use of small-volume samples of the waste stream. For example, remedy screening of an ion exchange process designed to treat aqueous wastes may require sample volumes on the order of 500 milliliters per run with only three runs through the test column.

Time/Cost

The duration and cost of remedy screening depend primarily on the type of technology being investigated and the number of parameters considered. Generally, remedy screening can be performed in a few days at a cost of between $10,000 and $50,000. This estimate of duration covers the time spent in the testing laboratory; it does not include sample analysis or data validation, as these elements depend on the analytical laboratory used. Neither does it include the time required for study planning and reporting. The cost estimate does include all of these elements, however.

The nature of remedy screening (i.e., simple equipment, small number of test samples and replicates, less-stringent QA/QC requirements, and minimum reporting requirements) makes it the least costly and time-consuming of the three treatability study tiers. Cost and time savings are increased by limiting sampling and analysis objectives to address only indicator contaminants that are representative of the families of chemicals present and their concentrations.

2.2.3 Remedy-Selection Testing

Remedy selection is the second step in the tiered approach. A remedy-selection treatability study is designed to verify whether a process option can meet the operable unit's cleanup criteria and at what cost. The purpose of this tier is to generate the critical performance and cost data necessary for remedy evaluation in the detailed analysis of alternatives during the FS.

After the feasibility of a treatment alternative has been demonstrated, either through remedy-screening studies or a literature review, process operating parameters are investigated at the remedy-selection tier. The choice of parameters to be studied is based on the goal of achieving the operable unit's cleanup criteria and other waste-specific performance goals. Investigation of equipment-specific parameters should generally be delayed until post-ROD RD/RA studies.

Results of remedy-selection treatability studies also should allow for estimating the costs associated with full-scale implementation of the alternative within an accuracy of +50/-30 percent, as required for the FS.

As shown in Figure 2, remedy-selection treatability studies are initiated during the pre-ROD site characterization and technology screening activities and continue through the evaluation of alternatives. General characteristics of the remedy-selection tier (outlined in Table 1) are discussed here.

Study Scale

Remedy-selection treatability studies are performed in the laboratory or field with bench-, pilot-, or full-scale equipment. The scale of equipment used is often technology specific, and it will also depend on the availability of funds and time and the data needs. Equipment should be designed to simulate the basic operations of the full-scale treatment process. Combinations of bench and field testing are also possible at this tier.

Type of Data Generated

Remedy-selection studies provide quantitative data for use in determining whether a technology can meet the operable unit's cleanup criteria and at what cost. The operational and performance information resulting from remedy-selection studies will be used to estimate full-scale treatment costs and schedules and to assess the technology against the RI/FS evaluation criteria.

For example, bench-scale remedy-selection studies of some technologies can provide the detailed performance data

needed to assess the technology against the reduction of toxicity, mobility, or volume criterion. Pilot-scale testing may identify waste-stream characteristics that could adversely affect the implementability of a technology. Treatment train considerations, such as the need for further processing of treated waste or treatment residuals, can also be addressed at this tier.

When planning remedy-selection treatability studies, the project manager, in consultation with management, must determine the overall quantitative data needs for a technology based on the intended use of the information and the availability of time and funds. Early consultation with technology experts and vendors is important when determining data needs for innovative and proprietary technologies.

Number of Replicates

Remedy-selection treatability studies require duplicate or triplicate test sample replication. Because the data generated at this tier will be used for remedy selection in the ROD, moderately to highly stringent levels of QA/QC are required. A stringent level of QA/QC is needed to increase the confidence in the decision that the selected remedy can achieve the cleanup goals for the site.

Process Type/Waste Stream Volume

Remedy-selection treatability studies may be conducted as either a batch or a continuous process. Waste-stream sample volumes should be adequate to simulate full-scale operations. For example, the waste-stream volume needed to perform continuous, bench-scale testing of an ion exchange treatment process for an aqueous waste may be on the order of 1 liter per minute for a treatment duration of 8 hours (which would require approximately 500 liters of waste). Waste-handling operations, such as pretreatment blending, also should be designed to simulate those expected for full-scale treatment.

Time/Cost

The duration and cost of remedy-selection testing depend primarily on the type of technology being investigated, the types of analyses being performed, and the level of QA/QC required. Most bench-scale studies can be performed within a period of days to weeks. Pilot-scale testing usually requires a longer period (i.e., weeks to months). This estimate covers only the actual performance of the test. It does not include sample analysis or data validation, as these elements depend on the analytical laboratory used; nor does it include study planning and reporting. Depending on its scale and complexity, a remedy-selection treatability study can be performed at a cost of between $50,000 and $250,000, including analytical support.

The higher cost and longer time requirements of remedy-selection treatability testing compared with remedy screening are directly related to the need for stringent QA/QC and the greater number of test samples and replicates to be analyzed.

2.2.4 RD/RA Testing

Treatability testing to support RD/RA activities is the final step in the three-tiered approach. The purpose of an RD/ RA treatability study is to generate the detailed design, cost, and performance data necessary to optimize and implement the selected remedy. As shown in Figure 2, RD/RA treatability studies are conducted after the ROD has been signed. These studies are performed 1) to select among multiple vendors and processes within a prescribed remedy (pre-qualification), 2) to implement the most appropriate of the remedies prescribed in a Contingency ROD, and 3) to support the Agency's detailed design specifications (if prepared) and the design of treatment trains. Most RD/RA treatability studies are performed by remediation contractors and technology vendors. The EPA RPM monitors the performance of these studies and reviews the results to assess their acceptability with regard to the ROD, RA goals, and, if applicable, the settlement agreement. General characteristics of the RD/RA tier (outlined in Table 1) are discussed here.

Study Scale

Most RD/RA treatability studies are performed in the field with pilot- or full-scale equipment. Some prequalification treatability studies will be performed in the laboratory; however, the system should closely approximate the proposed full-scale operations.

Type of Data Generated

Remedial design/remedial action treatability studies provide the detailed, quantitative design and cost data required to optimize critical parameters and to implement the selected remedy. The following are issues that may be addressed with RD/RA study data:

- Full-scale performance
- Treatment train performance
- Materials-handling characteristics
- Process upset and recovery

- Side-stream and residuals generation and treatment
- Energy and reagent usage
- Site-specific considerations, such as heavy equipment access and waste-feed staging space
- Field-screening analytical methods

The parameters investigated at the RD/RA tier may include feed rates (continuous processes), number of treatment cycles (batch processes), mixing rates, heating rates, and other eqnipment-specific parameters. Remedial design/ remedial action testing also may identify waste-stream characteristics that could adversely affect the implementability of the full-scale system.

When planning RD/RA treatability studies, the technology vendor, in consultation with the designer and the lead agency, must determine the overall quantitative data needs for a technology based on the intended use of the information. Early consultation with vendors is important in the determination of data needs for proprietary technologies.

Number of Replicates

Remedial design/remedial action treatability studies usually require duplicate or triplicate test sample replication. The data generated at this tier are used to design and optimize the process; therefore, stringent levels of QA/QC are required.

In the case of prequalification treatability studies, QA/QC requirements will be determined by the designer. The number and types of samples to be submitted by vendors will be outlined in the designer's prequalification announcement.

Process Type/Waste-Stream Volume

Remedial design/remedial action treatability studies may be conducted as either a batch or a continuous process, depending on the operation of the full-scale system. Waste-stream sample throughput and volume should achieve levels projected for full-scale operations. For example, the waste-stream sample volume needed to perform continuous, full-scale testing of an ion exchange treatment process for an aqueous waste may be on the order of 25 liters per minute for a treatment duration of 16 hours per day for 21 days (which would require more than 500,000 liters of waste).

Time/Cost

Because of the potentially significant mobilization requirements associated with any onsite operation, performing RD/RA treatability studies is significantly more time-consuming and costly than pre-ROD studies. The duration and cost depend primarily on the type of technology being investigated, the types of analyses being performed, and the level of QA/QC required. Most RD/RA studies can be performed within a period of weeks to months. This estimate covers only the actual performance of the test. It does not include the time required for mobilization, construction, shakedown, or demobilization of the unit, as these procedures are specific to the site and to the technology being tested; sample analysis or data validation, as these elements depend on the analytical laboratory used; or study planning and reporting. Most RD/RA treatability studies can be performed at a cost of between $250,000 and $1,000,000.

Prequalification treatability testing is an exception to these time and cost estimates because the tests are performed at the vendors' cost. Analytical support, however, is usually provided by the Agency.

2.3 Applying the Tiered Approach

The purpose of a pre-ROD treatability investigation is to generate data needed for a detailed analysis of the alternatives and, ultimately, the selection of a remedial action that can achieve the operable unit's cleanup criteria. Pre-ROD treatability studies are performed to enable the decision maker to evaluate all treatment and nontreatment alternatives on an equal basis.

The need for pre-ROD treatability testing at a Superfund site is a risk-management decision in which the cost and time required to conduct treatability studies are weighed against the risks inherent in the selection of a remedial technology. Factors in this decision are specific to the waste matrix, waste contaminants, and treatment technology. Determining whether pre-ROD treatability studies should be conducted may also depend on such nontechnical factors as State and community acceptance of an alternative; time constraints on the completion of the RI/FS and the ROD; and the discovery of new operable unit-, waste-, or technology-based data that may have an impact on treatment performance.

Of the management decision factors listed, schedule constraints may be of the most consequence. The performance of pre-ROD treatability studies that were planned and scheduled early (i.e., during the scoping of the RI/FS) generally should not delay the ROD. In some instances, however, the need for treatability studies may conflict with RI/FS and ROD schedule commitments. For example, if an innovative technology is being considered as part of an alterna-

tive, significant gaps in the technical literature may lengthen the time required to plan and perform a thorough treatability investigation. When the potential benefits of the innovative technology are known, pursuing the treatability study at the expense of ROD scheduling goals may be appropriate. The EPA's *Guidance for Increasing the Application of Innovative Treatment Technologies for Contaminated Soil and Ground Water* (EPA 1991a) and its cover memorandum indicate the Agency's willingness to adjust program goals and commitments, when appropriate, to achieve better cleanup solutions through innovative treatment technology development.

The flow diagram in Figure 3 traces the stepwise data reviews and management decisions that occur in the tiered approach. Site characterization and technology prescreening/treatability study scoping initiate the process. Technologies that are determined to be potentially applicable (based on effectiveness, implementability, and cost) are retained as alternatives; all others are screened out. The decision to conduct a treatability study on an alternative is based on the availability of technology-specific treatability information and on inputs from management. If a treatment technology is well demonstrated for the particular contaminants/matrix and sufficient information exists to permit its evaluation against the nine evaluation criteria in the detailed analysis of alternatives, a pre-ROD treatability study is not required.

If significant questions remain about the feasibility of a technology for remediating an operable unit, a remedy-screening treatability study should be performed. Innovative technologies or wastes that have not been extensively investigated should almost always be subjected to treatability testing at this tier. If a technology has been shown to be effective at treating the contaminants/matrix of concern but insufficient information exists for detailed analysis, the remedy-screening tier may be bypassed in favor of a remedy-selection treatability study. If a remedy-selection study indicates that a technology can meet the cleanup criteria, a detailed analysis of this alternative should then be performed. If the alternative is selected in the ROD, a post-ROD RD/RA treatability study may be required to design and optimize the full-scale system, to obtain detailed cost data, and to confirm performance.

2.4 Treatability Study Test Objectives

Each tier of treatability testing is defined by its particular purpose: remedy screening, to determine potential feasibility; remedy selection, to develop performance and cost data; and RD/RA, to develop detailed design and cost data and to confirm full-scale performance. For achievement of these purposes, the planning and design of treatability studies must reflect specific, predetermined test objectives. Depending on the tier of testing, test objectives may call for making qualitative engineering assessments, achieving quantitative performance goals, or both. Because test objectives are technology-, matrix-, and contaminant-specific, setting universal objectives for each tier of testing is impossible.

Qualitative assessments of performance are often appropriate at the remedy-screening tier. Simply demonstrating a reduction in contaminant concentration, for example, may be sufficient to confirm the potential feasibility of using an innovative treatment technology. For other technologies, a quantitative performance goal such as 50 percent reduction in contaminant mobility might indicate the potential to achieve greater reduction through process refinements and thus confirm the feasibility of a process option and justify additional testing at the remedy-selection tier.

Test objectives at the remedy-selection tier will include achieving quantitative performance goals based on the anticipated cleanup criteria to be established in the ROD. For example, if the cleanup criterion for a contaminant in the soil at a site is 1 ppm, the performance goal for a remedy-selection treatability study might also be 1 ppm. If no cleanup criteria have been established for the site, a 90 percent reduction in the contaminant concentrations will generally be an appropriate performance goal. This level of performance is in agreement with EPA's guideline established in the 1990 revised NCP, which states that ". . . treatment as part of CERCLA remedies should generally achieve reductions of 90 to 99 percent in the concentration or mobility of individual contaminants of concern, although there will be situations where reductions outside the 90 to 99 percent range that achieve health-based or other site- specific remediation goals (corresponding to greater or lesser reductions) will be appropriate" (55 FR 8721). Additional guidelines upon which a project manager should base remedy-selection performance goals are as follows:

- Protection of human health and the environment
- Compliance With ARARs
- Attainment of contaminant levels acceptable for waste delisting
- Attainment of contaminant levels accepted by the State or Region at other sites with similar waste characteristics

Remedy-selection treatability studies will generally have additional pre-ROD test objectives designed to provide the specific cost and engineering information necessary for a detailed analysis of the alternative. Cost data should be

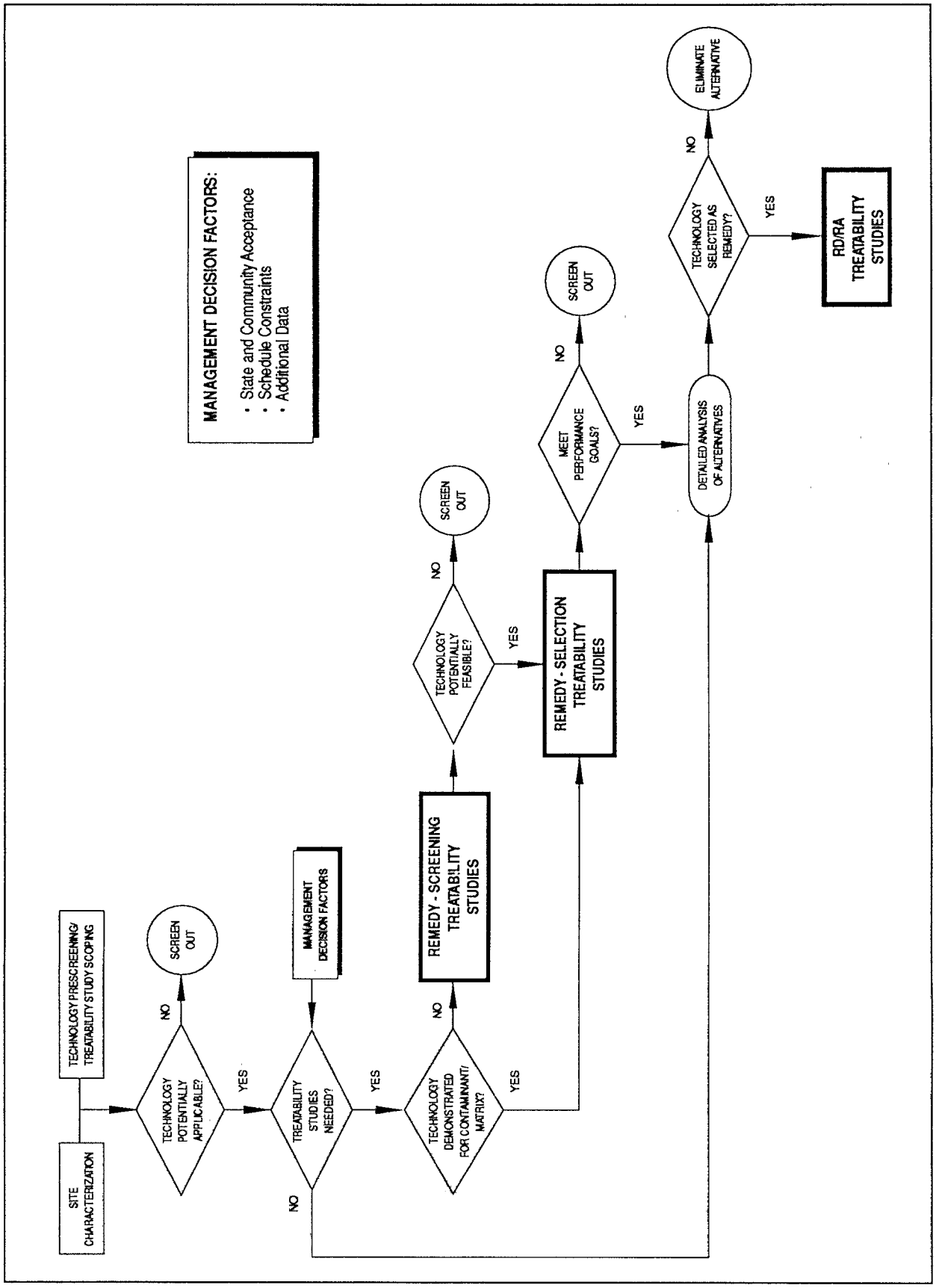


Figure 3. Flow diagram of the tiered approach.

sufficiently detailed to allow for the development of cost estimates with an accuracy of +50 to -30 percent.

Post-ROD test objectives depend on the nature of the treatability study. If a study is conducted to prequalify vendors, performance goals will be equivalent to the cleanup criteria defined in the ROD. Treatability studies conducted to select the most appropriate technology among those in a Contingency ROD will also have performance goals equivalent to the cleanup criteria. Additional test objectives may include investigation of materials-handling methods, confirmation of field-screening analytical techniques, and generation of detailed cost data. If an RD/RA treatability study is required to support the detailed design specifications, the designer will be responsible for defining the test objectives and performance goals. Test objectives will be focused on obtaining specific design data, optimizing performance, and minimizing cost. Treatment train issues such as unit sizing, materials handling, and systems integration can also be addressed through specific test objectives. A treatability study of an entire train can provide data to confirm compliance with ARARs and the cleanup criteria outlined in the ROD.

2.5 Special Issues

2.5.1 Innovative Treatment Technologies

One of the advantages of treatability testing is that it permits the collection of performance data on innovative treatment technologies. These newly developed technologies often lack sufficient full-scale application to be routinely considered for site remediation. Nevertheless, *Guidance for Increasing the Application of Innovative Treatment Technologies for Contaminated Soil and Ground Water* (EPA 1991a) states:

> "Innovative treatment technologies are to be routinely considered as an option in feasibility studies for remedial sites and engineering evaluations for removals in the Superfund program, where treatment is appropriate commensurate with the National Contingency Plan (NCP) expectations.... Innovative technologies considered in the remedy selection process for Superfund, RCRA, and UST should not be eliminated solely on the grounds that an absence of full-scale experience or treatability study data makes their operational performance and cost less certain than other forms of remediation.
>
> "When assessing innovative technologies, it is important to fully account for their benefits. Despite the fact that their costs may be greater than conventional options, innovative technologies may be found to be cost-effective, after accounting for such factors as increased protection, superior performance, and greater community acceptance. In addition, experience gained from the application of these solutions will help realize their potential benefits at other sites with similar contaminants."

Example 1 illustrates how treatability studies can be used to investigate innovative and conventional technologies concurrently on a single waste stream. Three innovative treatment technologies-thermal desorption, solvent extraction, and bioremediation-are investigated at various tiers. Decisions on testing are based on existing data in the literature and on prior treatability study results. Solidification/stabilization, a conventional option, is also tested because its performance for the particular waste stream was not established in the literature. This example reflects how treatability studies can be designed and tailored by the project manager to provide specific pieces of information required for remedy selection.

2.5.2 Treatment Trains

Treatment of a waste stream often results in residuals that require further treatment to reduce toxicity, mobility, or volume. Treatment technologies operated in series (treatment trains) can be used to provide complete treatment of a waste stream and any resulting residuals.

Treatment-train requirements for a waste stream may be evaluated by applying the tiered approach. Example 2 outlines a remedy-selection treatability study of a treatment train consisting of low-temperature volatilization followed by chemical treatment and solidification. The literature contains enough data concerning the individual unit operations to indicate that they are appropriate technologies for the specific contaminants. Treatability testing of these unit operations as a treatment train, however, is necessary to evaluate the most effective combination of operating parameters for treating the matrix.

2.5.3 In Situ Treatment Technologies

Testing of in situ treatment technologies during the RI/FS may entail remedy screening, bench-scale remedy-selection testing, and pilot-scale remedy-selection testing in the field. Remedy screening of in situ treatment technologies is conducted in the laboratory to determine process feasibility. Bench-scale testing is generally conducted in soil columns designed to simulate the subsurface environment. Field testing, however, is important for an adequate evalua-

EXAMPLE 1. TREATABILITY STUDIES OF MULTIPLE TECHNOLOGIES

Old Petroleum Refinery Site

Background

An old petroleum refinery site contained oily sludges and contaminated soils. The primary contaminants of concern were polynuclear aromatic hydrocarbons (PAHs), mainly benzo(a)pyrene. The literature survey identified five potentially applicable technologies for treating the hydrocarbon wastes: 1) incineration, 2) stabilization/solidification, 3) thermal desorption, 4) solvent extraction, and 5) bioremediation.

The literature survey also produced a significant amount of performance data for incineration and bioremediation. Because these data indicated that both technologies were valid for the types of wastes and contaminants of concern at the site, neither incineration nor bioremediation was evaluated at the remedy-screening tier.

Conversely, little data were found on thermal desorption, and the available performance data for solvent extraction and stabilization/solidification were inconclusive for hydrocarbon wastes. Therefore, these three technologies were evaluated at the remedy-screening tier to determine their feasibility for treatment of the site's wastes.

Remedy Screening

Samples of worst-case soils and sludges (most highly contaminated with PAHs) were collected for treatability studies of each technology. A performance goal of 90 percent reduction in the indicator contaminant benzo(a)pyrene was set.

Thermal desorption was evaluated at three temperatures. Solvent extraction was evaluated by using three solvents at two solution concentrations. Stabilization/solidification was evaluated by using organophilic clays at three mix ratios with 28-day curing. Benzo(a)pyrene concentration in duplicate samples of the untreated soil was determined by total waste analysis (EPA SW-846 Method 8270). Duplicate samples of the treated material from thermal desorption, solvent extraction, and stabilization/solidification (after sonication of the solidified monolith) were then analyzed for benzo(a)pyrene by the same method.

The results of the remedy screening showed that, of the three technologies, thermal desorption achieved the highest percentage removal of the indicator contaminant (greater than 95 percent). Solvent extraction showed a 90 percent removal efficiency. Stabilization/solidification, however, fixed only 50 percent of the contaminant. Thermal desorption and solvent extraction were thus retained for further analysis because both technologies achieved the screening performance goal.

Remedy-Selection Testing

Quantitative performance, implementability, and cost issues still remained unanswered after the remedy screening. Also, information from the literature on biodegradation rates and mechanisms for benzo(a)pyrene (the principal PAH of concern) was inconclusive. In addition, the anticipated cleanup criterion for benzo(a)pyrene in soils was very low (250 ppb). Therefore, thermal desorption, solvent extraction, and bioremediation were examined in bench-scale, remedy-selection testing. Performance goals were set at 250 ppb benzo(a)pyrene with a 95 percent data confidence level. Waste samples representing average and worst-case scenarios were tested, triplicate test samples were collected and analyzed, and several process variables were evaluated. After 6 months of testing, only low-temperature thermal treatment was found to meet the low cleanup levels required for benzo(a)pyrene.

Although thermal desorption was found to meet the cleanup requirements in bench-scale testing, this technology had not been previously demonstrated at full scale for similar contaminants and waste. Therefore, cost and design issues had to be addressed as part of the detailed analysis of alternatives. The RPM decided to conduct pilot-scale testing on thermal desorption and to compare the costs of constructing and operating the unit with those for incineration.

EXAMPLE 2. TREATABILITY STUDIES FOR TREATMENT TRAINS

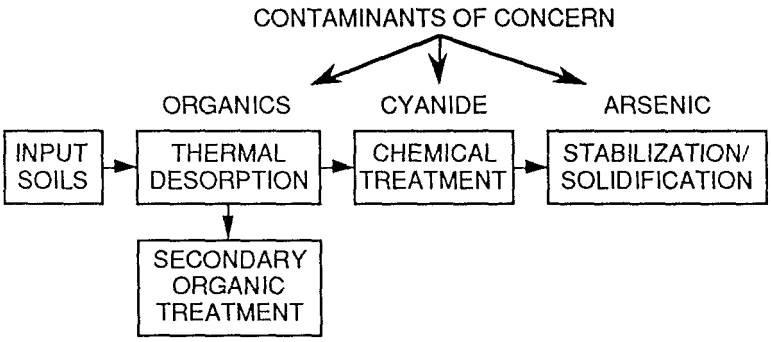
Former Chemical Manufacturing Company

Background

At a former chemical manufacturing company and current Superfund site, the contaminants of concern in the soils were dichloromethane, tetrachloroethene, benzene, polynuclear aromatic hydrocarbons (PAHs), cyanide, and arsenic. The cleanup criterion for each of these compounds had been identified. Both onsite treatment and offsite incineration were being considered as options for site remediation.

Remedy-Selection Testing

Remedy-selection testing of a treatment train to treat the contaminated soils on site was designed to include the following unit operations: 1) thermal desorption, 2) chemical treatment, and 3) stabilization/solidification. A schematic of the treatment train is presented below.



Schematic Representation of the Treatment Train

Bench-scale treatability testing of the treatment train was designed to meet the following three objectives:

- Objective 1 - Provide performance confirmation of the operation of the thermal desorption unit for removal of volatile and semivolatile organics. Determine the minimum operating conditions (temperature, residence time) necessary to achieve the site cleanup criteria. Determine the need for subsequent treatment units (chemical treatment, solidification).
- Objective 2 - Provide performance confirmation of the operation of the chemical treatment unit for destruction of cyanide. Determine the preferred reagent and dosage necessary to achieve the site cleanup criteria.
- Objective 3 - Provide performance confirmation of the operation of the stabilization/solidification unit for immobilization of arsenic. Determine the preferred binder and dosage necessary to achieve the site cleanup criteria.

Prior to initiating any treatability tests, the test plan called for the soil to be characterized for the following physical and chemical parameters:

- Moisture content
- Soil bulk density
- Grain size distribution
- Volatile and semivolatile organics
- Cyanide
- Arsenic (total and TCLP)

The remedy-selection testing consisted of the following three subtasks:

1) Perform bench-scale tests of thermal desorption at two temperatures (300 and 550EC) and three residence times (5, 15, and 30 minutes) to determine the efficacy of the unit for removal of

Example 2 (continued)

organics. Analyze the treated soil for the pollutants of concern (organics, cyanide, and arsenic). If cyanide is present in the soil residue at concentrations exceeding the cleanup criterion, continue with Subtask 2. Similarly, if arsenic is present, continue with Subtask 3. (This subtask addresses Objective 1.)

2) Perform bench-scale tests on the soil residue from the thermal desorption unit to investigate the effectiveness of hydrogen peroxide and hypochlorite for treatment of cyanide as a function of pH, the strength of solution, and the reagent-to-soil ratio. Analyze the treated soil for cyanide. (This subtask addresses Objective 2.)

3) Perform bench-scale tests of stabilization/solidification to immobilize arsenic in the soil residue from chemical treatment (if cyanide was present) or thermal desorption (if cyanide was not present) using three binders (portland cement, lime/fly ash, and fly ash/kiln dust) at two binder-to-soil ratios (0.20 and 0.50). Determine the unconfined compressive strength of the solid monolith. Extract the crushed solid in accordance with the toxicity characteristic leaching procedure and analyze the leachate for arsenic. (This subtask addresses Objective 3.)

Data from the remedy-selection treatability tests were used 1) to determine if the proposed treatment train could achieve the test objective of reducing all contaminant concentrations to the site cleanup criteria, and 2) to provide a preliminary basis for estimating the costs of full-scale remediation.

tion of in situ treatment. Because of the unique difficulties associated with simulating in situ conditions and monitoring the effectiveness of in situ treatment in the laboratory, field testing often may be the only way to obtain the critical information needed for the detailed analysis of alternatives during the FS. Example 3 demonstrates how the tiered approach may be applied to evaluate in situ soil flushing.

2.5.4 Generic Vs. Vendor Treatability Studies

When planning a treatability study, the project manager must determine whether results from treatability tests in which widely available chemicals and processes are used ("generic" studies) will be as useful as vendor-conducted tests involving the use of proprietary chemical reagents and treatment systems ("vendor" studies).

Because generic treatability studies eliminate the need for establishing contracts and schedules with a specific vendor, they can often be performed quickly and inexpensively; however, they may not always provide an adequate evaluation of a technology. For example, a generic treatability study may fail to meet site cleanup goals that could have been achieved by an experienced technology vendor using proprietary processes and equipment developed through years of research.

Generally, remedy-scrcening treatability studies can be performed generically because quantitative performance data are not required. Vendor-specific equipment or experience are often required, however, at the remedy-selection tier to assure the generation of high-quality quantitative data and the best performance of the technology. Remedial design/remedial action treatability studies should generally be performed in consultation with technology vendors. Tables 2 and 3 were adapted from tables developed by personnel at the U.S. EPA's Risk Reduction Engineering Laboratory (RREL) to provide general technology-specific guidance on this issue (dePercin, Bates, and Smith 1991). Information in these tables should not be used without consideration being given to site-specific contaminant and matrix treatability data.

Under 48 CFR Section 1536.209 of the Federal Acquisition Regulations, subcontractors performing treatability studies in support of remedy selection or remedy design are not prohibited from being awarded a contract on the construction of the remedy (55 FR 49283). For prime contractors performing treatability studies, however, approval by the Responsible Associate Director in the EPA Procurement and Contracts Management Division may be necessary before they can be awarded the construction contract. In reviewing requests for approval, EPA will take into account its policy of promoting the use of innovative technologies in the Superfund program.

2.5.5 PRP-led Pre-ROD Treatability Studies

Pre-ROD treatability studies may be conducted by potentially responsible parties with EPA oversight to evaluate PRP-proposed alternatives at enforcement-led sites. The steps involved in a PRP-led Study include performing a

EXAMPLE 3. TREATABILITY STUDIES FOR IN SITU TREATMENT TECHNOLOGIES

In Situ Soil Flushing

Background

An estimated 80,000 cubic meters of soil contaminated with chlorinated phenols, semivolatile organics, sulfur-containing compounds, and lead at an industrial facility requires corrective action. In situ soil flushing has been proposed as an alternative treatment technology. A two-tiered treatability study has been designed to evaluate its effectiveness.

Remedy Screening

Remedy screening will be performed to evaluate the effectiveness of various flushing reagents for enhancing the removal of the contaminants. A performance objective of 90 percent or greater reduction was set for evaluation of flushing reagent feasibility. Any reagent that achieves this level of contaminant reduction for each target contaminant will be evaluated at the remedy-selection tier. All others will be screened out. (Analyses of all samples for all site-specific contaminants will not be economically feasible; therefore, target compounds, each representative of a class of compounds present at the site, will be identified.)

The following general testing procedure will be used:

1) Analyze untreated soil samples for target compounds.
2) Place a known mass of soil in a small glass bottle. Add a measured volume of flushing reagent. Shake for a set period of hours. Centrifuge the mixture.
3) Analyze the supernatant liquid phase for target contaminants.
4) Analyze the treated soil phase for target contaminants.

Remedy-Selection Testing

Bench Scale

All flushing reagents identified as feasible during the remedy-screening treatability study will be evaluated in a bench-scale column test. The performance objective of this tier is to achieve contaminant reduction levels equal to the anticipated site cleanup criteria.
The following general testing procedure will be used:

1) Analyze untreated soil samples for target compounds.
2) Pack a large glass column with untreated soil to approximate the actual density of soil in the contaminated area. Introduce the soil-flushing solution into the top of the column.
3) Collect the column leachate at regular intervals (e.g., daily) and analyze for target contaminants.
4) Terminate the column test when the contaminant concentrations in the leachate remain the same for three consecutive leaching periods. Remove representative samples of the treated soil from the glass column and analyze them for target contaminants.

All flushing reagents that reduce the target contaminant concentrations in the soil to the site cleanup levels will be evaluated in the field.

Pilot Scale

The twofold purpose of this field pilot-scale treatability study is to evaluate the hydraulics of the treatment process under site conditions and to verify reagent performance under site conditions. The field test will yield site-specific flow, injection, and capture rates for the flushing system. These rates must be established to quantify the total time necessary for site-wide treatment and to estimate full-scale treatment costs. These and other data will be used in the detailed analysis of alternatives.

The field treatability study will involve the following tasks:

1) Prepare a treatment cell. Install an interception trench.
2) Install the irrigation and soil-flushing system.
3) Collect the cell leachate at regular intervals and analyze for all contaminants of interest.
4) Terminate the field test when the target contaminant concentrations in the leachate remain the same for three consecutive leaching periods. Remove representative samples of the treated soil from the cell and analyze them for all contaminants of interest.

Table 2. Aqueous Field Treatability Studies: Generic Versus Vendor Processes[a]

Treatment technology	Remedy screening	Remedy selection	RD/RA
Physical			
Oil/water separation	NA	G	G
Sedimentation	NA	G	G
Filtration	NA	G	G
Solvent extraction	G	G/V	G/V
Distillation	G	G	G/V
Air/steam stripping	G	G	G/V
Carbon adsorption	G	G	G
Ion exchange	G	G	G/V
Reverse osmosis	G	G/V	V
Ultra filtration	G	V	V
Chemical			
Neutralization	NA	G	G
Precipitation	G	G	G
Oxidation	G	G	G
Reduction	G	G	G
Dehalogenation	G	G/V	V
Thermal			
Incineration	G	G/V	V
Biological			
Suspended growth systems			
Aerobic	G	G	G
Anaerobic	G	G	G/V
Fixed growth systems			
Aerobic	G	G/V	G/V
Anaerobic	G	G/V	G/V
Constructed wetlands	G	G	G
Pact	G	G/V	V
In situ biological	NA	G	V

[a]G = Generic studies appropriate.
V = Vendor studies appropriate.
G/V = Generic and vendor studies appropriate.
NA = Not applicable at this tier.

literature search, submitting the Technical Memorandum identifying candidate technologies, designing the study, preparing the Project Plans (Work Plan, Sampling and Analysis Plan, and Health and Safety Plan), performing the test, analyzing the data, and preparing a final report on the results.

During the study, the EPA project manager will provide oversight and assistance. The EPA's *Guidance on Oversight of Potentially Responsible Party Remedial Investigations and Feasibility Studies* (EPA 1991b) recommends that the EPA project manager and the oversight assistant perform the following activities to oversee PRPs:

- Provide the PRPs with relevant guidance documents and sources of other technical information (Appendix A presents sources of treatability information).
- Review and approve the Technical Memorandum prepared by the PRP that identifies candidate treatment technologies and describes the literature search.
- Meet with the oversight assistant, the Technical Support Team (TST), and representatives from ORD to review the list of candidate technologies. Innovative treatment technologies should be adequately represented. Decisions on the need for treatability studies should be made for each technology.
- Review and approve the PRP's schedule of treatability activities.

Table 3. Soils/Sludges Field Treatability Studies: Generic Versus Vendor Processes[a]

Treatment technology	Remedy screening	Remedy selection	RD/RA
Physical			
Oil/water separation	G	G	V
Sedimentation	G	G	V
Filtration	G	G	V
Solvent extraction	G/V	V	V
Soil washing	G	G/V	V
Vacuum extraction	G	V	V
Distillation	G	G	V
Air/steam stripping	G	G/V	V
Thermal stripping	G	V	V
Carbon adsorption	G	G/V	V
Ion exchange	G/V	V	V
Chemical			
Neutralization	G	G	V
Precipitation	G	G/V	V
UV photolysis	G	V	V
Ozonation	G	G/V	V
Oxidation	G	V	V
Reduction	G	V	V
Dehalogenation	G/V	V	V
Thermal			
Incineration	G	G/V	G/V
Biological			
In situ treatment	G	G	V
Composting	G/V	G/V	G/V
Stabilization			
Pozzolanic for inorganics	G	G/V	V
Pozzolanic for organics	V	V	V
Asphalt	G	V	V
Polymerization	V	V	V
Vitrification	G/V	V	V
Material handling			
Screening	NA	G	G/V
Conveying	NA	G	G/V

[a]G = Generic studies appropriate.
V = Vendor studies appropriate.
G/V = Generic and vendor studies appropriate.
NA = Not applicable at this tier.

- Revise and amend the original PRP Project Plans to address the treatability study work to be performed.
- Verify the qualifications of all personnel involved in the test, including the PRP, the PRP's contractor, and the analytical laboratory. In addition, the EPA project manager should verify that the PRP laboratory protocols conform to EPA standards.
- Verify the test objectives and performance goals of each study.
- Conduct a site visit during the initial stages of a study.
- Collect and analyze split samples before and after treatment.
- Review and validate the data generated by each study.
- Monitor compliance with ARARs.
- Review and approve the draft PRP Treatability Study Evaluation Report with input and comments from the TST, ORD, other support staff, and the State. (The report should be prepared in the standard format presented in Subsection 3.12.)
- Continually update the Administrative Record File and cost recovery documentation.

Conduct of PRP-led treatability studies will be based on the language of the Administrative Order on Consent (AOC) and the Statement of Work (SOW). The model *Administrative Order on Consent for Remedial Investigation/Feasibility Study* (EPA 1991c) contains standard language for requiring PRPs to conduct Treatability studies. The *Model Statement of Work for a Remedial Investigation and Feasibility Study Conducted by Potentially Responsible Parties* (EPA 1989c) provides standard language for requiring PRPs to perform treatability studies in accordance with the RI/FS guidance. (Note: The Model SOW does not yet incorporate the treatability study terminology and guidance presented in this document. Until the Model SOW is updated, every effort should be made to require PRPs to conduct treatability studies in accordance with this guidance.)

2.5.6 Treatability Study Funding

The planning process for treatability studies should begin during the budget cycle in the year prior to the planned performance. The potential need for and scope of treatability studies should be identified and their costs estimated to ensure that adequate resources will be available. This information will be used to prepare the Region's Superfund Comprehensive Accomplishments Plan (SCAP).

Federally funded treatability studies performed in support of the RI/FS or the RD/RA are funded as a line item in the Region's "Other Remedial Account." Should treatability study funding requirements exceed planned allocations (because of the cost of the studies or the need for studies that were not planned for in the SCAP), the SCAP should be updated to reflect the necessary additional funding.

Funding for treatability studies is currently separate from RI/FS funding and is not included in the RI/FS target cost of $750,000. The Agency is considering a revision of this procedure based on the need to fund direct site work through a Site-Specific Allowance. This will facilitate efficient tracking of direct site costs.

SECTION 3
PROTOCOL FOR CONDUCTING TREATABILITY STUDIES

3.1 Introduction

Treatability studies should be performed in a systematic fashion to ensure that the data generated can support remedy selection and implementation. This section describes a general protocol for conducting treatability studies that EPA project managers, PRPs, and contractors should follow. The protocol includes:

- Establishing data quality objectives
- Identifying sources for treatability studies
- 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

These elements are described in detail in the remaining subsections. General information applicable to all treatability studies is presented first, followed by information specific to remedy screening, remedy-selection testing, and RD/RA testing.

Pre-ROD treatability studies for a particular site will often entail multiple tiers of testing, as described earlier in Subsection 2.3. Duplication of effort can be avoided by recognizing this possibility in the early planning stages of the project. The Work Assignment, Work Plan, and other supporting documents should include all expected activities. Generally, a single contractor should be retained to ensure continuity of the project as it moves from one tier to another.

3.2 Establishing Data Quality Objectives

Data quality objectives (DQOs) are qualitative and quantitative statements that specify the quality of the data required to support decisions concerning remedy selection and implementation. The end use of the treatability study data to be collected will detennine the appropriate DQOs. At all tiers of treatability testing, the establishment of DQOs will help to ensure that the data collected are of sufficient quality to substantiate the decision. Established DQOs are incorporated into the Work Plan, the study design, and the Sampling and Analysis Plan (SAP). Because treatability testing is used to help select and implement a site remedy, establishing DQOs is a critical initial step in the planning of treatability studies.

The quality and quantity of treatability data required for a study should correspond to the significance and ramifications of the decisions that will be based on these data. Limited QA/QC is generally required for remedy-screening data used to decide whether a treatment process is potentially feasible and warrants further consideration. More rigorous QA/QC is required for RD/RA testing when quantitative performance, design, and cost data will be used in the implementation of the selected remedy.

3.2.1 General

The guidance document *Data Quality Objectives for Remedial Response Activities* (EPA 1987a) defines the frame-

work and process by which DQOs are developed. This document (hereinafter referred to as the DQO guidance) focuses on site investigations during the RI/FS; however, the same framework and process may be applied to DQO development for treatability studies. The DQO guidance describes a process that includes the following three stages: 1) identification of decision types and study objectives, 2) identification of data uses/needs, and 3) design of the data-collection program. The three stages of DQO development summarized in Table 4 can be applied to each of the three tiers of testing. The stages provide a systematic process for development of the DQOs for treatability studies.

Stage 1

The type and magnitude of the decisions to be made are determined in Stage 1. Tasks include identifying the data users and coordinating their efforts for the establishment of the DQOs, evaluating existing data, developing a conceptual model, and specifying the test objectives (including performance goals) of the treatability study. Stage 1 efforts should result in the specification of the decision-making process and the identification of any new data needed and why. Stage 1 of the DQO process corresponds to technology prescreening and treatability study seeping as described in Subsection 2.2.1.

The data users will be those who rely on treatability results to support their decisions. They may include the RPM, the OSC, the PRP project manager, technical specialists, the State, enforcement personnel, U.S. Army Corps of Engineers, and others. Project review and audit personnel should be involved to help ensure the integrity of the QA program and compliance with program policy.

Stage 1 also includes a detailed evaluation of available information. Useful information may include site characterization data, technology-specific information, and previous treatability study data. Several factors should be considered in an evaluation of the quality of these data and their relevance to the DQO establishment process, including the age of the data, the analytical methods used, the detection limits of those methods, and the QA/QC procedures applied.

A conceptual model of the site and site conditions should be developed and included in Stage 1. A model may already have been developed for the site; if so, it should be adopted for use in the treatability study DQO development process.

Test objectives for the treatability study are determined in Stage 1. Identifying these objectives also entails identifying the problems to be solved (i.e., whether the study is needed to determine the potential feasibility of the technology or to confirm the attainment of a treatment standard). Test objectives will include achieving quantitative performance goals and collecting data to support qualitative engineering assessments and cost estimates.

Stage 2

During Stage 2, the data required to meet the test objectives specified in Stage 1 are determined, and the criteria for

Table 4. Summary of Three-Stage DQO Development Process

Stage 1
• Identify data users. • Consult appropriate data bases for relevant information. • Develop a conceptual model of the site. • Identify the treatability study test objectives and performance goals.
Stage 2
• Identify data uses. • Identify data types. • Identify data quality needs. • Identify data quantity needs. • Evaluate sampling and analysis options. • Review precision, accuracy, representativeness, completeness, and comparability parameters.
Stage 3
• Determine DQOs; select methods for obtaining data of acceptable quality and quantity. • Incorporate DQOs into the Work Plan and the SAP.

determining data adequacy are stipulated. Data must be of sufficient quality to determine whether the test objectives have been met.

Data types are identified by broad categories such as environmental media samples or source samples. Specifying data type by medium helps to identify overlapping data needs and analytical efforts.

Data quality and quantity are defined in Stage 2. The EPA's *Quality Assurance Procedures for RREL* (EPA 1989d) establish four quality assurance categories for use in research and development projects. Categories IV, III, and II are applicable to treatability studies. In general, QA Category IV applies to remedy-screening treatability studies, and QA Categories III and II apply to both remedy selection and RD/RA treatability studies. In determining the appropriate QA category, the decision maker must consider the intended use of the data and the risks associated with selecting an ineffective remedy based on the quality and quantity of the treatability data collected.

When the data quality needs for a project have been defined, confidence limits can be established for the data to be generated. Specific confidence limits have not been established for each treatability study tier. Rather, the intended use of the data and the limitations and costs of various analytical methods will assist the decision maker in defining appropriate confidence limits for the tier of testing being planned. Sampling and analysis options are reviewed in Stage 2 of the DQO development process. Issues to be considered during the review process include the data uses; data types; data quality needs; data quantity needs; precision, accuracy, representativeness, completeness, and comparability (PARCC) parameters (Table 5); analytical costs; and the time required for analysis.

The PARCC parameters are defined by the intended use of the data and are indicative of data quality. As the data quality and quantity needs increase, the PARCC parameter goals must rise. It is not practical to set universal PARCC goals for treatability testing because of the variability in sites, technologies, and contaminants.

Stage 3

Methods for obtaining data of acceptable quality and quantity are chosen and incorporated into the project Work Plan and SAP during Stage 3. The purpose of Stage 3 is to assemble the data collection components into a comprehensive data collection program. As data quality needs increase, the need for detailed goals and documentation components in the collection program will increase.

3.2.2 Remedy Screening

The DQOs established for remedy screening are usually stated in qualitative terms. Remedy screening provides a qualitative engineering assessment of the potential feasibility of a technology (i.e., go/no go. Therefore, QA Category IV usually provides data of sufficient quality for remedy screening. According to *Quality Assurance Procedures for RREL*, QA Category IV is designed to support basic research that may change direction several times in

Table 5. PARCC Parameters

Precision	A quantitative measure of the variability of a group of measurements, normally stated in terms of standard deviation, range, or relative percent difference. Precision is determined from analytical laboratory replicates (split samples) and test replicates (collocated samples).
Accuracy	A quantitative measure of the bias in a measurement system, normally stated in terms of percent recovery. Accuracy is determined by QC samples and matrix spikes with known concentrations.
Representativeness	A qualitative statement regarding the degree to which data accurately and precisely represent a population or condition. Representativeness is addressed by ensuring that sampling locations are selected properly and that a sufficient number of samples are collected.
Completeness	The percentage of the measurements that are judged to be valid. Regardless of the use of the data, a sufficient amount of the data generated should be valid.
Comparability	A qualitative statement regarding the confidence with which one data set can be compared with another. Comparability is achieved through the use of standard techniques to collect and analyze samples and to report results.

the course of testing. The PARCC requirements are therefore broadly defined in this category to permit flexibility during the actual testing. Confidence limits established for data derived from remedy screening are typically wide, in keeping with the characteristics of this tier (i.e., low cost, quick turnaround, and limited QA/QC). A minimum number of QC checks are required to assess accuracy and precision. Remedy screening does not require a significant amount of replication in the test samples and the analytical tests performed. The need for accuracy checks such as matrix spikes and blanks is also limited.

3.2.3 Remedy-Selection Testing

For remedy selection, DQOs are primarily quantitative in nature. For example, a performance goal for remedy-selection testing involving solvent extraction and chemical dehalogenation may be to reduce polychlorinated biphenyls (PCBs) to less than 30 ppm in soils (the target cleanup goal specified for the site). The data required to meet this quantitative goal are derived from detailed waste characterizadon and performance testing. These data will be used to select one of the technologies in the ROD.

Because data used in support of remedy selection must have a high level of confidence, QA Categories III or II are recommended for remedy-selection testing. These categories are designed to support the evaluation and selection of technologies. The PARCC parameters are therefore narrowly defined and test data are well documented. The selection of Category III (less stringent) or Category II (more stringent) for treatability testing depends on the intended use of the data and on time and cost constraints.

Narrow confidence limits are typically required at this tier. Quality control checks for accuracy and precision will be more thorough than for remedy screening. A significant amount of test sample and analytical sample replication will be required to determine accuracy and precision parameters. The representativeness of the data must be carefully documented, and a sufficient amount of the data generated should be judged valid. Standard sampling and analysis techniques should be used whenever possible to assure data comparability. The testing apparatus should be designed to generate enough treated material to support this QA program.

The need for detailed analyses and high-quality data at the remedy-selection tier will result in significantly higher analytical costs and longer turnaround times compared with those for remedy screening. These factors must be considered when establishing DQOs for remedy-selection treatability studies.

3.2.4 RD/RA Testing

The principal objective of RD/RA testing is to obtain quantitative performance, design, and cost data for use in the implementation of the selected remedial technology. Data quality objectives for RD/RA treatability studies are therefore primarily quantitative.

The need for design, cost, and performance information will dictate the frequency of sampling and testing, the required confidence limits, and the level of QA/QC. The uses for RD/RA treatability study data differ from those for remedy-selection data, but the required level of data quality will be the same or less. Therefore, QA Categories III or II are recommended for RD/RA testing.

In general, RD/RA testing will involve significant replication in test sampling (collecated samples) and laboratory analyses (split samples). Typically, PARCC parameters are narrowly defined and test data are well documented. Confidence limits will be similar to those for remedy-selection testing.

3.3 Identifying Sources for Treatability Studies

3.3.1 General

Once the decision to conduct a treatability study has been made and the scope of the project has been defined, the project manager must identify a qualified program contractor or technology vendor with the requisite technical capabilities and experience to perform the work. Treatability studies can be performed in house or via several contract mechanisms that exist for the rernedial and removal programs under CERCLA.

In-house Capabilities

In support of Superfund, EPA has created several programs and documents to assist EPA site managers in the performance of treatability studies. These include the Superfund Technical Assistance Response Team (START), the RREL Remedy-Screening Treatability Study Laboratory, the Environmental Response Team (ERT), and the Inventory of Treatability Study Vendors.

Superfund Technical Assistance Response Team. Site-specific, long-term assistance is available to project managers through START. Sponsored by ORD-RREL, the START program provides comprehensive engineering assistance from early RI/FS scoping through RA implementation at a limited number of sites. Sites are chosen by the

Regions for START support because of their complex contaminants and matrices.

Treatability support services available to project managers through START include:

- Identification of potentially applicable technology options
- Determination of need for treatability studies
- Performance of remedy-screening treatability studies
- Review of treatability study Project Plans
- Oversight of PRP-conducted treatability studies
- Review of PRP deliverables and final reports

Treatability support through the START program can be obtained by contacting the RREL Technical Support Branch in Cincinnati, Ohio.

RREL Remedy-Screening Treatability Study Laboratory. The RREL has developed a series of remedy-screening treatability tests. These protocols are designed to provide the Regions with inexpensive, preliminary assessments of the potential feasibility of a given technology for remediating contaminated soil. In-house testing can be performed for:

- Soil vapor extraction
- Solvent extraction
- Soil washing
- Soil flushing
- Biological degradation
- Chemical dehalogenation
- Solidification/stabilization
- Thermal desorption
- Incineration technologies

Regions can have these tests performed by contacting the RREL Technical Support Branch in Cincinnati, Ohio (see Appendix A).

Environmental Response Team. Serving as the EPA's in-house consultants on Superfund issues and oil spills, the Environmental Response Team provides technical support to OSCs and RPMs for both emergency removal and long-term remedial actions. With support from the Response Engineering and Analytical Contractor, the ERT's Alternative Technology Section can design and perform remedy-screening and remedy-selection treatability studies for a wide range of technologies. The Section can provide testing oversight and evaluate and interpret treatability test results. Regions can request treatability study support by contacting the ERT in Edison, New Jersey (see Appendix A).

Inventory of Treatability Study Vendors. The ORD has compiled a list of vendors and contractors who have expressed an interest in performing treatability studies. This document, entitled *Inventory of Treatability Study Vendors, Volumes I and II* (EPA 1990a), was compiled from information received from contractor/vendor responses to a published request. It lists commercial firms that offer treatability study services and describes their capabilities. (This information has not been verified by EPA.) The inventory is sorted by treatment technology, contaminant group, and company name. It can be searched electronically by contacting the EPA Alternative Treatment Technology Information Center (ATTIC) (see Appendix A). Figure 4, an example page from the document, shows the types of information the inventory contains.

Contractors or Vendors

Three available methods for obtaining treatability study services from contractors are discussed here.

ARCS, ERCS, and TAT Contracts. Alternative Remedial Contracts Strategy (ARCS) contracts are used to obtain the program management and technical services needed to support remedial response activities at CERCLA sites. To retain a treatability study vendor through this contract mechanism, the EPA project manager (in conjunction with the EPA contract officer) must issue to the prime contractor a Work Assignment outlining the required tasks. The prime contractor may elect to perform this work or to assign it to one of its subcontractors. Emergency Response Cleanup Services (ERCS) and Technical Assistance Team (TAT) contracts provide similar support services at CERCLA removal sites. Both ERCS and TAT contractors can be directed to perform treatability studies.

Technical Assistance and Support Contracts. When a specific waste at a particular site requires the specialized services of a contractor that can treat that waste (e.g., a mixed radioactive/hazardous waste) and such services are not available from firm's accessible through existing contracts, the EPA project manager may need to investigate which firms

TREATABILITY STUDY VENDORS BY COMPANY NAME

F

COMPANY: Company Type: SMALL BUS
Address:
City: State: Zip:
Contact: Phone:
Treatment Technology: ACTIVATED CARBON
Other Treatment Capability: 5 TECHNOLOGIES

CURRENT AVAILABLE FACILITY: LABORATORY
Permitting Status: EPA ID AS SMALL GENERATOR Studies/Month: INP
Mobile Facility? YES Fixed Facility? YES
Bench Scale? YES Pilot Scale? NO
Unit Capacity: INFORMATION NOT PROVIDED Location: ATLANTA, GA
Price Information: INFORMATION NOT PROVIDED
Media Treated: 1. AQUEOUS MEDIA 2. ORGANIC LIQUID
3. 4.
5. Other:
Contaminant Groups Treated: 1. HALOGENATED NONVOLATILES 2. HALOGENATED VOLATILES
3. NONHALOGENATED NONVOLATILES 4. NONHALOGENATED VOLATILES
5. NONVOLATILE METALS 6. ORGANIC CORROSIVES
7. ORGANIC CYANIDES 8. PCBs
9. VOLATILE METALS 10.
11. 12.
Other Contaminant Groups That Can Be Treated: NOT SPECIFIED

Experience at Superfund Sites? YES

F

SUPERFUND SITE # 1: A & F MATERIAL RECLAIMING EPA Region: 5 ID #: 17
Site Location: GREENVILLE State: IL
Start Date: 00/84 End Date: INP
Unit Utilized for/at Site: INFORMATION NOT PROVIDED
Price Information: INFORMATION NOT PROVIDED
Media Treated 1. AQUEOUS MEDIA 2.
3. 4.
5. Other:
Contaminant Groups Treated: 1. VOLATILE METALS 2. PCBs
3. 4.
5. 6.
7. 8.
9. 10.
11. 12.
Other Contaminant Groups Treated:

SUPERFUND SITE # 2: AMERICAN CREOSOTE EPA Region: 5 ID #: 72
Location: JACKSON State: TN
Start Date: 00/86 End Date: INP
Unit Utilized for/at Site: INFORMATION NOT PROVIDED
Price Information: INFORMATION NOT PROVIDED
Media Treated: 1. AQUEOUS MEDIA 2.
3. 4.
5. Other:

F

Contaminant Groups Treated: 1. NONVOLATILE METALS 2. PCBs
3. CREOSOTE 4.
5. 6.
7. 8.
9. 10.
11. 12.
Other Contaminant Groups: OTHER ORGANICS

Figure 4. Information contained in the ORD Inventory of Treatability Study Vendors.

with this specialized capability are accessible through other contracting mechanisms. Access to technical assistance and support contracts may be available through the RREL, the U.S. Bureau of Mines, or the U.S. Army Corps of Engineers.

Request for Proposal. In the absence of an existing contracting mechanism for accessing the required treatability study services for a specific waste at a particular site, a new contracting mechanism can be established. This will generally be the prime mechanism by which PRPs obtain treatability study services. Obtaining the services of a specific firm through a new contracting mechanism usually involves three steps: 1) a request for proposal (RFP), 2) a bid review and evaluation, and 3) a contract award. (Note: This can be a time-consuming process.)

An RFP is an invitation to firms to submit proposals to conduct specific services. It usually contains the following key sections:

- The type of contract to be awarded (e.g., fixed-price or cost plus fixed fee)
- Period of performance
- Level of effort
- Type of personnel (levels and skills)
- Project background
- Scope of work
- Technical evaluation criteria
- Instructions for bidders (e.g., due date, format, assumptions for cost proposals, page limit, and number of copies)

Appropriate firms listed in ORD's *Inventory of Treatability Study Vendors* should be notified of the RFP in accordance with the Federal Acquisition Regulations. Proposals submitted by a fixed due date in response to an RFP go to several reviewers to determine the abilities of the prospective firms to conduct the required services. The technical proposals should be evaluated (scored) with a standard rating system that is based on the technical evaluation criteria presented in the RFP. Contact award should be based on a firm's ability to meet the technical requirements of the testing involved, its qualifications and experience in conducting similar studies, the availability and adequacy of its personnel and equipment resources, and (other things being equal) a comparison of cost estimates.

3.3.2 Remedy Screening

Remedy screening involves relatively simple tests that require no special equipment. These studies can often be performed generically (as discussed in Subsection 2.5.4) by the RREL; by the ARCS, ERCS, or TAT contractor; or by the State or PRP prime support services contractor.

3.3.3 Remedy-Selection Testing

Remedy-selection testing of proven or demonstrated technologies can sometimes be performed by the ARCS, ERCS, or TAT contractor. Tests involving innovative technologies, however, may require special vendor-specific capabilities that are only accessible through technical assistance and support contracts or an RFP.

3.3.4 RD/RA Testing

Post-ROD testing entails more complex tests involving the use of specialized equipment. Because such capabilities may not be available through any existing contracting mechanism within the Agency, it may be necessary to issue an RFP to obtain RD/RA treatability study services. The RFP will generally be issued by the designer.

3.4 Issuing the Work Assignment

The Work Assignment is a contractual document that outlines the scope of work to be provided by the contractor. It presents the rationale for conducting the study, identifies the waste stream and technology(ies) to be tested, and specifies the tier(s) of testing required. Table 6 presents the suggested organization of the treatability study Work Assignment.

3.4.1 Background

The background section of the Work Assignment describes the site, the waste stream, and the treatment technology under investigation. Site-specific concerns that may affect waste handling, the experimental design, or data interpretation, as well as specific process options of interest, should be duly noted. The results of any previous treatability studies conducted at the site also should be included.

3.4.2 Test Objectives

This section defines the objectives of the treatability study and the intended use of the data (i.e., to determine potential feasibility; to develop performance or cost data for remedy selection; or to provide detailed design, cost, and performance data for remedy implementation). The test objec-

Table 6. Suggested Organization of Treatability Study Work Assignment

1. Background
   - 1.1 Site description
   - 1.2 Waste stream description
   - 1.3 Treatment technology description
   - 1.4 Previous treatability studies at the site
2. Test Objectives
3. Approach
   - 3.1 Task 1 - Work Plan preparation
   - 3.2 Task 2 - SAP, HSP, and CRP preparation
   - 3.3 Task 3 - Treatabiflty study execution
   - 3.4 Task 4 - Data analysis and interpretation
   - 3.5 Task 5 - Report preparation
   - 3.6 Task 6 - Residuals management
4. Reporting Requirements
   - 4.1 Deliverables
   - 4.2 Monthly reports
5. Schedule
6. Level of Effort

tives will include performance goals that are based on established cleanup criteria for the site or, when such criteria do not exist, on contaminant levels that are protective of human health and the environment. If the treatability study Work Assignment is issued before site cleanup goals have been established, the test objectives should be written with enough latitude to accommodate changes as the treatability testing proceeds without modifying the Work Assignment.

3.4.3 Approach

The approach describes the manner in which the treatability study is to be conducted. It should address the following six tasks: 1) Work Plan preparation; 2) Sampling and Analysis Plan (SAP), Health and Safety Plan (HSP), and Community Relations Plan (CRP) preparation; 3) treatability study execution; 4) data analysis and interpretation; 5) report preparation; and 6) residuals management.

Task 1 - Work Plan Preparation

This task outlines the elements to be included in the Work Plan. If a project kickoff meeting is needed to define the objectives of the treatability study or to review the experimental design, it should be specified here. The contractor should not begin work on subsequent tasks until receipt of the project manager's approval of the Work Plan.

Task 2 - SAP, HSP, and CRP Preparation

This task describes activities specifically related to the treatability study that should be incorporated into the existing site SAP, HSP, and CRP. Examples of such activities include field sampling and waste stream characterization, operation of pilot-plant equipment, and public meetings to discuss treatability study findings.

Task 3 - Treatability Study Execution

Requirements for executing the treatability study are outlined in this task. It should include requirements that the contractor review the literature and site-specific information, identify key parameters for investigation, and specify conditions of the test. This task also should identify guidance documents (such as this guide or other technology-specific protocols) to be consulted during the planning and execution of the study.

Task 4 - Data Analysis and Interpretation

This task describes how data from the treatability study will be used in the evaluation of the remedy. If statistical analysis of the data will be necessary, the requirements should be stipulated here.

Task 5 - Report Preparation

This task describes the contents and organization of the final project report. If multiple tiers of testing are expected, an interim report may be requested upon completion of each tier. The contractor should be required to follow the reporting format outlined in Subsection 3.12.

Task 6 - Residuals Management

Residuals generated by treatability testing must be managed in an environmentally sound manner. This task should specify whether project residuals are to be returned to the site or shipped to an acceptable offsite facility. In the latter case, the responsible waste generators (lead agency, PRP, or contractor) should be clearly identified.

3.4.4 Reporting Requirements

This section identifies the project deliverables and monthly reporting requirements. Project deliverables include the Work Plan; the SAP, HSP, and CRP (as appropriate); and interim and final reports. It should indicate the format specifications (as outlined in this guidance) and the number of copies to be delivered. All remedial and removal Work Assignments must include a requirement for one camera-ready master copy of the treatability study report to be

provided to the Office of Research and Development (EPA 1989e) for use in updating the RREL Treatability Data Base. (The report should be sent to the address listed in Subsection 3.12.)

Monthly reports should summarize the progress made in the current month, projected progress for the coming month, any problems encountered, and expected versus actual costs incurred.

3.4.5 Schedule

The schedule establishes the time frame for conducting the treatability study and includes due dates for submission of the major project deliverables. Sufficient time should be allowed for approval of the Work Plan, subcontractors, and other required administrative approvals; site access and sampling; analytical turnaround; equipment setup and shakedown; data analysis and interpretation; and review and comment on reports.

3.4.6 Level of Effort

The level of effort estimates the number of technical hours required to complete the project. Special skills or expertise are required for most treatability studies, and these requirements should be so noted.

3.5 Preparing the Work Plan

Treatability studies must be carefully planned to ensure that the data generated are useful for evaluating the feasibility or performance of a technology. The Work Plan, which is prepared by the 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 also assigns responsibilities and establishes the project schedule and costs. Table 7 presents the suggested organization of a treatability study Work Plan. The Work Plan must be approved by the project manager before subsequent tasks are initiated. Each of the principal Work Plan elements is described in the following subsections.

3.5.1 Project Description

The project description section of the Work Plan provides background information on the site and summarizes existing waste characterization data (matrix type and characteristics and the concentrations and distribution of the contaminants of concern). This information can be obtained from the Work Assignment or other background documents such as the RI. The project description also specifies the type of study to be conducted, i.e., remedy screening,

Table 7. Suggested Organization of Treatability Study Work Plan

1. Project Description
2. Treatment Technology Description
3. Test Objectives
4. Experimental Design and Procedures
5. Equipment and Materials
6. Sampling and Analysis
7. Data Management
8. Data Analysis and Interpretation
9. Health and Safety
10. Residuals Management
11. Community Relations
12. Reports
13. Schedule
14. Management and Staffing
15. Budget

remedy-selection testing, or RD/RA testing. For treatability studies involving multiple tiers of testing, this section states how the need for subsequent testing will be determined from the results of the previous tier.

3.5.2 Treatment Technology Description

This section of the Work Plan briefly describes the treatment technology to be tested. It may include a flow diagram showing the input stream, the output stream, and any side streams generated as a result of the treatment process. For treatability studies involving treatment trains, the technology description addresses all the unit operations the system comprises. A description of the pre- and posttreatment requirements also may be included.

3.5.3 Test Objectives

This section of the Work Plan defines the objectives of the treatability study and the intended use of the data (i.e., to determine potential feasibility; to develop performance or cost data for remedy selection; or to provide detailed design, cost, and performance data for remedy implementation). The test objectives will include performance goals that are based on established cleanup criteria for the site or, when such criteria do not exist, on contaminant levels that are protective of human health and the environment.

3.5.4 Experimental Design and Procedures

The experimental design identifies the tier and scale of

testing, the volume of waste material to be tested, the critical parameters, and the type and amount of replication. Examples of critical parameters include pH, reagent dosage, temperature, and reaction (or residence) time. Some form of replication is usually incorporated into a treatability study to provide a greater level of confidence in the data. Two methods are used to collect different types of test sample replicates:

1) Dividing a sample in half or thirds at the end of the experiment and analyzing each fraction. This method provides information on laboratory error.

2) Analyzing two or three samples prepared independently of each other under the same test conditions. This method provides information on total error.

The data quality objectives and the costs associated with replication must be considered in the design of the experiment. A matrix outlining the test conditions and the number of replicates, such as the example in Figure 5, should be included in the Work Plan.

The specific steps to be followed in the performance of the treatability study are described in the standard operating procedures (SOP). The SOP should be sufficiently detailed to permit the laboratory or field technician to conduct the test, to operate the equipment, and to collect the samples with minimal supervision, as shown in Example 4. The SOP can be appended to the Work Plan.

3.5.5 Equipment and Materials

This section lists the equipment, materials, and reagents that will be used in the performance of the treatability study. The following specifications should be provided for each item listed:

- Quantity
- Volume/capacity
- Calibration or scale
- Equipment manufacturer and model number
- Reagent grade and concentration

A diagram of the test apparatus also should be included in the Work Plan.

3.5.6 Sampling and Analysis

A Sampling and Analysis Plan is required for all field activities conducted during the RI/FS. This section describes how the existing SAP will be modified to address field sampling, waste characterization, and sampling and analysis activities in support of the treatability study. It describes the kinds of samples that will be collected and specifies the level of QA/QC required. (Preparation of the treatability study SAP is discussed in Subsection 3.6.)

Appendix C contains waste feed characterization parameters specific to biological, physical/chemical, immobilization, thermal, and in situ treatment technologies. Generally, these are the characterization parameters that must be established before a treatability test is conducted on the corresponding technology. Site-specific conditions may necessitate the use of additional parameters.

3.5.7 Data Management

This section of the Work Plan describes the procedures for recording observations and raw data in the field or laboratory, including the use of bound notebooks, data collection sheets, and photographs. If proprietary processes are involved, this section also describes how confidential information will be handled.

3.5.8 Data Analysis and Interpretation

This section of the Work Plan describes the procedures that will be used to analyze and interpret data from the treatability

	I - Zeolite			II - Zeolite				
Soil	A%	B%	C%	A%	B%	C%	III - limestone	IV - control
X	3	3	3	3	3	3	3	3
Y	3	3	3	3	3	3	3	3

Figure 5. Example test matrix for zeolite amendment remedy-selection treatability study.

EXAMPLE 4. TREATABILITY STUDY STANDARD OPERATING PROCEDURE

Standard Operating Procedure for Thermal Desorption Remedy-Screening Treatability Study

1. Define and record planned experiment in the data book (i.e., time, temperature, soil, etc.).
2. Weigh the empty clean tray.
3. Transfer a representative aliquot of prepared soil from the jar to the tray with a stainless steel spatula.
4. Weigh the soil and tray and adjust the soil quantity to achieve a uniform layer approximately 2.5 to 3 mm deep in the bottom of the tray.
5. Distribute and level the soil within the tray.
6. Turn on the purge-gas flow to the proper setting on the rotameter.
7. Place the tray with soil in the oven at ambient temperature and close the oven door.
8. Set the oven temperature controller set-point to the target test temperature and start the timer.
9. Monitor and record the temperatures and time periodically throughout the test period.
10. When the prescribed residence time at the target temperature is reached, shut off the oven heater and purge-gas flow and open the oven door.
11. Cautiously withdraw the hot tray and soil with special tongs, place a cover on the tray, and place the covered tray in a separate hood to cool for approximately 1 hour.
12. Weigh the tray (without cover) plus treated soil.
13. Transfer an aliquot (typically about 20 g) of treated soil from the tray to a tared, 60-cm^3, wide-mouth, amber bottle with Teflon-lined cap. Code, label, and submit this aliquot for analysis. Transfer the remainder of the treated soil to an identical type bottle, label, and store as a retainer.
14. Clean the tray, cover, and nondisposable implements by the following procedure:
    - Rinse with acetone and wipe clean.
    - Scrub with detergent solution and rinse with hot tap water followed by distilled water.
    - Rinse with acetone and allow to dry.
    - Rinse three times with methylene chloride (i.e., approximately 15 to 25 mL each rinse for the tray).
    - Air dry and store.

study, including methods of data presentation (tabular and graphical) and statistical evaluation. (Data analysis and interpretation are discussed in Subsection 3.11.)

3.5.9 Health and Safety

A Health and Safety Plan is required for all cleanup operations involving hazardous substances under CERCLA and for all operations involving hazardous wastes that are conducted at RCRA-regulateld facilities. This section of the Work Plan describes how the existing site or facility HSP will be modified to address the hazards associated with treatability testing. Hazards may include, but are not limited to, chemical exposure; fires, explosions, or spills; generation of toxic or asphyxiating gases; physical hazards; electric al hazards; and heat stress or frostbite. (Preparation of the treatability study HSP is discussed in Subsection 3.7.)

3.5.10 Residuals Management

This section of the Work Plan describes the management of treatability study residuals. Residuals generated by treatability testing must be managed in an environmentally sound manner. Early recognition of the types and quantities of residuals that will be generated, the impacts that managing these residuals will have on the project schedule and costs, and the roles and responsibilities of the various

parties involved in the generation of residuals is important for their proper disposal.

The Work Plan should include estimates of both the types and quantities of residuals expected to be generated during treatability testing. These estimates should be based on knowledge of the treatment technology and the experimental design. Project residuals may include the following:

- Unused waste not subjected to testing
- Treated waste
- Treatment residuals (e.g., ash, scrubber water, and combustion gases)
- Laboratory samples and sample extracts
- Used containers or other expendables
- Contaminated protective clothing and debris

This section outlines how treatability study residuals will be analyzed to determine if they are hazardous wastes and specifies whether such wastes will be returned to the site or shipped to a permitted treatment, storage, or disposal facility (TSDF) (see Subsection 3.9). In the latter case, this section also identifies the waste generator (lead agency, responsible party, or contractor) and delineates the parameters that will be analyzed for properly manifesting the waste and for obtaining disposal approval from the TSDF (see Table 8).

3.5.11 Community Relations

A Community Relations Plan is required for all removal and remedial response actions under CERCLA. This section describes the community relations activities that will be performed in conjunction with the treatability study. These activities include, but are not limited to, preparing fact sheets and news releases, conducting workshops or community meetings, and maintaining an up-to-date information repository. (Conducting community relations activities for treatability studies is discussed in detail in Subsection 3.8.)

3.5.12 Reports

This section of the Work Plan describes the preparation of interim and final reports documenting the results of the treatability study. For treatability studies involving more than one tier of testing, interim reports (or project briefings) provide a means of determining whether to proceed to the next tier. This section also describes the preparation of

Table 8. Typical Waste Parameters Needed to Obtain Disposal Approval at an Offsite Facility[a]

Incineration parameters	Treatment parameters
Total solids	pH
% Water	Specific gravity
% Ash	Oil and grease
pH	Total organic carbon (TOC)
Specific gravity	Total sulfide
Flash point	Total cyanide
Btu/pound	Total phenolics
Total sulfide	Total metals (RCRA plus Cu, Ni, Zn)
Total sulfur	TCLP metals
Total organic nitrogen	TCLP organics (D-list)
Total cyanide	
Total phenolics	Landfill parameters (solids only)
Total organic halogen (TOX)	% Water
Polychlorinated biphenyls (PCBs)	% Ash
Total RCRA metals (eight)	pH
TCLP metals	Specific gravity
TCLP organics (D-list)	Total sulfide
Priority pollutant organics	Total cyanide
Volatile	Total phenolics
Semivolatile (BN/A-extractable)	PCBs
Remaining F-listed solvents	TCLP metals (extraction and RCRA)
	TCLP organics (D-list)
	TCLP solvents (F-list)

[a]Analysis of these parameters may be required unless they can be ruled out based on knowledge of the waste.

monthly reports detailing the current and projected progress on the project. (Treatability study reporting is discussed in detail in Subsection 3.12.)

3.5.13 Schedule

The Work Plan should contain a schedule indicating the planned starting and ending dates for the tasks outlined in the Work Assignment. The length of a treatability study will vary with the technology being investigated and the level of testing being conducted. Entire remedy-screening studies can usually be performed within a few weeks. Remedy-selection studies, however, may require several months. In addition to the time required for actual testing, the schedule must allow time for obtaining approval of the various plans; securing any necessary environmental, testing, or transportation permits; shipping analytical samples and receiving results; seeking review and comment on the project's deliverables; and disposing of the project's residuals.

The schedule may be displayed as a bar chart, such as that shown in Figure 6. In this example, both remedy-screening and remedy-selection treatability studies are planned. Performance of the selection studies is contingent upon the results of the screening studies, which are presented in the Interim Report. In this particular schedule, the actual treatability tests (Subtasks 3b and 7a) will require only 1 to 2 weeks to perform. The entire two-tiered study, however, spans a period of 8 months.

3.5.14 Management and Staffing

This section of the Work Plan identifies key management and technical personnel and defines specific project roles and responsibilities. The line of authority is usually presented in an organization chart such as that shown in Figure 7. The EPA Project Manager is responsible for project planning and oversight. At Federal- and State-lead sites, the remedial contractor directs the treatability study and is responsible for the execution of the project tasks. At private-lead sites, the PRP performs this function. The treatability study may be subcontracted wholly or in part to a vendor or testing facility with expertise in the technology being evaluated.

3.5.15 Budget

The treatability study budget presents the projected costs for completing the treatability Study as described in the Work Plan. Elements of a budget include labor, administrative costs, and fees; equipment and reagents; site preparation (e.g., building a concrete pad) and utilities; permitting and regulatory fees; unit mobilization; on-scene health and safety requirements; sample transportation and analysis; emissions and effluent monitoring and treatment; unit decontamination and demobilization; and residuals transportation and disposal. Appendix B discusses these various cost elements.

The size of the budget will generally reflect the complexity of the treatability study. Consequently, the number of operating parameters chosen for investigation at the remedy-selection tier and the approach used to obtain these measurements will often depend on the available funding. For example, for some treatment processes it may be less costly to obtain data on contaminant reduction versus reaction time at the completion of a test run rather than periodically throughout the test. This kind of information can be obtained from the technology vendor during the planning of the treatability study.

Analytical costs can have a significant impact on the project's overall budget. Sufficient funding must be allotted for the amount of analytical work projected, the chemical and physical parameters to be analyzed, and the required turnaround time. Specialty analyses (e.g., for dioxins and furans) can quickly increase the analytical costs.

A 34-week remedy-screening/remedy-selection treatability study such as the one presented in Figure 6 can be performed at a cost of between $50,000 and $ 100,000.

3.6 Preparing the Sampling and Analysis Plan

3.6.1 General

A Sampling and Analysis Plan is required for all field and test activities conducted to support a treatability study. The purpose of the SAP is to ensure that samples obtained for characterization and testing are representative and that the quality of the analytical data generated is known. The SAP addresses field sampling, waste characterization, and sampling and analysis of the treated wastes and residuals from the testing apparatus or treatment unit.

Table 9 presents the suggested organization of the treatability study SAP. The SAP consists of two parts-the Field Sampling Plan (FSP) and the Quality Assurance Project Plan (QAPP).

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 necessary equipment and procedures for collecting the samples; the

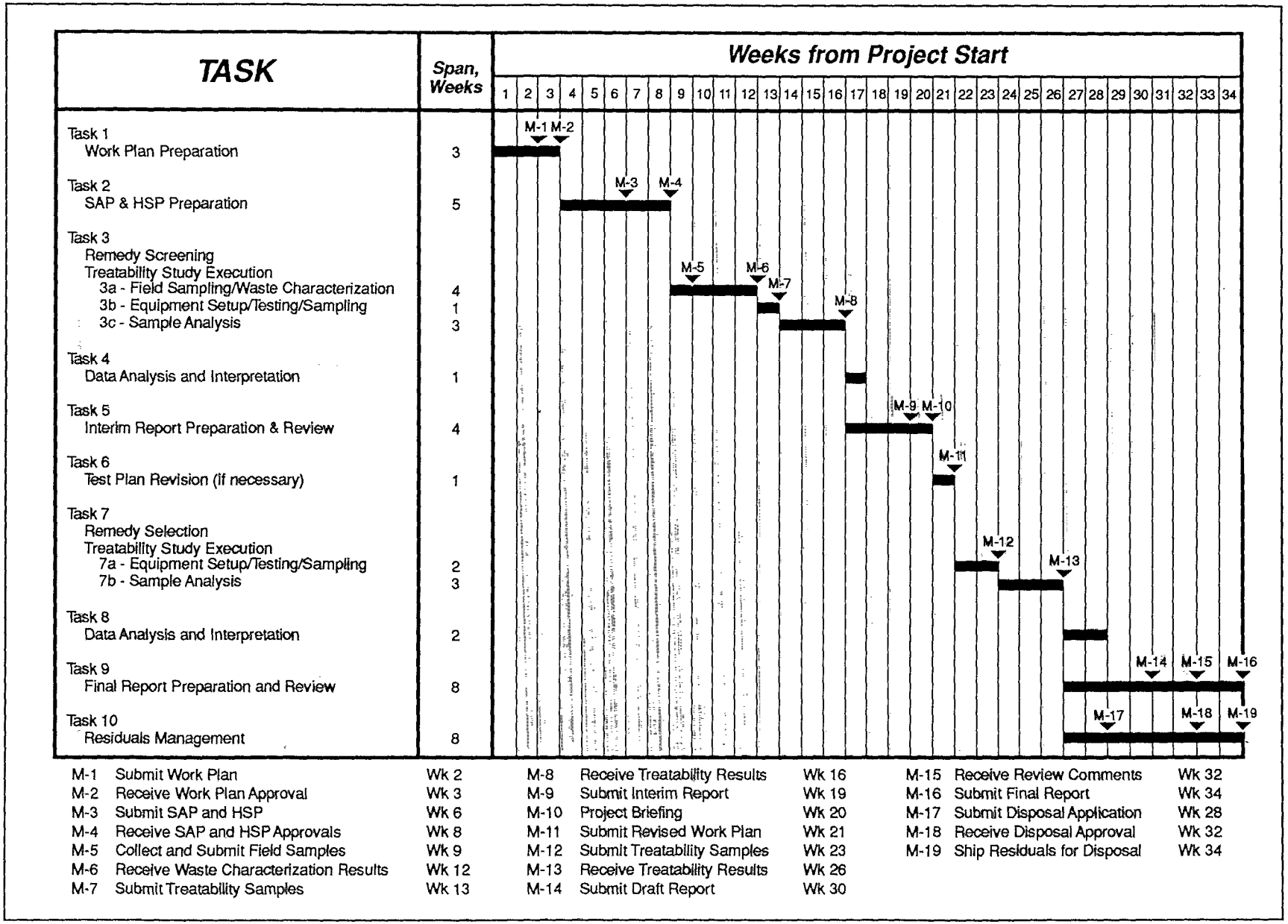


Figure 6. Example project schedule for a two-tiered chemical dehalogenation treatability study.

sample chain-of-custody procedures; and the required packaging, labeling, and shipping procedures.

The sampling objectives must support the test objectives of the treatability study. For example, if an objective of RD/RA testing is to investigate process upsets and recovery, the objective of field sampling should be to collect samples representing the "worst case." If soils will be blended in the full-scale process, however, the field sampling objectives should be to collect samples representing "average" conditions at the site.

Whatever the sampling objectives, the samples collected must be representative of the conditions being evaluated. Guidance on representative samples and statistical sampling is contained in *Test Methods for Evaluating Solid Waste* (EPA 1986).

Additional guidance for the selection of field methods, sampling procedures, and chain-of-custody requirements can be obtained from *A Compendium of Superfund Field Operations Methods* (EPA 1987b).

Quality Assurance Project Plan

The second component of the SAP, the QAPP, details the quality assurance objectives (precision, accuracy, representativeness, completeness, and comparability) for critical measurements and the quality control procedures established to achieve the desired QA objectives for a specific treatability study. Guidance for preparing the QAPP can be obtained from *Quality Assurance Procedures for RREL* (EPA 1989d) and *Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans* (EPA 1980). In general, QAPPs are based on the type of project being conducted and on the intended use of the data generated by the project. The QAPP recommended in Table 9 corresponds to the QA Category II plan presented in *Quality Assurance Procedure for RREL*. This plan should be implemented only for remedy-selection treatability studies requiring exceptionally high levels of QA (i.e., where treatability data will play an important role in the ROD). As discussed in the following subsections, less stringent QAPPs will be adequate for all other treatability studies.

3.6.2 Remedy Screening

Remedy screening requires a less stringent level of QA/QC. Technologies determined to be potentially feasible through remedy screening are evaluated further at the remedy-selection tier; therefore, the QA/QC requirements associated with this screening are less rigorous. Nevertheless, the test data should be well documented. The

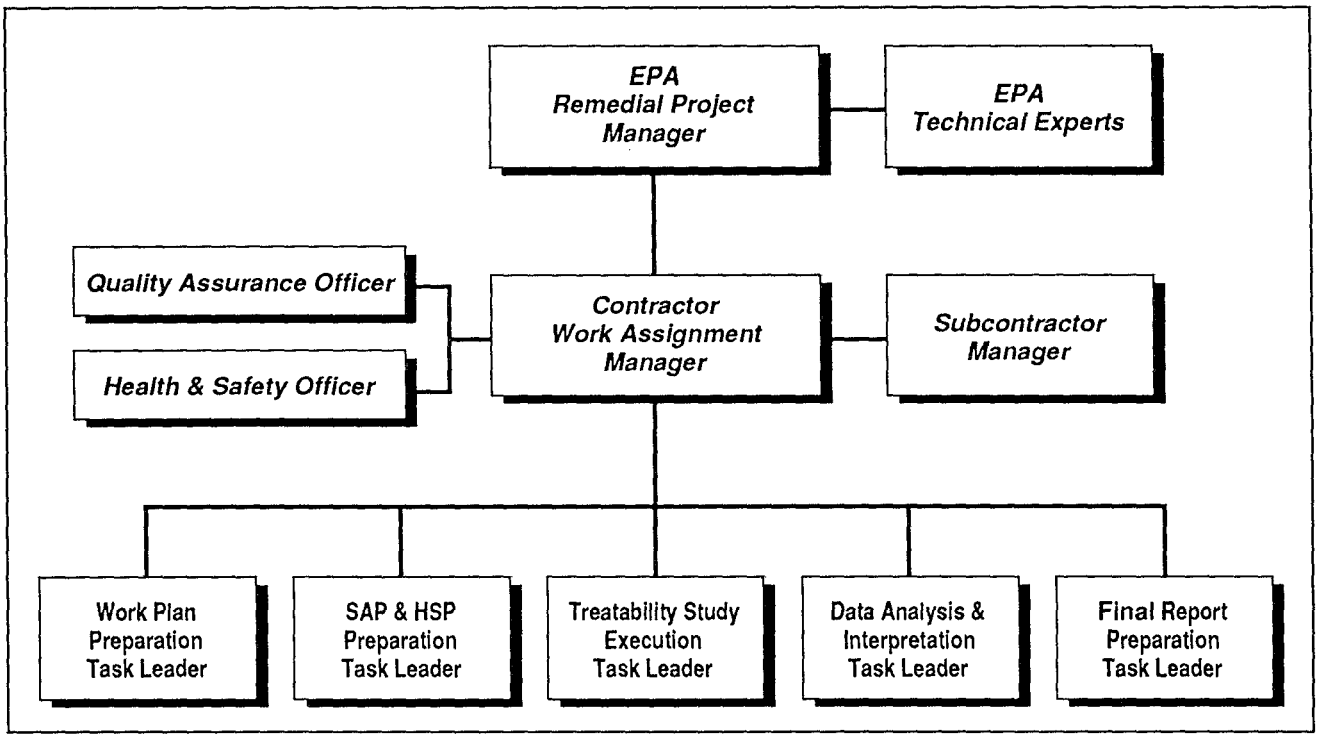


Figure 7. Example project organization chart.

Table 9. Suggested Organization of a Treatability Study Sampling and Analysis Plan

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

Quality Assurance Project Plan
1. Project Description
2. Project Organization and Responsibilities
3. Quality Assurance Objectives
4. Site Selection and Sampling Procedures
5. Analytical Procedures and Calibration
6. Data Reduction, Validation, and Reporting
7. Internal Quality Control Checks
8. Performance and Systems Audits
9. Calculation of Data Quality Indicators
10. Corrective Action
11. Quality Control Reports to Management
12. References

Appendices
A. Data Quality Objectives
B. EPA Methods Used
C. SOP for EPA Methods Used
D. QA Project Plan Approval Form

Category IV QAPP is recommended for remedy-screening treatability studies.

3.6.3 Remedy-Selection Testing

Remedy-selection testing requires a moderately to highly stringent level of QA/QC. The data generated in remedy-selection testing are generally used for evaluation and selection of the remedy; therefore, the QA/QC associated with this tier should be rigorous and the test data well documented. The Category III QAPP will provide a sufficient level of quality assurance for most remedy-selection treatability studies. In cases where remedy-selection data will be highly scrutinized or have a significant impact on decision making, the Category II QAPP may be required.

3.6.4 RD/RA Testing

Treatability testing to support remedial design/remedial action requires a moderately to highly stringent level of QA/QC. The data generated in RD/RA testing are used in support of remedy optimization and implementation; therefore, the QA/QC associated with this tier should be rigorous and the test data well documented. In most cases, the Category III QAPP will provide data of sufficient quality for RD/RA treatability studies.

3.7 Preparing the Health and Safety Plan

3.7.1 General

A project-specific Health and Safety Plan is required for all treatability studies conducted on site or at an offsite laboratory or testing facility permitted under RCRA, including research, development, and demonstration facilities. The vendor or testing facility should submit the HSP with the treatability study Work Plan. The HSP describes the work to be performed in the field and in the laboratory, identifies the possible physical and chemical hazards associated with each phase of field and laboratory operations, and prescribes appropriate protective measures to minimize worker exposure. Hazards that may be encountered during treatability studies include the following:

- Chemical exposure (inhalation, absorption, or ingestion of contaminated soils, sludges, or liquids)
- Fires, explosions, or spills
- Toxic or asphyxiating gases generated during storage or treatment
- Physical hazards such as sharp objects or slippery surfaces
- Electrical hazards such as high-voltage equipment
- Heat stress or frostbite

Table 10 presents the suggested organization of the treatability study HSP, which addresses the Occupational Safety and Health Administration (OSHA) requirements in 29 CFR 1910.120(b)(4). Guidance for preparing the HSP is contained in two documents**S***A Compendium of Superfund Field Operations Methods* (EPA 1987b) and *Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities* (NIOSH/OSHA/USCG/EPA 1985).

Supervisors, equipment operators, and field technicians engaged in onsite operations must satisfy the training requirements in 29 CFR 1910.120(e) and must participate in a medical surveillance program, as described in 29 CFR 1910.120(f). Laboratory personnel must be trained with

Table 10. Suggested Organization of a Treatability Study Health and Safety Plan

1.	Hazard Analysis
2.	Employee Training
3.	Personal Protective Equipment
4.	Medical Surveillance
5.	Personnel and Environmental Monitoring
6.	Site Control Measures
7.	Decontamination Procedures
8.	Emergency Response Plan
9.	Confined-Space Entry Procedures
10.	Spill Containment Program

regard to container labeling and Material Safety Data Sheets (MSDS) in accordance with the OSHA Hazard Communication Standard in 29 CFR 1910.1200. Before any treatability studies are initiated, the Health and Safety Officer should conduct a briefing to ensure that all personnel are appraised of the HSP. The Health and Safety Officer also should conduct inspections during the course of the treatability study to determine compliance with and effectiveness of the HSP.

3.7.2 Remedy Screening

The safety and health hazards associated with remedy screening are relatively minor because of the small volumes of wastes that are handled and subjected to testing. In general, the HSP should provide for skin and eye protection during the handling of wastes. It need not require respiratory protection if the tests are conducted in a fume hood.

3.7.3 Remedy-Selection Testing

The HSP for a remedy-selection treatability study must provide for skin and eye protection during the handling of wastes. It also may require respiratory protection when treatment processes tested at the bench scale involve mixing or aeration (e.g., solidification/stabilization, aerobic biological treatment) that could generate dust or volatilize organic contaminants. Because pilot-scale testing involves significantly greater volumes of waste, the health and safety risks will increase.

3.7.4 RD/RA Testing

Pilot- and field-scale RD/RA treatability studies may pose significant health and safety hazards to operators and onsite personnel. The HSP must outline skin, eye, and respiratory protection (Level C or higher); decontamination procedures; and emergency procedures (such as equipment shutdown and personnel evacuation).

3.8 Conducting Community Relations Activities

3.8.1 General

Community relations activities provide interested persons an opportunity to comment on and participate in decisions concerning site actions, including the performance of treatability studies. Public participation in the removal, RI/FS, and RD/RA processes ensures that the community is provided with accurate and timely information about site activities. From the beginning of the RI/FS, a description of the treatability study activities that will be performed during the feasibility study should be included in the discussion on how the alternatives will be delineated for the particular site. Presenting clear, concise explanations of treatability studies (accompanied by appropriate graphics) before activities have been performed will create a more open and positive Agency/public relationship.

The Agency designs and implements community relations activities according to CERCLA and the National Oil and Hazardous Substances Pollution Contingency Plan. The NCP requires the lead Agency to prepare a Community Relations Plan for all remedial response actions and for all removal actions of more than 45 days' duration, regardless of whether RI/FS activities are fund-financed or conducted by PRPs (40 CFR 300.67). This plan outlines all community relations activities that will be conducted during the RI/FS and projects the future activities required during completion of remedial design and implementation. These future activities are outlined more clearly in a revised plan developed after the feasibility study and before the remedial design phase.

Guidance for preparing a CRP and conducting community relations activities can be acquired from *Community Relations in Superfund: A Handbook* (EPA 1988b). Table 11 presents the CRP organization suggested in this handbook.

Community interviews should be conducted before the CRP is prepared. These interviews are informal discussions held with State and local officials, community leaders, media representatives, and interested citizens to assess the public's concern and desire to be involved in site response activities. Discussions with citizens regarding the possible need for conducting onsite treatability studies will allow the Agency to anticipate and respond better to community concerns as the treatability testing process proceeds and will allow government officials and citizens to under-

Table 11. Suggested Organization of Community Relations Plan

1.	Overview of Community Relations Plan
2.	Capsule Site Description
3.	Community Background
4.	Highlights of the Community Relations Program
5.	Community Relations Activities and Timing
Appendices	
A.	Contact List of Key Community Leaders and Interested Parties
B.	Suggested Locations of Meetings and Information Repositories

stand that several technologies may be tested before the preferred alternative(s) are listed in the final FS report.

Conducting treatability studies on site is a potentially controversial issue within a community and may demand considerable effort on the part of the Agency. As the site investigation progresses, community relations activities should focus on providing information to the community concerning the technology screening process and on obtaining feedback on community concerns associated with potentially applicable treatment technologies. Activities may include, but are not limited to, the following:

- Preparing fact sheets and news releases describing treatment technologies identified during the development and screening of alternatives.
- Discussing the possibility of treatability studies being conducted during the initial public meeting. Presenting professionally produced video tapes or slide shows on treatability studies at the public meeting can demonstrate that the Agency is attempting to educate the public regarding the treatability study process.
- Conducting a workshop to present to concerned citizens, local officials, and the media the Agency's rationale for choosing the treatment technologies to be studied.
- Holding small group meetings with involved members of the community at regular intervals throughout the RVFS process to discuss treatability study findings and site decisions as they develop.
- Ensuring citizen access to treatability study information by maintaining a complete and up-to-date information repository.
- Presenting results of the treatability studies performed and explaining how these results influenced the selection of the remedy at the final RI/FS public meeting.

Fact sheets on the planned treatability studies should be made available to the public and should include a discussion of treatability-specific issues such as the following:

- Uncertainties (risk) pertaining to innovative technologies
- The degree of development of potentially applicable technologies identified for treatability testing
- Onsite treatability testing and analysis
- Offsite transportation of contaminated materials
- Materials handling
- Residuals management
- RI/FS schedule changes resulting from the unexpected need for additional treatability studies
- Potential disruptions to the community

3.8.2 Remedy Screening

Remedy-screening treatability studies are relatively low-profile and, if conducted offsite, will require relatively feed community relations activities. Distributing fact sheets and placing the results from remedy screening in the information repository will generally be sufficient.

3.8.3 Remedy-Selection Testing

Bench-scale remedy-selection testing may not be particularly controversial if conducted offsite. Onsite bench-scale testing, however, may require more community relations activities.

Onsite, pilot-scale testing may attract considerable community interest. In some cases (e.g., onsite thermal treatment), the strength of public opinion concerning treatability testing may not have been indicated by the level of interest demonstrated during the RI and previous treatability studies. Because of the very real potential for conflict and misunderstanding at the remedy-selection testing stage of the FS, it is vital that a strong program of community relations and public participation be established well in advance of any treatability testing.

Community acceptance is one of the nine RI/FS evaluation

criteria. Remedy-selection testing may provide data that can convince a community of a technology's ability to remediate a site effectively. Early, open, and consistent communication with the public and their full participation in the decision-making process may help to prevent the testing, development, and selection of a remedy that is unacceptable to the community and results in delayed site remediation and higher remediation costs.

3.8.4 RD/RA Testing

Post-ROD treatability testing may not be especially controversial within a community because the remedy or remedies being investigated have already been reviewed and selected during the RI/FS. Fact sheets and news releases covering RD/RA treatability study progress may be appropriate.

3.9 Complying With Regulatory Requirements

Treatability studies involving Superfund wastes are subject to various requirements under CERCLA [as amended in 1986 by SARA] and RCRA [as amended in 1984 by the Hazardous and Solid Waste Amendments (HSWA)]. The applicability of these requirements depends on whether the studies are conducted on site (e.g., in a mobile trailer) or at an offsite laboratory or testing facility.

Figure 8 summarizes the facility requirements for treatability testing. Figure 9 summarizes the shipping requirements for offsite treatability testing. These requirements are described in the succeeding subsections.

3.9.1 Onsite Treatability Studies

Onsite treatability studies under CERCLA may be conducted without any Federal, State, or local permits [40 CFR 300.400(e)(1)]; however, such studies must comply with ARARs under Federal and State environmental laws to the extent practicable or justify a waiver under CERCLA Section 121(d)(4). For example, treatability studies involving surface-water discharge must meet effluent limitations even though a discharge permit is not required.

3.9.2 Offsite Treatability Studies

Section 121(d)(3) of CERCLA and *Revised Procedures for Implementing Off-Site Response Actions* (the "Revised Off-Site Policy") (EPA 1987c) generally state that offsite facilities that receive CERCLA wastes must be 1) operating in compliance with applicable Federal and State laws, and 2) controlling any relevant releases of hazardous substances to the environment. Currently, the Revised Off-Site Policy does not specifically exempt the transfer of CERCLA wastes offsite for treatability studies; therefore, off-site laboratories or testing facilities that receive CERCLA wastes must be in compliance with the offsite requirements.

Off-site treatability studies under CERCLA must be conducted under appropriate Federal or State permits or authorization and other legal requirements. Two alternatives to a full RCRA facility permit are available to technology vendors and other laboratory or testing facilities for compliance with these requirements: a Research, Development, and Demonstration (RD&D) permit, which covers limited-duration and limited-quantity testing of actual hazardous waste, and the treatability exclusion under RCRA, which may exempt small-scale testing activities from certain RCRA permitting requirements.*

Research, Development, and Demonstration Permits

Hazardous waste treatment facilities that propose to use an innovative and experimental treatment technology or process for which RCRA permit standards have not been promulgated under Part 264 or 266 may obtain an RD&D permit (40 CR 270.65). This provision is intended to expedite the permit review and issuance process.

An RD&D permit may be required for laboratories or testing facilities that perform pilot-scale tests that are likely to exceed the storage and treatment rate limits specified under the treatability exclusion. Limitations on the types and quantities of hazardous waste that can be received and treated by the facility under an RD&D permit and the requirements for testing, reporting, and protection of human health and the environment (as deemed necessary by the Agency) are specified in the terms and conditions of the permit. The RD&D permits are issued for a period of 1 year and may be renewed up to three times for one additional year each.

The status of the RD&D permit authority in a particular State can be determined by contacting the appropriate Region's RCRA Coordinator for that State.

---

* The Agency intends to address large-scale treatability studies in separate rulemaking at some future date; the Agency also is considering developing regulations under 40 CFR Part 264, Subpart Y, that would establish permitting standards for experimental facilities conducting research and development on the storage, treatment, or disposal of hazardous waste.

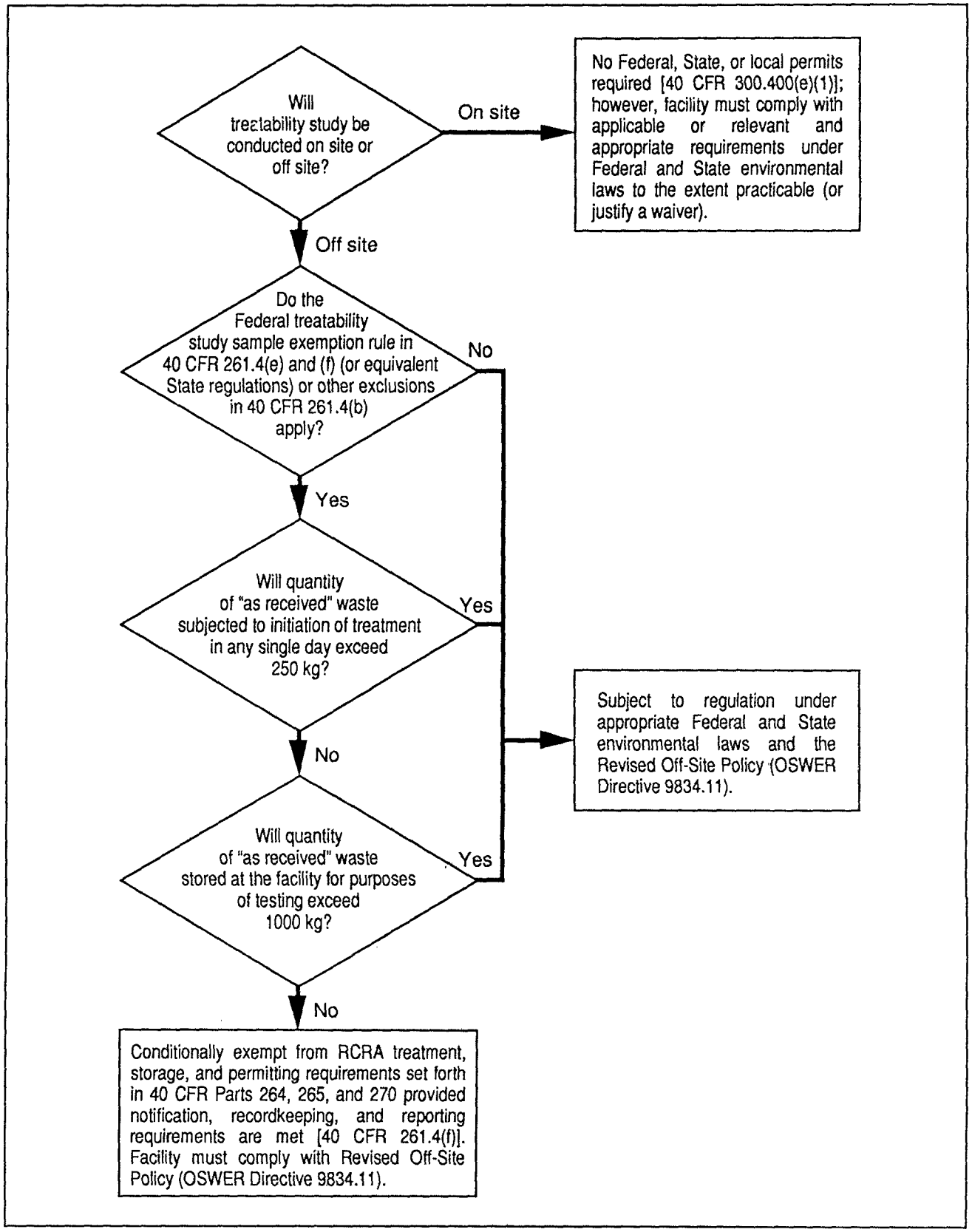


Figure 8. Facility requirements for treatability testing.

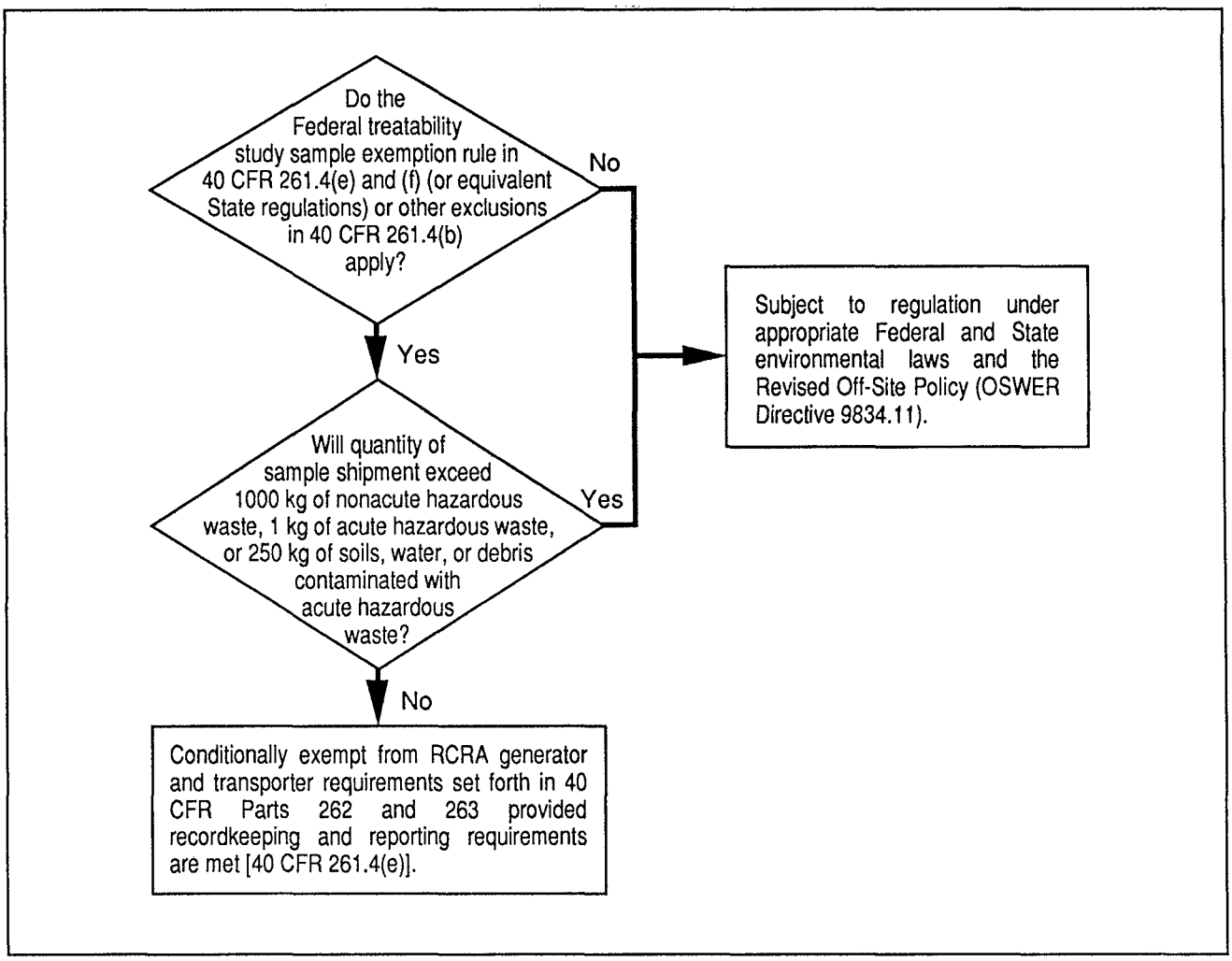


Figure 9. Shipping requirements for offsite treatability testing.

Treatability Exclusion

Effective July 19, 1988, the sample exclusion provision [40 CFR 261.4(d)], which exempts waste samples collected for the sole purpose of determining their characteristics or composition from regulation under Subtitle C of RCRA, was expanded to include waste samples used in small-scale treatability studies (53 FR 27301). Because it is considered *less* stringent than authorized State regulations for RCRA permits, the Federal Treatability Study Sample Exemption Rule is applicable only in those States that do not have final authorization or in authorized States that have revised their program to adopt equivalent regulations under State law. Although the provision is optional, the EPA has strongly encouraged authorized States to adopt the exemption or to exercise their authority to order treatability studies (in case of imminent and substantial endangerment to health or the environment) or to grant a general waiver, permit waiver, or emergency permit authority to authorize treatability studies. The status of the treatability exclusion in a particular State can be determined by contacting the appropriate Region's RCRA Coordinator for that State.

Under the treatability exclusion, persons who generate or collect samples of hazardous waste (as defined under RCRA) for the purpose of conducting treatability studies are conditionally exempt from the generator and transporter requirements (40 CFR Parts 262 and 263) when the samples are being collected, stored, or transported to an offsite laboratory or testing facility [40 CFR 261.4(e)] provided that:

1) The generator or sample collector uses no more than 1000 kg of any nonacute hazardous waste, 1 kg of acute hazardous waste, or 250 kg of soils, water, or debris contaminated with acute hazardous waste per waste stream per treatment process.

On a case-by-case basis, the Regional Administrator or State Director may grant requests for waste stream limits up to an additional 500 kg of nonacute hazardous waste, 1 kg of acute hazardous waste, and 250 kg of soils, water, or debris contaminated with acute hazardous waste.

2) The quantity of each sample shipment does not exceed these quantity limitations.

3) The sample is packaged so that it will not leak, spill, or vaporize from its packaging during shipment, and the transportation of each sample shipment complies with U.S. Department of Transportation (DOT), U.S. Postal Service (USPS), or any other applicable regulations for shipping hazardous materials.

4) The sample is shipped to a laboratory or testing facility that is exempt under 40 CFR 261.4(f) or that has an appropriate RCRA permit or interim status.

5) The generator or sample collector maintains copies of the shipping documents, the contract with the facility conducting the treatability study, and records showing compliance with the shipping limits for 3 years after completion of the treatability study.

6) The generator provides the preceding documentation in its biennial report.

Similarly, offsite laboratories or testing facilities (including mobile treatment units) are conditionally exempt from the treatment, storage, and permitting requirements (40 CFR Parts 264, 265, and 270) when conducting treatability studies [40 CFR 261.4(f)] provided that:

1) The facility notifies the Regional Administrator or State Director that it intends to conduct treatability studies.

2) The laboratory or testing facility has an EPA identification number.

3) The quantity of "as received" hazardous waste that is subjected to initiation of treatment in all treatability studies in any single day is less than 250 kg.

4) The quantity of "as received" hazardous waste stored at the facility does not exceed 1000 kg, which can include 500 kg of soils, water, or debris contaminated with acute hazardous waste or 1 kg of acute hazardous waste.

5) No more than 90 days have elapsed since the treatability study was completed, or no more than 1 year has elapsed since the generator or sample collector shipped the sample to the laboratory or testing facility.

6) The treatability study involves neither placement of hazardous waste on the land nor open burning of hazardous waste.

7) The facility maintains records showing compliance with the treatment rate limits and the storage time and quantity limits for 3 years following completion of each study.

8) The facility keeps a copy of the treatability study contract and all shipping papers for 3 years after the completion date of each study.

9) The facility submits to the Regional Administrator or State Director an annual report estimating the number of studies and the amount of waste to be used in treatability studies during the current year and providing information on treatability studies conducted during the preceding year.

10) The facility determines whether any unused sample or residues generated by the treatability study are hazardous waste [unless they are returned to the sample originator under the 40 CFR 261.4(e) exemption].

11) The facility notifies the Regional Administrator or State Director when it is no longer planning to conduct any treatability studies at the site.

Laboratories or testing facilities that perform bench-scale tests generally meet the storage and treatment rate limits outlined in the preceding items. Facilities not operating within these limitations are subject to appropriate regulation.

3.9.3 Residuals Management

Treatability study residuals generated at an offsite laboratory or testing facility may be returned to the sample originator under the Federal Treatability Study Sample Exemption Rule (or equivalent State regulations) if the storage time limits in 40 CFR 261.4(f) are not exceeded. This includes any unused sample or residues. If the exemption does not apply, the disposal of treatability study residuals is subject to appropriate regulation, including the RCRA land disposal restrictions for contaminated soil and debris when these regulations become effective. Treatability study re-

siduals managed offsite must be packaged, labeled, and manifested in accordance with 40 CFR Part 262 and applicable DOT regulations for hazardous materials under 49 CFR Part 172.

As discussed earlier, the Revised Off-Site Policy does not specifically exempt the transfer of treatability study residuals offsite for disposal; therefore, offsite treatment or disposal facilities that receive these wastes must be in compliance with the offsite requirements. The acceptability of a commercial facility for receiving CERCLA wastes can be determined by contacting the appropriate Regional Offsite Contact, as shown in Table 12.

Table 12. Regional Offsite Contacts for Determining Acceptability Of Commercial Facilities to Receive CERCLA Wastes[a]

Region	Primary contact/phone	Backup contact/phone
I	Lin Hanifan (617) 573-5755	Robin Biscaia (617) 573-5754
II	Gregory Zaccardi (212) 264-9504	Joe Golumbek (212) 264-2638 John Gorman (212) 264-2621
III	Naomi Henry (215) 597-8338	Rita Tate (215) 597-8175
IV	Alan Antley (404) 347-4450	Gregory Fraley (404) 347-7603
V	Gertrude Matuschkovitz (312) 353-7921	Paul Dimock (312) 886-4445
VI	Trish Brechlin (214) 655-6765	Randy Brown (214) 655-6745
VII	David Doyle (913) 236-2891	Marc Rivas (913) 236-2891
VIII	Felix Flechas (303) 293-1524	Mike Gansecki (303) 293-1510 Terry Brown (303) 293-1823
IX	Diane Bodine (415) 744-2130	Jane Diamond (415) 744-2139
X	Al Odmark (206) 553-1886	Ron Lillich (206) 553-6646

[a]These contacts are subject to change.

3.10 Executing the Study

Execution of the treatability study begins after the project manager has approved the Work Plan and other supporting documents. Steps include collecting a sample of the waste stream for characterization and testing, conducting the test, and collecting and analyzing samples of the treated waste and residuals.

3.10.1 Field Sampling and Waste Stream Characterization

Field samples should be collected and preserved in accordance with the procedures outlines in the SAP. They should be representative of either "average" or "worst-case" conditions (as dictated by the test objectives), and the sample should be large enough to complete all of the required tests and analyses in the event of some anomaly. Collocated field samples also should be collected in accordance with the QAPP. To the extent possible, field sampling should be coordinated with other onsite activities to minimize costs. Samples shipped to an offsite laboratory for testing or analysis must be packaged, labeled, and shipped in accordance with DOT, USPS, or other applicable shipping regulations (see Subsection 3.9). A chain-of-custody record must accompany each sample shipment.

The waste sample should be thoroughly mixed to ensure that it is homogeneous. This permits a comparison of results under different test conditions. Small-volume soil samples can be mixed with a Hobart mixer, and large-volume samples can be mixed with a drum roller. Stones and debris should be removed by screening. Care must be exercised during these procedures to avoid contaminating the waste samples (or allowing volatiles to escape) and to ensure effective homogenization.

Characterization samples should be collected from the same material that will be used in the performance of the treatability study. Characterization is necessary to determine the chemical, physical, and/or biological properties exhibited by the waste stream so that the results of the treatability study can be properly gauged.

3.10.2 Treatability Testing

The treatability study should be performed in accordance with the test matrix and standard operating procedures described in the Work Plan. Any deviations from the SOP should be recorded in the field or laboratory notebook.

The EPA or a qualified contractor should oversee testing conducted by vendors and PRPs. Oversight activities were discussed in Subsection 2.5.5.

3.10.3 Sampling and Analysis

Samples of the treated waste and process residuals (e.g. off-gas, scrubber water, and ash for incineration tests) should be collected in accordance with the SAP. The SAP speci-

fies the location and frequency of sampling, proper containers, sample preservation techniques, and maximum holding times. Quality assurance/quality control samples will be collected at the same time as the treatability study samples in accordance with the QAPP. All samples must be logged in the field or laboratory notebook. Samples shipped to an offsite laboratory must be packaged, labeled, and shipped in accordance with DOT, USPS, or other applicable shipping regulations, and a chain-of custody record must accompany each sample shipment.

Treatability study samples should be analyzed in accordance with the methods specified in the SAP. Normal sample turnaround time is 3 to 5 weeks for most analyses; the laboratory may charge a premium if results are required in less time.

3.11 Analyzing and Interpreting the Data

3.11.1 Data Analysis

Upon completion of a treatability study, the data must be compiled and analyzed. The first goal of data analysis is to determine the quality of the data collected. All data should be checked to assess precision, accuracy, and completeness. Both testing and analytical error must be assessed to determine total error. If the QA objectives specified in the QAPP have not been met, the project manager and the EPA Work Assignment Manager must determine the appropriate corrective action.

Data are generally summarized in tabular or graphic form. The exact presentation of the data will depend on the experimental design and the relationship between the variables being compared. For data presented graphically, independent variables, which are controlled by the experimenter, are generally plotted on the abscissa whereas dependent variables, which change in response to changing the independent variables, are plotted on the ordinate. Examples of independent variables are pH, temperature, reagent concentration, and reaction time. Examples of dependent variables are removal efficiency and substrate utilization.

For determining whether statistically significant differences in treatment effectiveness exist between two or more values of an independent variable, the use of analysis of variance and other statistical techniques may be appropriate. These techniques can assist in identifying the most cost-effective combination of parameters in a treatment system with multiple independent variables. Statistical analysis of treatability study data, however, should only be performed when planned and budgeted for.

3.11.2 Data Interpretation/Pre-ROD

Interpretation of treatability study data must be based on the test objectives established prior to testing. Data interpretation is an important part of the treatability study report. Therefore, the contractor or other party performing the study and preparing the report must fully understand the study objectives and the role the results will play in remedy screening, selection, or implementation. The investigating party, not the RPM, is responsible for interpreting the treatability study data.

The purpose of a pre-ROD treatability investigation is to provide the data needed for a detailed analysis of alternatives and, ultimately, the selection of a remedial action that can achieve the site cleanup criteria. The results of a treatability study should enable the RPM to evaluate all treatment alternatives on an equal basis during the detailed analysis of alternatives.

The Work Plan outlines the treatability study's test objectives and describes how these objectives will be used in the evaluation of the technology (i.e., remedy screening or remedy selection). As discussed in Section 2, the 1990 revised NCP Section 300.430(c) specifies nine evaluation criteria to be considered in the assessment of remedial alternatives. These criteria were developed to address both the specific statutory requirements of CERCLA Section 121 (threshold criteria) and the technical and policy considerations that are important in the selection of remedial alternatives (primary balancing criteria and modifying criteria). The nine RI/FS evaluation criteria are as follows:

Threshold criteria:

- Overall protection of human health and the environment
- Compliance with ARARs

Primary balancing criteria:

- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, and volume through treatment
- Short-term effectiveness
- Implementability
- Cost

Modifying criteria:

- State acceptance
- Community acceptance

As discussed in the following subsections, treatability studies provide important data for use in the assessment of an alternative against both the threshold criteria and the primary balancing criteria. The results of treatability studies can also influence evaluations against the State and community acceptance criteria. Figure 10 lists factors important to the analysis of the RI/FS evaluation criteria. These factors are often technology-specific, as are the treatability study data that support the analysis of each factor. Example 5 outlines some of the specific analysis factors applicable to chemical dehalogenation treatment technologies and several types of data from a chemical dehalogenation treatability study that provide information for each of these factors.

Evaluations against the nine criteria are performed for the overall alternative, of which the treatment technology is only a part. The alternative will generally include additional, treatment, containment, or disposal technologies. Detailed guidance on the Superfund program's remedy-selection process as established in the 1990 revised NCP Section 300.430(f) is available in the RI/FS guidance and in *A Guide to Selecting Superfund Remedial Actions* (EPA 1990b).

Threshold Criteria

The two statutory-based threshold criteria should be used to set treatability study performance goals. Only those alternatives that satisfy the threshold criteria are eligible for remedy selection.

Overall Protection of Human Health and the Environment

This evaluation criterion provides an overall assessment of how well each alternative achieves and maintains protection of human health and the environment. The analysis of overall protection will draw on the assessments conducted under the primary evaluation criteria and the compliance with ARARs. It will focus on the ability of an alternative to eliminate, reduce, or control overall site risks.

Treatability studies will provide general data for the evaluation under this criterion. Target contaminant concentrations in the treated product and any treatment residuals will demonstrate how well the process or treatment train can eliminate site risks. If an ecological risk assessment is being conducted, bioassessments of these materials will generate the data required to evaluate the reduction in risk to site biota.

Compliance with ARARs

Applicable or relevant and appropriate requirements are any local, State, or Federal regulations or standards that pertain to chemical contaminant levels, locations, and actions at CERCLA sites. Treatability study performance goals are generally based on ARARs. Performance data indicating how well the process achieved these goals will aid in evaluating the technology against the compliance with ARARs criterion.

Chemical-specific ARARs are health or risk-based numerical values or methodologies that, when applied to site-specific conditions, result in the establishment of maximum acceptable amounts or concentrations of chemicals that may be found in or discharged to the ambient environment. For example, chemical-specific ARARs may include RCRA Land Disposal Restrictions (LDRs) on the placement of treated soil or Safe Drinking Water Act Maximum Contaminant Levels (MCLs) and Clean Water Act Water Quality Criteria for the treatment and discharge of wastewater. Chemical-specific ARARs will be expressed in terms of contaminant concentrations in the treated product and treatment residuals. Often, these ARARs define the "target" contaminants for the treatability study.

Location-specific ARARs are restrictions placed on the concentration of hazardous substances or the conduct of activities solely because they are in a specific location, such as a floodplain, a wetland, or a historic place. Location-specific cleanup criteria may include, for example, biotoxicity requirements for treated product and treatment residuals if runoff from the treatment area or the disposal site could have an impact on a sensitive wildlife habitat.

Action-specific ARARs are technology- and activity-based requirements or limitations on actions taken with respect to hazardous wastes. Action-specific requirements may be particularly applicable to the discharge of residuals such as wastewater. Target contaminant concentrations in the treatability study wastewater will aid in identifying action specific ARARs.

The actual determination of which requirements are applicable or relevant and appropriate will be made by the lead agency. Detailed guidance on determining whether requirements are applicable or relevant and appropriate is provided in *CERCLA Compliance with Other Laws Manual: Interim Final* (EPA 1988c) and *CERCLA Compliance with Other Laws Manual: Part II* (EPA 1989f).

Primary Balancing Criteria

The five primary balancing evaluation criteria should be used for guidance in setting treatability study test objectives.

Long-Term Effectiveness and Permanence

This evaluation criterion addresses risks remaining at the site after the remedial response objectives have been met.

Overall Protection of Human Health and the Environment	Compliance With ARARs
• How Alternative Provides Human Health and Environmental Protection	• Compliance With Chemical-Specific ARARs • Compliance With Action-Specific ARARs • Compliance With Location-Specific ARARs • Compliance With Other Criteria, Advisories, and Guidances

Long-Term Effectiveness and Permanence	Reduction of Toxicity, Mobility, or Volume Through Treatment	Short-Term Effectiveness	Implementability	Cost
• Magnitude of Residual Risk • Adequacy and Reliability of Controls	• Treatment Process Used and Materials Treated • Amount of Hazardous Materials Destroyed or Treated • Degree of Expected Reductions in Toxicity, Mobility, and Volume • Degree to which Treatment is Irreversible • Type and Quantity of Residuals Remaining After Treatment	• Protection of Community During Remedial Actions • Protection of Workers During Remedial Actions • Environmental Impacts • Time Until Remedial Response Objectives Are Achieved	• Ability to Construct and Operate the Technology • Reliability of the Technology • Ease of Undertaking Additional Remedial Actions, If Necessary • Ability to Monitor Effectiveness of Remedy • Ability to Obtain Approvals From Other Agencies • Coordination With Other Agencies • Availability of Offsite Treatment, Storage, and Disposal Services and Capacity • Availability of Necessary Equipment and Specialists • Availability of Prospective Technologies	• Capital Costs • Operating and Maintenance Costs • Present Worth Cost

State Acceptance*	Community Acceptance*

* These criteria are assessed following comment on the RI/FS report and the proposed plan.

EPA 1988a

Figure 10. Evaluation criteria and analysis factors for detailed analysis fo alternatives.

EXAMPLE 5. APPLICABILITY OF CHEMICAL DEHALOGENATION TREATABILITY STUDY DATA TO RI/FS EVALUATION CRITERIA

Evaluation Criteria	Analysis Factors	Treatabillity Study Data
Long-Term Effectiveness and permanence	Magnitude of residual risk	• Target contaminant concentrations in treated product and treatment residuals • Presence of specific reaction byproducts in treated product • Results of bioassays performed on treated product
Reduction of Toxicity, Mobility, or Volume Through Treatment	Reduction in toxicity	• Percent reduction in target contaminant concentrations • Comparison of bioassay results before and after treatment
	Irreversibility of the treatment	• Material balance data combined with target contamination concentrations in treated product and treatment residuals
	Type and quantity of, and risks posed by, treatment residuals	• Target contaminant concentrations in treatment residuals • Presence of specific reaction byproducts in treatment residuals • Results of bioassays performed on treatment residuals • Volume of treatment residuals
Short-Term Effectiveness	Time until remedial response objectives are achieved	• Reaction time
Implementability	Reliable and potential for schedule delays	• Reliability and schedule delays during testing • Reaction time/throughout • Physical characteristics of waste matrix • Contaminant variability in untreated waste
Cost	Direct capital costs	• Reaction time/throughout • Reaction usage/recovery • Reaction temperature • Physical characteristics of waste matrix • Site characteristics
Compliance with ARARs	Chemical-specific ARARs	• Target contaminant concentrations in treated product and treatment residuals
Overall Protection of Human Health and the Environment	Ability to eliminate, reduce, or control site risks	• Target contaminant concentrations in treated product and treatment residuals • Presence of specific reaction byproducts in treated product and treatment residuals • Results of bioassays performed on treated product and treatment residuals

Assessment of the residual risks from untreated waste and treated product left on site must involve the same assumptions and calculation procedures as those used in the baseline risk assessment. If engineered controls (e.g., containment systems) are to be used to manage these remaining materials, their adequacy and reliability also should be evaluated under this criterion.

Remedy-selection treatability studies can often provide data on the site's post-remediation residual risk. If treated product will remain on site, the contaminant concentrations in this material must meet the site's cleanup criteria. As discussed in Subsection 2.4, these cleanup criteria translate into specific performance goals. The concentrations of target contaminants in the treated product and treatment residuals after treatability testing indicate the magnitude of the site's residual risk after treatment.

If an ecological risk assessment is to be performed, the residual risks posed to biota by the replacement of the treated product on site can be assessed under this criterion. The literature survey may provide adequate data to evaluate the biotoxicity of treated soils. If the literature contains little or no biotoxicity data on the contaminants/matrix of interest, this data need can be addressed by performing bioassays at the remedy-selection tier. A treatability study test objective that stipulates a reduction in the toxicity of the treated product to test organisms will provide data for the assessment of the technology against the long-term effectiveness and permanence criterion.

Reduction of Toxicity, Mobility, and Volume Through Treatment

This evaluation criterion addresses the statutory preference for selecting technologies that permanently and significantly reduce the toxicity, mobility, or volume of the hazardous substances. This preference is satisfied when treatment is used to reduce the principal threats at a site through destruction of toxic contaminants, reduction of the total mass of toxic contaminants, irreversible reduction in contaminant mobility, or reduction of the total volume of contaminated media.

Treatability studies should provide detailed performance data on the percentage, reduction in the toxicity, mobility, or volume of the treated product. As discussed in Subsection 2.4, a performance goal of greater than 50 percent reduction in toxicity, mobility, or volume may be appropriate at the remedy-screening tier. If this performance goal is met, the technology is considered to be potentially feasible. At the remedy-selection tier, the process should be capable of achieving the site cleanup criteria with an acceptable level of confidence. If no cleanup criteria have been established for the site, a 90 percent reduction in contaminant concentration will generally be an appropriate performance goal.

Another measure of reduction in toxicity is the comparison of bioassay results from tests performed on the waste before and after treatment. If treated product is to remain on site, a reduction in biotoxicity should be identified as a treatability test objective for remedy-selection testing.

Irreversibility of the treatment process is another factor in the evaluation of a technology against this criterion. Material balance data from a treatability study combined with the target contaminant concentrations found in the treated product and treatment residuals can indicate the level of irreversibility achieved through treatment. These data can be used to construct a mass balance for the target contaminants, which will approximate the contaminant destruction efficiency of the treatment process.

Taking the treatment residuals into consideration is an important part of the assessment of a technology against the reduction in toxicity, mobility, and volume criterion. Concentrations of target contaminants in treatability study residuals indicate the risks posed by onsite treatment and disposal of the process residuals. Data on the biotoxicity and volume of treatability study residuals also provide information for this assessment.

Short-Term Effectiveness

The short-term effectiveness criterion is concerned with the effects of the alternative on human health and the environment during its construction and implementation. The RI/FS guidance outlines several factors that may be addressed, if appropriate, when assessing an alternative against this criterion. Treatability studies can provide information on three of these factors: 1) protection of the community during remedial actions, 2) protection of the workers, and 3) time required to achieve remedial response objectives.

If a site is located near a population center, any short-term health risks posed by the remedial action must be addressed. The treatability study waste characterization can identify some of these risks. For example, physical characteristics of the waste matrix, such as moisture content and particle-size distribution, could indicate a potential for the generation of contaminated dust during material-handling operations. The presence or volatile contaminants in the waste also could pose risks to community health during material handling and treatment. Treatment residuals should be carefully characterized to assist in the post-ROD design of proper air and water treatment systems.

For the protection of workers during implementation of the remedy, the physical and chemical characteristics of the untreated waste matrix and the treatment residuals are important data to be collected during treatability testing. These data will aid in the assessment of any threats posed to workers and the effectiveness and reliability of the protective measures to be taken. Treatability systems can also be monitored for any adverse conditions that may develop during testing.

The time required to achieve the remedial response objectives for the site depends on the volume of soil to be treated and the throughput of the full-scale unit or treatment train system. Treatability studies of some technologies will generate treatment duration data sufficient to allow estimates of throughput to be made.

Implementability

This evaluation criterion assesses the technical and administrative feasibility of implementing an alternative and the availability of the equipment and services required during implementation. The process of designing and performing treatability studies may assist in the analysis of the following implementability factors:

- Difficulties associated with construction and operation
- Reliability and potential for schedule delays
- Ability to monitor treatment effectiveness
- Commercial availability of the treatment process and equipment

The literature survey should provide historical information regarding most of the preceding factors. If an alternative has been shown to be capable of achieving the desired cleanup levels but has never been demonstrated at full scale, reliability data may be insufficient for its assessment under the implementability criterion. In this case, data from a pre-ROD pilot-scale test may be required.

The reliability of the pilot system, including any schedule delays encountered during its testing, will serve as an indicator of the implementability of the full-scale system. The treatment duration and throughput can also provide information on potential schedule delays. Characteristics of the matrix that could lead to equipment failure or diminished treatment effectiveness, such as high clay content, can be investigated during a pre-ROD treatability study. Contaminant variability in the untreated waste could also lead to schedule delays by requiring repeated treatment of some soils. Treatability testing of multiple waste types with differing contaminant concentrations can provide important data for analysis of the reliability factor and the implementability evaluation criterion.

Cost

The cost criterion evaluates the full-scale capital and operation and maintenance (O&M) costs of each remedial action alternative. The assessment of this criterion requires the development of cost estimates for the full-scale remediation of the site. These estimates should provide an accuracy of +50 percent to -30 percent. A comprehensive discussion of costing procedures for CERCLA sites is included in *Remedial Action Costing Procedures Manual* (EPA 1985). The cost estimate prepared under this criterion will be based on information obtained from the literature and from technology vendors. Preparation of the estimate may also require remedy-selection treatability study data.

Direct capital costs for treatment will include expenditures for the equipment, labor, and materials necessary to install the system. If the technology vendor has already constructed a mobile, full-scale treatment unit, treatability study data will not be required to determine direct equipment costs. If no full-scale system exists, however, treatability studies can provide the operational data necessary for equipment scale-up. Characteristics of the matrix identified during treatability testing, such as particle-size distribution and moisture content, will have an impact on decisions regarding front-end material handling operations and equipment and post-treatment equipment for processing of the product and residuals in a treatment train. Characteristics of the site that may have an impact on the logistical costs associated with mobilization and onsite treatment can be identified during the treatability study sample-collection visit.

Estimates of utility costs, residuals treatment and disposal costs, and O&M costs will depend on the physical/chemical characteristics of the waste and residuals (which affect the difficulty of treatment) and the throughput (which affects the total time for treatment). These data are available from remedy-selection treatability studies.

3.11.3 Data Interpretation/Post-ROD

As opposed to pre-ROD treatability studies, no clearly defined criteria exist on which to base the interpretation of post-ROD RD/RA treatability study results. The purpose of an RD/RA treatability study is to generate specific, detailed design, cost, and performance data. These data are then used 1) to prequalify vendors and processes within the prescribed remedy, 2) to implement the most appropriate of

the remedies prescribed in a Contingency ROD, or 3) to support preparation of the Agency's detailed design specifications and the design of treatment trains.

When an RD/RA treatability study is performed to prequalify vendors, data interpretation consists of a straightforward determination by the lead agency or the designer regarding whether the vendor has attained the preset performance goals. Little or no cost data are generated by prequalification treatability studies. Based on these results, the lead agency determines which vendors are qualified to bid on the RA. Generally, the vendor should achieve results equivalent to the cleanup criteria defined in the ROD to be considered for prequalification.

In the case of a Contingency ROD, implementation of the selected remedy may depend on the results of RD/RA treatability testing. Treatability studies performed to support a Contingency ROD are designed to obtain performance and cost data on the selected remedy that were not available during the RI/FS. After this information is obtained, data interpretation focuses on determining whether the selected remedy will provide superior protection of human health and the environment at a cost comparable to that of the contingency remedy. If so, the selected remedy is designed and implemented. If not, the contingency remedy is implemented.

Post-ROD treatability study results are also used to support the preparation of the detailed design specifications and the design of treatment trains. Because the treatability study is designed to provide specific detailed operations data on the remedy for use by the remedial design contractor, the designer is generally responsible for data interpretation.

3.12 Reporting the Results

3.12.1 General

The final step in conducting a treatability study is reporting the test results. Complete and accurate reporting is critical, as decisions about treatment alternatives will be based partly on the outcome of the treatability studies. Besides assisting in the selection and implementation of the remedy, the performance of treatability studies will increase the existing body of scientific knowledge about treatment technologies.

To facilitate the reporting of treatability study results and the exchange of treatment technology information, Table 13 presents a suggested organization for a treatability study report. Reporting treatability study results in this manner will expedite the process of comparing treatment alternatives. It will also allow other individuals who may be studying similar technologies or waste matrices to gain valuable insight into the applications and limitations of various treatment processes.

If a treatment technology is to be tested at multiple tiers, preparation of a formal report for each tier of the testing may not be necessary. Interim reports prepared at the completion of each tier may suffice. Also, it may be appropriate to conduct a project briefing with the interested parties to present the study findings and to determine the need for additional testing. A final report that encompasses the entire study should be developed after all testing is complete.

As an aid in the selection of remedies and the planning of future treatability studies, the Office of Emergency and Remedial Response requires that a copy of all treatability study reports be submitted to the Agency's RREL Treatability Data Base repository, which is being developed by the ORD (EPA 1989e). This requirement applies to both the removal and remedial programs of Superfund. Submitting treatability study reports in accordance with the suggested organization will increase the usability of this repository and assist in maintaining and updating the data base. One camera-ready master copy of each treatability study report should be sent to the following address:

Mr. Glenn M. Shaul
RREL Treatability Data Base
U.S. Environmental Protection Agency
Office of Research and Development
Risk Reduction Engineering Laboratory
26 W. Martin Luther King Drive
Cincinnati, Ohio 45268

The following subsections describe the contents or the treatability study report.

Introduction

The introductory section of the treatability study report contains background information about the site, waste stream, and treatment technology. Much of this information will come directly from the previously prepared treatability study Work Plan. This section also includes a summary of any treatability studies previously conducted at the site.

Conclusions and Recommendations

This section of the report presents the conclusions and recommendations regarding the applicability of the treat-

Table 13. Suggested Organization of Treatability Study Report

1. Introduction
   - 1.1 Site description
     - 1.1.1 Site name and location
     - 1.1.2 History of operations
     - 1.1.3 Prior removal and remediation activities
   - 1.2 Waste stream description
     - 1.2.1 Waste matrices
     - 1.2.2 Pollutants/chemicals
   - 1.3 Treatment technology description
     - 1.3.1 Treatment process and scale
     - 1.3.2 Operating features
   - 1.4 Previous treatability studies at the site
2. Conclusions and Recommendations
   - 2.1 Conclusions
   - 2.2 Recommendations
3. Treatability Study Approach
   - 3.1 Test objectives and rationale
   - 3.2 Experimental design and procedures
   - 3.3 Equipment and materials
   - 3.4 Sampling and analysis
     - 3.4.1 Waste stream
     - 3.4.2 Treatment process
   - 3.5 Data management
   - 3.6 Deviations from the Work Plan
4. Results and Discussion
   - 4.1 Data analysis and interpretation
     - 4.1.1 Analysis of waste stream characteristics
     - 4.1.2 Analysis of treatability study data
     - 4.1.3 Comparison to test objectives
   - 4.2 Quality assurance/quality control
   - 4.3 Costs/schedule for performing the treatability study
   - 4.4 Key contacts

References

Appendices

A. Data summaries
B. Standard operating procedures

ment process tested. It should attempt to answer questions such as the following:

- Were the performance goals met? Were the other test objectives achieved? If not, why not?
- Were there any problems with the treatability study design or procedures?
- What parts of the test (if any) should have been performed differently? Why?
- Are additional tiers of treatability testing required for further evaluation of the technology? Why or why not?
- Are data sufficient for adequately assessing the technology against the RI/FS evaluation criteria (if pre-ROD)?
- Are data sufficient for designing and implementing the remedy (if post-ROD)?

The conclusions and recommendations should be stated briefly and succinctly. Information that is pertinent to the discussion and exists elsewhere in the report should be referenced rather than restated in this section.

This section should provide an analysis of the results as they relate to the objectives of the study and the relevant evaluation criteria. When appropriate, the results should be extrapolated to full-scale operation to indicate areas of uncertainty in the analysis and the extent of this uncertainty.

Treatability Study Approach

This section reports why and how the treatability study was conducted. It describes in detail the procedures and methods that were used to sample and analyze the waste stream and documents any deviations from the Work Plan. Like the introduction, this section contains information from the previously prepared Work Plan.

Results and Discussion

The final section of the treatability study report includes the presentation and a discussion of results (including QA/QC). Results for the contaminants of concern should be reported in terms of the concentration in the input and output streams and the percentage reduction in toxicity, mobility, or volume that was achieved. The use of charts and graphs may aid in the presentation of these results. This section also includes the costs and time required to conduct the study and any key contacts for future reference.

Appendices

Summaries of the data generated and the standard operating procedures used are included in appendices,

3.12.2 Remedy Screening

Remedy screening results will be reported in the format shown in Table 13; however, some of the sections may be

abbreviated if remedy-selection testing is planned. The conclusions and recommendations will focus primarily on whether the technology investigated is potentially feasible for the site and will attempt to identify critical parameters for future treatability testing. Data will be presented in simple tables or graphs. Statistical analysis is generally not required. Because remedy screening does not involve rigorous QA/QC, the discussion of this subject will be brief.

3.12.3 Remedy-Selection Testing

Conclusions and recommendations resulting from remedy-selection testing will focus primarily on the technology's performance (i.e., ability to meet the performance goals and test objectives) and will attempt to identify critical parameters for future treatability testing, if needed. A detailed discussion of data quality should be included in the results section. The results section may also include a statistical evaluation of the data.

3.12.4 RD/RA Testing

Conclusions and recommendations resulting from RD/RA testing will focus on the technology's ability to achieve the performance goals and test objectives. Any process optimization parameters that were identified should also be discussed. The results should include a detailed discussion of data quality.

REFERENCES

dePercin, P., E. Bates, and D. Smith. 1991. Designing Treatability Studies for CERCLA Sites: Three Critical Issues. J. Air Waste Manage. Assoc., 41(5):763-767.

National Institute for Occupational Safety and Health/Occupational Safety and Health Administration/U.S. Coast Guard/U.S. Environmental Protection Agency. 1985. Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities. DHHS (NIOSH) Publication No. 85-115.

U.S. Environmental Protection Agency. 1980. Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans. QAMS-005/80.

U.S. Environmental Protection Agency. 1985. Remedial Action Costing Procedures Manual. EPA/600/8-87/049. OSWER Directive No. 9355.0-10.

U.S. Environmental Protection Agency. 1986. Test Methods for Evaluating Solid Waste. 3rd ed. SW-846.

U.S. Environmental Protection Agency. 1987a. Data Quality Objectives for Remedial Response Activities. Development Process (Volume I). EPA/540/G-87/003, OSWER Directive 9355.0-7B.

U.S. Environmental Protection Agency. 1987b. A Compendium of Superfund Field Operations Methods. EPA/540/P-87/001.

U.S. Environmental Protection Agency. 1987c. Revised Procedures for Implementing Off-Site Response Actions. OSWER Directive No. 9834.11, November 13, 1987.

U.S. Environmental Protection Agency. 1988a. Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA. Interim Final. EPA/540/G-89/004. OSWER Directive 9355.3-01.

U.S. Environmental Protection Agency. 1988b. Community Relations in Superfund: A Handbook. Interim Version. EPA/540/G-88/002. OSWER Directive 9230.0-3B.

U.S. Environmental Protection Agency. 1988c. CERCLA Compliance with Other Laws Manual: Interim Final. EPA/540/G-89/006.

U.S. Environmental Protection Agency. 1989a. Management Review of the Superfund Program. EPA/540/8-89/007.

U.S. Environmental Protection Agency. 1989b. Guide for Conducting Treatability Studies Under CERCLA. Interim Final. EPA/540/2-89/058.

U.S. Environmental Protection Agency. 1989c. Model Statement of Work for a Remedial Investigation and Feasibility Study Conducted by Potentially Responsible Parties. OSWER Directive No. 9835.8, June 2, 1989.

U.S. Environmental Protection Agency. 1989d. Quality Assurance Procedures for RREL. RREL Document Control No. RREL(QA)-001/89.

U.S. Environmental Protection Agency. 1989e. Treatability Studies Contractor Work Assignments. Memo from Henry L. Longest, II, Director, Office of Emergency and Remedial Response, to Superfund Branch Chiefs, Regions I through X. OSWER Directive 9380.3-01, July 12, 1989.

U.S. Environmental Protection Agency. 1989f. CERCLA Compliance with Other Laws Manual: Part II. Clean Air Act and Other Environmental Statutes and State Requirements. EPA/540/G-89/009. OSWER Directive No. 9234.1-02.

U.S. Environmental Protection Agency. 1990a. Inventory of Treatability Study Vendors, Volumes I and II. EPA/540/2-90/003a and b.

U.S. Environmental Protection Agency. 1990b. A Guide to Selecting Superfund Remedial Actions. OSWER Directive 9355.0-27FS.

U.S. Environmental Protection Agency. 1991a. Guidance for Increasing the Application of Innovative Treatment Technologies for Contaminated Soil and Ground Water. OSWER Directive 9380.0-17, June 10, 1991.

U.S. Environmental Protection Agency. 1991b. Guidance on Oversight of Potentially Responsible Party Remedial Investigations and Feasibility Studies. Volume 1. EPA/540/G-91/010a. OSWER Directive No. 9835.1(c).

U.S. Environmental Protection Agency. 1991c. Administrative Order on Consent for Remedial Investigation/Feasibility Study. OSWER Directive No. 9835.3-2A, July 2, 1991.

APPENDIX A
SOURCES OF TREATABILITY INFORMATION

A wide range of technical resources exists within the EPA to assist in the planning and performance of treatability studies. These resources include reports and guidance documents, electronic data bases, and Agency-sponsored technical support. This appendix describes the primary treatability study resources currently available.

Reports and Guidance Documents

Knowledge gained during the performance of treatability studies is available in reports and technical guidance documents. The following documents can be used to identify technology-specific treatability resources.

Superfund Treatability Clearinghouse Abstracts. U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, DC. EPA/540/2-89/001, March 1989.

Inventory of Treatability Study Vendors, Volumes I and II. U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, DC. EPA/540/2-90/003a and b, February 1990.

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, DC. EPA/540/5-90/006, November 1990.

Guide to Treatment Technologies for Hazardous Wastes at Superfund Sites. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, DC. EPA/540/2-89/052, March 1989.

Treatability Potential for EPA Listed Hazardous Wastes in Soil. U.S. Environmental Protection Agency, Office of Research and Development, Ada, OK. EPA/600/2-89/011, March 1989.

Catalog of Superfund Program Publications. U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, DC. EPA/540/8-90/015, October 1990.

Electronic Information Systems

Several electronic data bases and information systems are available to Federal, State, and private sector personnel for retrieving innovative technology and treatability data.

RREL Treatability Data Base

Contact: Glenn Shaul
Risk Reduction Engineering Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
(513) 569-7408

Developed by the Risk Reduction Engineering Laboratory (RREL), this data base provides data on the treatability of contaminants in water, soil, debris, sludge, and sediment. Target users include Federal and State agencies, academia, and the private sector. For each contaminant, the data base provides physical/chemical properties and treatability data such as technology types, matrices treated, study scale, and treatment levels achieved. Each data set is referenced and quality-coded based on the analytical methods used, the quality assurance/quality control efforts reported, and operational information.

Version 4.0 of the data base is provided on a computer diskette free of charge. The menu-driven program is compiled and does not require specialized software. Computer hardware and software requirements are as follows:

- IBM-compatible personal computer and monitor
- 8-megabyte hard disk storage
- 640-K RAM memory
- DOS versions 2.0 to 3.3 or 5.0
- 12-pitch printer

Requests for the data base must specify diskette format (3½ HD, 5¼ HD, or DD).

Alternative Treatment Technology Information Center

Contact: Greg Ondich
Office of Environmental Engineering and Technology Demonstration
U. S. Environmental Protection Agency
(202) 260-5747

System Operator
(301) 670-6294

System (online)
(301) 670-3808

The Alternative Treatment Technology Information Center (ATTIC) is a comprehensive information retrieval system containing up-to-date technical information on innovative methods for treatment of hazardous wastes. Designed for use by remediation personnel in the Federal, State, and private sectors, ATTIC can be easily accessed free of charge through an online system or the system operator.

The ATTIC system is a collection of hazardous waste data bases that are accessed through a bulletin board. The bulletin board includes features such as news items, special interest conferences (e.g., the Bioremediation Special Interest Group), and a message board that allows direct communications between users and with the ATTIC System Operator (i.e., Chat Mode). Users can access any of four data bases: 1) the main ATTIC Data Base; 2) the RREL Treatability Data Base; 3) the Technical Assistance Directory, which identifies experts on a given technology or contaminant type; and 4) the Calendar of Events, which contains information on upcoming relevant conferences, seminars, and workshops.

The main ATTIC Data Base contains abstracts of Federal, State, and private sector technical reports collected into a keyword searchable format. Technologies are grouped into five categories: 1) biological treatment, 2) chemical treatment, 3) physical treatment, 4) solidification/stabilization, and 5) thermal treatment.

In 1992, users of ATTIC will have online access to the Inventory of Treatability Study Vendors (ITSV) data base. The ITSV will aid in identifying vendors possessing qualifications to perform specific types of treatability studies and will supplement the existing two-volume, hard-copy publication of the same name developed by RREL. The online version of the ITSV will give users the ability to screen the data base electronically and to review the information by each of three main categories: technology, media, and contaminant group.

Users can access ATTIC directly with a personal computer and a modem. New users can register themselves and assign their own password by calling the ATTIC System. Communications software should be set according to the following parameters prior to dialing:

- Baud Rate: 1200 or 2400
- Terminal Emulation: VT-100
- Data Bits: 8
- Stop Bits: 1
- Parity: None
- Duplex: Full

The ATTIC User's Guide is available by calling the System Operator or leaving a message on the bulletin board.

Computerized On-Line Information System

Contact: Robert Hillger
Risk Reduction Engineering Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
(908) 321-6639

System Operator
(908) 906-6851

System (online)
(908) 548-4636

The Computerized On-Line Information System (COLIS) is operated by the Technical Information Exchange (TIX) at the EPA's Risk Reduction Engineering Laboratory in Edison, New Jersey. A consolidation of several computerized data bases, COLIS currently contains the following files:

- Underground Storage Tank (UST) Case History File–provides technical assistance to Federal, State, and local officials in responding to UST releases.
- Library Search System–contains catalog cards and abstracts for technical documents in the TIX Library.
- SITE Applications Analysis Reports–provides performance and cost information on technologies evaluated under the Superfund Innovative Technology Evaluation (SITE) Program.
- RREL Treatability Data Base

The system is menu-oriented, and online help is available. Federal, State, and private sector personnel can access COLIS free of charge by using a personal computer, a modem, and a communications program. The COLIS User's Guide is available by contacting the System Operator.

Vendor Information System for Innovative Treatment Technologies

Contact: VISITT Hotline
(800) 245-4505

The Vendor Information System for Innovative Treatment Technologies (VISITT) is an automated data base that provides information on innovative treatment technologies. The data base contains information submitted by developers and vendors of innovative treatment technology equipment and services. Technologies to treat ground water in situ, soils, sludges, and sediments are included.

Each vendor file in VISITT includes information on the vendor, the technology, and the applicable contaminants/matrices. Performance data, unit costs, equipment availability, permits obtained, treatability study capabilities, and references may also be available for some vendors/technologies.

The VISITT data base is available on diskette and requires a personal computer using a DOS operating system. Future updates may be available on-line.

Superfund Technical Support Project

Contact: Marlene Suit
Technology Innovation Office
Office of Solid Waste and Emergency Response
U.S. Environmental Protection Agency
(703) 308-8800

The Office of Solid Waste and Emergency Response (OSWER), Regional Superfund Offices, and the Office of Research and Development (ORD) established the Superfund Technical Support Project (TSP) in 1987 to provide direct, technology-based assistance to the Regional Superfund programs through ORD laboratories. The project consists of a network of Regional Technical Support Forums, five specialized Technical Support Centers (TSCs) located in ORD laboratories, and one TSC located at the Office of Emergency and Remedial Response (OERR) Environmental Response Branch. The objectives of the TSP are:

- To provide state-of-the-science technical assistance to Regional Remedial Project Managers (RPMs) and On-Scene Coordinators (OSCs).
- To improve communications among the Regions and the ORD laboratories.
- To ensure coordination and consistency in the application of remedial technologies.
- To furnish high-technology demonstrations, workshops, and information to RPMs and OSCs.
- To facilitate the evaluation and application of alternative investigatory and remedial techniques at Superfund sites.

The TSP is accessed by contacting one of the TSC Directors. Any Regional staff member involved in the Superfund program can contact the Centers directly or with the assistance of a Forum member from their Region. Additional information on the TSP is available in:

> Superfund Technical Support Project: Guide for RPMs/OSCs. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Technology Innovation Office, Washington, DC.

Engineering Technical Support Center

Contact: Ben Blaney or Joan Colson
Risk Reduction Engineering Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
(513) 569-7406

One of the TSCs is the Engineering Technical Support Center (ETSC) located at ORD's RREL Technical Support Branch in Cincinnati, Ohio. The ETSC provides technical assistance for reviewing and overseeing treatability work plans and studies, feasibility studies, sampling plans, remedial designs, remedial actions, and traditional and innovative remediation technologies. Areas of expertise include treatment of soils, sludges, and sediments; treatment of aqueous and organic liquids; materials handling and decontamination; and contaminant source control structures. The following are examples of the types of technical assistance that can be obtained through the ETSC and the RREL Technical Support Branch:

- Characterization of a site for treatment technology identification
- Performance of remedy-screening treatability studies and support for treatability studies of innovative technologies at all tiers of testing
- Review of treatability study RFPs, work plans, and final reports
- Oversight of treatability studies performed by contractors and PRPs
- Assistance in design and startup of full-scale systems

Treatability study assistance through the Superfund Technical Assistance Response Team (START) discussed in Section 3.3 is also available through the ETSC contact listed here.

Environmental Response Team Technical Support Center

Contact: Joseph LaForNara
Environmental Response Branch
Office of Emergency and Remedial Response
U.S. Environmental Protection Agency
(908) 321-6740

The Environmental Response Team (ERT) TSC is located at the OERR Environmental Response Branch in Edison, New Jersey. The ERT provides technical expertise for the development and implementation of innovative treatment technologies through its Alternative Technology Section.

The following are examples of the types of technical assistance that can be obtained through the ERT:

- Consultation on water and air quality criteria, ecological risk assessment, and treatability study test objectives
- Development and implementation of site-specific health and safety programs
- Performance of in-house bench- and pilot-scale treatability studies of chemical, physical, and biological treatment technologies
- Sampling and analysis of air, water, and soil
- Provision of onsite analytical support
- Oversight of treatability study performance
- Interpretation and evaluation of treatability study data

APPENDIX B
COST ELEMENTS ASSOCIATED WITH TREATABILITY STUDIES

Section 2 of this guide describes three tiers of treatability testing: remedy screening, remedy-selection testing, and remedial design/remedial action testing. This appendix presents the cost elements associated with the various tiers of treatability studies. In some cases, unit costs are provided; in other cases, project-specific examples are provided that lend insight into the costs of various elements of treatability studies.

Many cost elements are applicable to all levels of treatability testing; however, some (e.g., the volume of residuals or cost of analytical services) will increase from remedy screening to remedy-selection testing to RD/RA testing. Other cost elements (e.g., site preparation and utilities) are only applicable to RD/RA testing. Figure 11 shows the applicability of the various cost elements to the different treatability study tiers. The following is a discussion of some of the key cost elements.

Vendor equipment rental is a key cost element in the performance of RD/RA testing. Most vendors have established daily, weekly, and monthly rates for the use of their treatment systems. These charges cover wear and tear on the system, utilities, maintenance and repair, and system preparation. In some cases, vendors include their operators, personal protective equipment, chemicals, and decontamination in the rental charge. Treatment system rental charges typically run about $5,000 to $20,000 per week. Also, if the vendor sets up a strict timetable for testing, the client may be billed $4000 to $5000 a day for each day the waste is late in arriving at the facility.

Site preparation and logistics costs include costs associated with planning and management, site design and development, equipment and facilities, health and safety equipment, soil excavation, feed homogenization, and feed handling. Costs associated with the majority of these activities are normally incurred only with RD/RA testing of mobile field-scale units; however, some of these cost elements (e.g., feed homogenization and health and safety) are also incurred in bench- and pilot-scale remedy-selection testing.

Analytical costs apply to all tiers of treatability studies and have a significant impact on the total project costs. Several factors affect the cost of the analytical program, including the laboratory performing the analyses, the analytical target list, the number of samples, the required turnaround time, QA/QC, and reporting. Analytical costs vary significantly from laboratory to laboratory; however, before prices are compared, the laboratories themselves should be properly compared. The following are typical of questions that should be asked:

- What methods will be used for sample preparation and analysis?
- What detection limits are needed?
- Does each laboratory fully understand the matrix that will be received (e.g., tarry sludge, oily soil, slag) or interference compounds that may be in the sample (e.g., sulfide)?

If all information indicates that the laboratories are using the same methods and equipment and understand the objectives of the analytical program, the costs for analysis can be compared.

One should also be aware that some analytes cost more to analyze than others. Often, the project manager would like to investigate some analytes for informational purposes that may not be critical to the study. The decision as to whether to analyze for these parameters could be simple if the parameter-specific costs were known. For example, TOC analysis of soil costs about $90/sample, whereas analysis for total dioxins costs about $650/sample.

The number of samples, turnaround time, QA/QC, and reporting also affect analytical costs. Laboratories often give discounts on sample quantities greater than 5, greater than 10, and greater than 20 when the samples arrive in the laboratory at the same time. The laboratory also applies premium costs of 25, 50, 100, and 200 percent when ana-

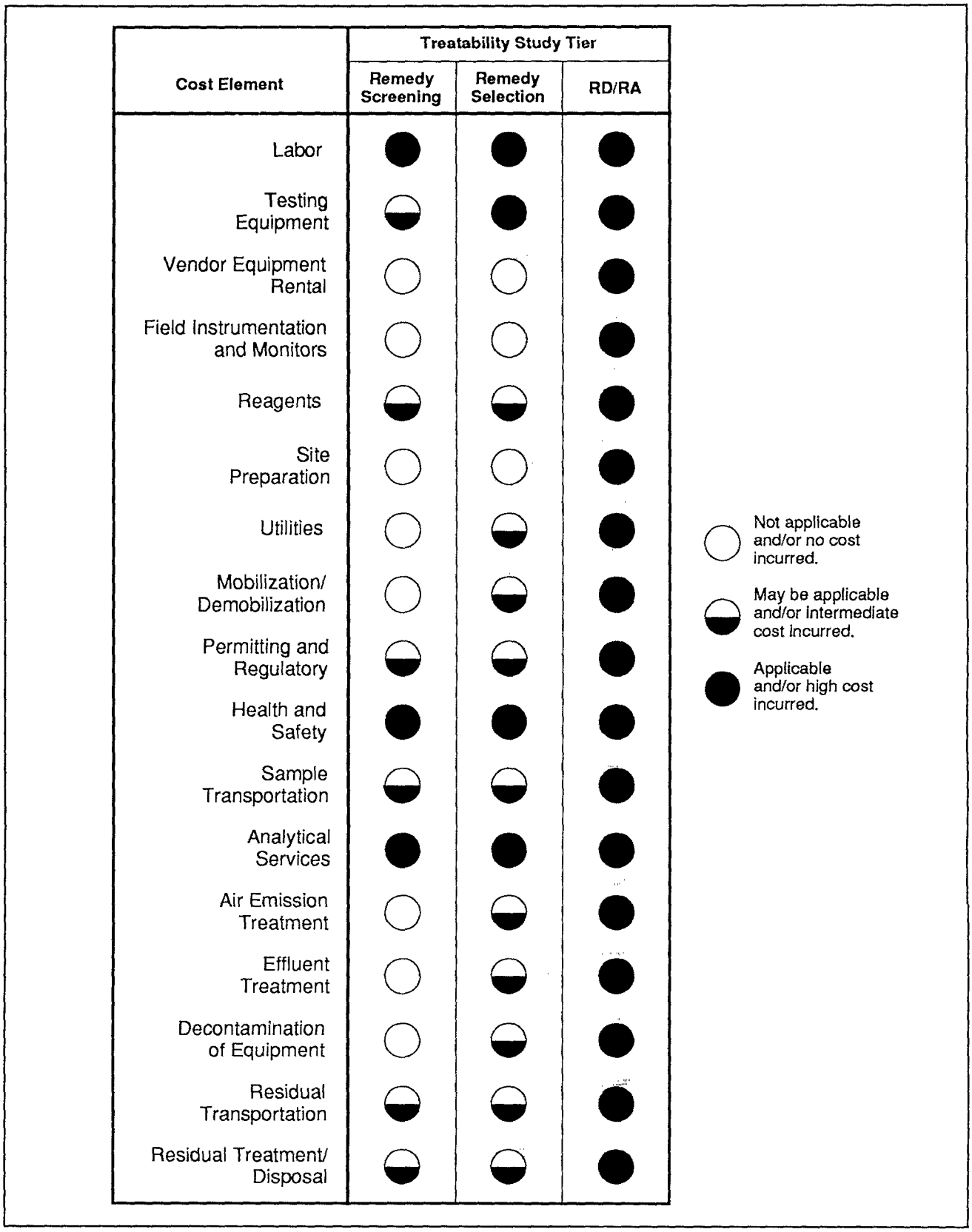


Figure 11. General applicability of cost elements to various treatability study tiers.

lytical results are requested faster than the normal turnaround time. If matrix spike and matrix spike duplicates are required, the analytical cost will triple for those QA/QC samples. Also, whether the laboratory provides a cover letter with the attached data or a complete analytical report will affect the analytical costs.

Residual transportation and disposal are also important elements that must be budgeted in the performance of all treatability studies. Depending on the technology(ies) involved, a number of residuals will be generated. Partially treated effluent, scrubber water, sludge, ash, spent filter media, scale, and decontamination liquids/solids are examples of residuals that must be properly transported and treated or disposed of in accordance with all local, State, and Federal regulations. Unused feed and excess analytical sample material also must be properly managed. Typically, a laboratory will add a small fee (e.g., $5 per sample) to dispose of any unused sample material; however, the unused raw material and residuals, which could amount to a sizeable quantity of material, will cost significantly more to remove. Transportation cost for a dedicated truck (as opposed to a truck making a "milk run") is about $3.25 to $3.75 per loaded mile. Costs for treatment of inorganic wastewaters may range from $65 to $200 per 55-gallon drum. Incineration of organic-contaminated wastewaters ranges from $200 to $1000 per 55-gallon drum, and landfilling a 55-gallon drum of inorganic solids could cost between $75 and $200. Disposal facilities also may have some associated fees, surcharges, and other costs for minimum disposal, waste approval, State and local taxes, and stabilization.

APPENDIX C
TECHNOLOGY-SPECIFIC CHARACTERIZATION PARAMETERS

The tables in Appendix C contain waste feed characterization parameters specific to biological, physical/chemical, immobilization, thermal, and in situ treatment technologies. Generally, these are the characterization parameters that must be established before a treatability test is conducted on the corresponding technology. Additional parameters may be required due to site-specific conditions.

Each table is divided by technology, waste matrix, parameter, and purpose of analysis. These tables are designed to assist the RPM in planning a treatability study.

Table 14. Waste Feed Characterization Parameters for Biological Treatment

Treatment Technology	Matrix	Parameter	Purpose
General	Soil/sludges	Physical:	
		Moisture content	To identify potential for microbial metabolism inhibition and need for pretreatment.
		Temperature	To identify potential for microbial metabolism inhibition and need for pretreatment.
		Oxygen availability	To identify potential for microbial metabolism inhibition and need for pretreatment.
		Chemical: pH	To identify potential for microbial metabolism inhibition and need for pretreatment.
		Total organic carbon	To determine the need for possible organic carbon supplementation to support acceptable levels of biological activity.
		Redox potential	To determine potential for stimulating and/or enriching growth of indigenous aerobic, anoxic, sulfate reducing, and obligate anaerobic microbial populations.
		C:N:P ratio	To determine mineral nutrient requirements.
		Heavy metals	To identify potential for microbial metabolism inhibition and need for pretreatment.
		Chlorides/inorganic salts	To identify potential for microbial metabolism inhibition and need for pretreatment.
		Biological: Soil biometry	To determine biodegradation potential and to quantify biodegradation rates.
		Respirometry	To identify oxygen uptake and boidegratation rates.
		Microbial identification and enumeration	To determine the indigenouse or adapted microbial population densities in the inoculum.
		Microbial toxicity/growth inhibition	To determine microbial activity.
	Liquids	Chemical: pH	To identify potential for microbial metabolism inhibition and need for pretreatment.
		Dissolved oxygen	To determine presence or absence of oxygen as a potential indicator, respectively, of the absence or presence of indigenous microbial activity.
		Chemical oxygen demand	To determine total oxygen demand, both organic and inorganic, in the liquid matrix.
		Biological: Biological oxygen demand	To determine the fraction of the chemical oxygen demand that is aerobically degradable.
		Respirometry	To determine oxygen uptake and biodegradation rates.
		Microbial identification and enumeration	To determine the indigenous or adapted microbial population densities in the inoculum.
		Microbial toxicity/growth inhibition	To determine microbial activity.

Table 15. Waste Feed Characterization Parameters for Physical/Chemical Treatment

Treatment Technology	Matrix	Parameter	Purpose and comments
General	Soils/sludges	Physical:	
		Type, size of debris	To determine need for pretreatment.
		Dioxins/furans, radionuclides, asbestos	To determine special waste-handling procedures.
Extraction - Aqueous - Solvent - Critical fluid - Air/steam	Soils/sludges	Physical: Particle size distribution	To determine volume reduction potential, pretreatment needs, solid/liquid separability.
		Clay content	To determine adsorption characteristics of soil.
		Moisture content	To determine conductivity of air through soil.
		Chemical:	
		Organics	To determine concentration of target or interfering constituents, pretreatment needs, extraction medium.
		Metals (total)	To determine concentration of target or interfering constituents, pretreatment needs, extraction medium.
		Metals (leachable)	To determine mobility of target constituents, posttreatment needs.
		Contaminant characteristics: • Vapor pressure • Solubility • Henry's Law constant • Partition coefficient • Boiling point • Specific gravity	To aid in selection of extraction medium.
		Total organic carbon, humic acid	To determine presence of organic matter, adsorption characteristics of soil.
		Cation exchange capacity	To determine adsorption characteristics of soil.
		Chemical oxygen demand	To determine fouling potential.
		pH	To determine pretreatment needs, extraction medium.
		Cyandies, sulfides, fluorides	To determine potential for generating toxic fumes at low pH.
		Biological: Biological oxygen demand	To determine fouling potential.
Chemical dehalogenation	Soils/sludges	Physical: Moisture content	To determine reagent formulation/loading.
		Particle-size distribution	To determine experimental apparatus.
		Chemical: Halogenated organics	To determine concentration of target constituents, reagent requirements.
		Metals	To determine concentration of other alkaline-reactive constituents, reagent requirements.
		pH/base absorption capacity	To determine reagent formulation/loading.
	Liquids	Chemical: Halogenated organics	To determine concentration of target constituents, reagent requirements.

Table 15. (continued)

Treatment Technology	Matrix	Parameter	Purpose and comments
Oxidation/ reduction	Soils/sludges	Physical:	
		Total suspended solids	To determine the need for slurrying to aid mixing.
		Chemical:	
		Chemical oxygen demand	To determine the presence of oxidizable organic matter, reagent requirements.
		Metals (Cr^{+3}, Hg, Pb, As)	To determine the presence of constitutions that could be oxidized to more toxic or mobile forms.
		pH	To determine potential chemical interferences.
Flocculation/ sedimentation	Liquids	Physical:	
		Total suspended soils	To determine reagent requirements.
		Specific gravity of suspended solids	To determine settling velocity of suspended solids.
		Viscosity of liquid	To determine settling velocity of suspended solids.
		Chemical:	
		pH	To aid in selection of flocculating agent.
		Oil and grease	To determine need for emulsifying agents, oil/water separation.
Carbon adsorption	Liquids	Physical:	
		Total suspended solids	To determine need for pretreatment to prevent clogging.
		Chemical:	
		Organics	To determine concentration of target constituents, carbon loading rate.
		Oil and grease	To determine need for pretreatment to prevent clogging.
		Biological:	
		Microbial plate count	To determine potential for biodegradation of adsorbed organics and/or problems due to clogging or odor generation.
	Gases	Physical:	
		Particulates	To determine need for pretreatment to prevent clogging.
		Chemical:	
		Volatile organic compounds, sulfur compounds, mercury	To determine concentration of target constituents, carbon loading rate.
Ion exchange	Liquids	Physical:	
		Total dissolved solids	To determine concentration of target constituents, carbon loading rate.
		Total suspended solids	To determine need for pretreatment to prevent clogging.
		Chemical:	
		Inorganic cations and anions, phenols	To determine concentration of target constituents.
		Oil and grease	To determine need for pretreatment to prevent clogging.

Table 15. (continued)

Treatment Technology	Matrix	Parameter	Purpose and comments
Reverse osmosis	Liquids	Physical:	
		Total suspended solids	To determine need for pretreatment to prevent plugging of membrane.
		Chemical:	
		Metal ions, organics	To determine concentration of target constituents.
		pH	To evaluate chemical resistance of membrane.
		Residual chlorine	To evaluate chemical resistance of membrane.
		Biological:	
		Microbial plate count	To determine potential of biological growth outside membrane that would cause plugging.
Liquid/liquid extraction	Liquid	Physical:	
		Solubility, specific gravity	To determine miscibility of solvent and liquid waste.
		Chemical:	
		Contaminant characteristics: • Solubility • Partition coefficient • Boiling point	To aid in selection of solvent, separation of phases, etc.
Oil/water separation	Liquids	Physical:	
		Viscosity	To determine separability of phases.
		Specific gravity	To determine separability of phases/emulsions.
		Settleable solids	To determine amount of residual solids.
		Temperature	To determine rise rate of oil globules.
		Chemical:	
		Oil and grease	To determine concentration of target constituents.
		Organics	To determine need for posttreatment.
Air/steam stripping	Liquids	Chemical:	
		Hardness	To determine potential for scale formation.
		Volatile organic compounds	To determine concentration of target constituents.
		Contaminant characteristic:	To determine strippability of contaminants, size of units, and need for posttreatment.
		• Solubility • Vapor pressure	To determine stripping factor.
		• Henry's Law constant • Boiling point	To determine packing height.
		• Mass transfer coefficient Chemical oxygen demand	To determine fouling potential.
		Biological:	
		Biological oxygen demand	To determine fouling potential.
Filtration	Liquids	Physical:	
		Total suspended solids	To determine need for pretreatment to prevent clogging.
		Total dissolved solids	To determine need for posttreatment.

Table 15. (continued)

Treatment Technology	Matrix	Parameter	Purpose and comments
Dissolved air flotation	Liquids	Physical:	
		Total suspended solids	To determine amount of residual sludge.
		Specific gravity	To determine separability of phases.
		Chemical:	
		Oil and grease	To determine concentration of target constituents.
		Volatile organic compounds	To determine need for air emission controls, posttreatment.
Neutralization	Liquids	Chemical:	
		Ph	To determine reagent requirements.
		Metals	To determine need for posttreatment.
		Acidity/alkalinity	To determine reagent requirements.
		Cyanides, sulfides, fluorides	To determine potential for generating toxic fumes at low pH.
Precipitation	Liquids	Chemical:	
		metals	To determine concentration of target constituents, reagent requirements.
		pH	To determine solubility of metal precipitates, reagent requirements.
		Organics, cyanides	To determine concentration of interfering constituents, reagent requirements.
Oxidation (alkaline chlorination)	Liquids	Chemical:	
		cyanides	To determine concentration of target constituents, reagent requirements.
		pH	To determine suitable reaction conditions.
		Organics	To determine potential for forming hazardous compounds with excess chlorine (oxidizing agent).
		Redox potential	To determine reaction success.
Reduction	Liquids	Chemical:	
		Metals (Cr^{+6}, Hg, Pb)	To determine concentration of target constituents, reagent requirements.
Hydrolysis	Liquids	Chemical:	
		Organics	To determine concentration of target constituents, reagent requirements, posttreatment needs.
		pH	To determine reagent requirements.

Table 16. Waste Feed Characterization Parameters for Immobilization

Treatment Technology	Matrix	Parameter	Purpose and comments
Stabilization/ solidification	Soils/sludges	Physical:	
		Description of materials	To determine waste handling methods (e.g., crusher, shredder, removal equipment).
		Particle-size analysis	To determine surface area available for binder contact and leaching.
		Moisture content	To determine amount of waste to add/remove in S/S mixing process.
		Density testing	To evaluate changes in density between untreated and treated waste and to determine volume increase
		Weight ratio additives to waste	To determine effects of dilution due to volume increase.
		Chemical:	
		Total organic content	To determine reagent requirements.
		pH	To evaluate changes in leaching as function of pH between untreated and treated waste.
		Alkalinity	To evaluate changes in leaching as function of alkalinity between untreated and treated waste.
		Interfering compounds	To evaluate viability of S/S process. (Interfering compounds are those that impede fixation reactions, cause adverse chemical reactions, generate excessive heat; interfering compounds vary with type of S/S).
		Indicator compounds	To evaluate performance.
		Leach testing	
		• TCLP	To evaluate performance based on regulatory test.
		• TCLP-water	To evaluate performance under natural conditions.
		Heat of hydration	To measure temperature changes during mixing.
		Total waste analysis	To evaluate performance.
Vitrification	Soils/sludges	Physical:	
		Depth of contamination and water table	Technology is applied in unsaturated soils.
		Soil permeability	Dewatering of saturated soils may be possible. Technology is applied in unsaturated soils.
		Metal content of waste material and placement of metals within the waste	Greater the 5 to 15% by weight or significant amounts of metal near electrodes interfere with process.
		Combustible liquid/solid content of waste	Greater than 5 to 15% by weight interferes with process (may ignite).
		Rubble content of waste	Greater than 10 to 20% by weight interferes with process
		Void volumes	large, individual voids (greater than 150 ft^3) impede process, may cause subsidence.
		Moisture content	To determine power requirements.
		Particle-size analysis	To determine surface area available for binder contact and leaching.
		Chemical:	
		Leach testing	To evaluate performance.
		Total waste analysis	To evaluate performance.

Table 17. Waste Feed Characterization Parameters for Thermal Treatment

Treatment technology	Matrix	Parameter	Purpose and comments
General	Soils/sludges	Physical:	
		Moisture content	Affects heat value and material handling.
		Ash content	To determine the amount of ash that must be disposed or treated further.
		Ash fusion temperature	High temperature can cause slagging problems with inorganic salts having low melting points.
		Heat value	To determine auxiliary fuel requirements and feed rates.
		Chemical:	
		Volatile organics, semivolatile organics	Allows determination of principal organic hazardous constituents.
		Principal organic hazardous constituents	Allows determination of destruction and removal efficiency.
		Total halogens	To determine air pollution control devices for control of acid gases.
		Total sulfur, total nitrogen	Emissions of SO_x and No_x are regulated; to determine air pollution devices.
		Phosphorus	Organic phosphorus compounds may contribute to refractory attack and slagging problems.
		PCBs and dioxins (if suspected)	99.9999% destruction and removal efficiency required for PCBs; safety considerations; incineration is required if greater than 500 ppm PCBs present.
		Metals	Volatile metals (Hg, Pb, Cd, Zn, As, Sn) may require flue-gas treatment; other metals may concentrate in ash. Trivalent chromium may be oxidized to hexavalent chromium, which is more toxic. Presence of inorganic alkali salts, especially potassium and sodium sulfate, can cause slagging. Determine posttreatment needs.
	Liquids	Physical: Viscosity	Waste must be pumpable and atomizable.
		Total solids content	Affects pumpable and heat transfer.
		Particle-size distribution of solid phases	Affects pumpable and heat transfer.
		Heat value	Determine auxiliary fuel requirements and feeds rates.
		Chemical:	
		Volatile organics, semivolatile organics	Allows determine of principal ad removal constituents.
		Principal organic hazardous constituents	Allows determine of destruction and removal efficiency
		Total halogens	To determine air pollution control devices for control of acid gases. Chlorine could contribute to formation of dioxins.
		Total sulfur, total nitrogen	Emissions of So_x and No_x are regulated; to determine air pollution devices.
		Phosphorus	Organic phosphorus compounds may contribute to refractory attack and slagging problems.
		PCBs, dioxins (if suspected)	99.9999% destruction and removal efficiency required for PCBs; safety considerations; incineration is required if greater than 500 ppm PCBs present.

Table 17. (continued)

Treatment Technology	Matrix	Parameter	Purpose and comments
General (cont.)	Liquids	Metals	Volatile metals (Hg, Pb, Cd, Zn, As, Sn) may require flue-gas treatment; other metals may concentrate in ash. Trivalent chromium may be oxidized to hexavalent chromium, which is more toxic. Presence sodium sulfate, can cause slagging. Determine posttreamtent needs.
Rotary kiln	Soils/sludges	Physical: Particle-size distribution	Fine particle size results in high particulate loading and slagging. Large particle size may present feeding problems.
	Debris	Physical: Amount, description of materials	Oversized debris presents handling problems and kiln refractory loss.
		Presence of spherical or cylindrical wastes	Spherical or cylindrical waste can roll through kiln before combusting.
Fluidized-bed	Soils/sludges	Physical: Ash fusion temperature	For materials with a melting point less than 1600°F, particles melt and become sticky at high temperatures, which causes defluidization of the bed.
		Ash content	Ash contents greater than 65% can foul the bed.
		Bulk density	As density increases, particle size must be decreased for sufficient heat transfer.
Thermal desorption	Soils/sludges	Physical: Moisture content	Affects heating and materials handling.
		Particle-size distribution	Large particles result in poor performance. Fine silt or clay generate fugitive dusts.
		Chemical: pH	Very high or very low pH waste may corrode equipment.
		Volatile organic contaminants	To determine concentration of target constituents, posttreatment needs.
		Volatile metals	To determine concentration of target constituents, posttreatment needs.
		Nonvolatile metals	To determine posttreatment needs.
		Total chlorine	Presence of chlorine can affect volatilization of some metals.
		Total organic content	Limited to ~ 10 percent or less.
	Liquids	Physical: Total solids content	Minimum of 23-30 percent solids required.

Table 18. Waste Feed Characterization Parameters for In Situ Treatment

Treatment Technology	Matrix	Parameter	Purpose and comments
Vapor extraction -Vacuum extraction -Steam-enhanced -Hot-air-enhanced	Soils/sludges	Physical: Vapor pressure of contaminants	To estimates ease of Volatilization.
		Soil permeability, porosity, particle-size distribution	To determine if the soil matrix will allow adequate air and fluid movement.
		Depth of contamination and water table	To determine relative distance; technology applicable in vadose zone.
Solidification/ stabilization (undisturbed) -Pozzolanic -Polymerization -Precipitation	Soils/sludges	Physical: presence of subsurface barriers (e.g., drums, large objects, debris, geologic formations)	To assess the feasibility of adequately delivering and mixing the S/S agents.
		Depth to first confining layer	To determine required depth of treatment.
Soil flushing -Stream/hot water -Surfactant -Solvent	Soils/sludges	Physical: Presences of subsurface barriers (e.g., drums, large objects, debris, geologic formations)	To assess the feasibility of adequately delivering the flushing solution.
		Hydraulic conductivity	To assess permeability of the soils.
		Moisture content (for vadose zone)	To calculate pore volume to determine rate of treatment.
		Soil/water partition coefficient	To assess removal efficiency and to correlate between filed and theoretical calculations.
		Octanol/water partition coefficient	To assess removal efficiency and correlates between filed and theoretical calculations.
		Cation exchange capacity	To evaluate potential for contaminant flushing.
		Alkalinity soil	To estimate the likelihood of precipitation.
		Chemical: major cations/anions present in soil	To estimate the likelihood of precipitation; to estimate potential for plugging of pore volumes.
Vitrification	Soils/sludges	Physical: Depth of contamination and water table	Technology is only applied in the unsaturated zone.
Electrokinetics	Soils/sludges	Physical: Hydraulic conductivity	Technology applicable in zones of low hydraulic conductivity.
		Depth to water table	Technology applicable in saturated soils.
		Chemical: Presence of soluble metal contaminants	Technology applicable to soluble metals, but not organics and insoluble.
Microbial degradation -Aerobic	Soils/sludges	Physical: Permeability of soil	To determine ability to deliver nutrients or oxygen to matrix and to allow movement of microbes.
		Chemical/biological: Contaminant concentration and toxicity	To determine viability of microbial population in the contaminated zone.
-Anaereobic	Soils/sludges	Chemical/biological: Contaminant concentration and toxicity	To determine viability of microbial population in the contaminated zone.
Adsorption (trench)	Soils/sludges	Physical: Depth of contamination and water table	Technology applicable in saturated zone.
		Horizontal hydraulic flow rate	To determine if ground water will come into contact with adsorbent.

United States
Environmental Protection Agency
Center for Environmental Research Information
Cincinnati, OH 45268

Official Business
Penalty for Private Use
$300

EPA/540/R-92/071a

Please make all necessary changes on the below label, detach or copy, and return to the address in the upper left-hand corner.

If you do not wish to receive these reports CHECK HERE **9** ; detach, or copy this cover, and return to the address in the upper left-hand corner.

BULK RATE
POSTAGE & FEES PAID
EPA
PERMIT No. G-35