United States
Environmental Protection
Agency

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Technology Transfer

EPA

Seminar on the Use of Treatability Guidelines in Site Remediation

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GENERIC GUIDELINES

GUIDE FOR CONDUCTING TREATABILITY STUDIES UNDER CERCLA

A

Presentation Outline

1.0 Introduction

2.0 Overview of Treatability Studies

3.0 Protocol for Conducting Treatability Studies

B

Purpose of Treatability Studies

- To Aid in Selection, Design, and Implemention of Appropriate Remedial Technologies as Defined by Section 121(b) of CERCLA

C

Audiences for the Guidance Document

- Remedial Project Managers (RPMs)
- On-Scene Coordinators (OSCs)
- Potentially Responsible Parties (PRPs)
- Consultants/Contractors
- Technology Vendors

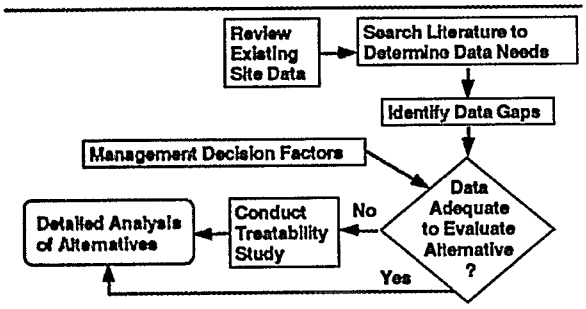
A

RI/FS Process Connections with Treatability Studies

- Two Important Aspects of the RI Process Are:
  - Site Characterization
  - Treatability Studies
- Both Can Provide Data to Address the First Seven RI/FS Evaluation Criteria Directly

B

Treatability Study Determination



C

Management Decision Factors

- State and Community Acceptance
- Scheduling Constraints
- Presumptive Remedies
- Additional Site or Technological Data

A

Treatability Study Scoping

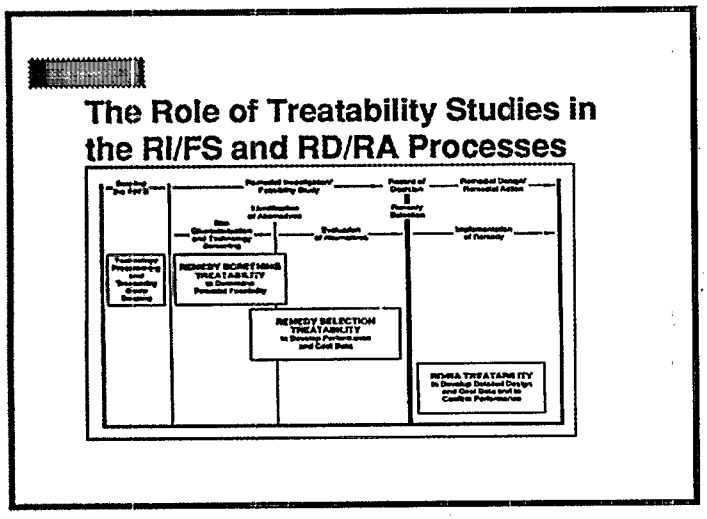
- Treatability Studies Produce Both Qualitative and Quantitative Data on One or More Technologies, as Applied to a Specific Site
- Treatability Studies Should Be Started as Early as Possible So Their Results Can Be Most Usefully Applied

B

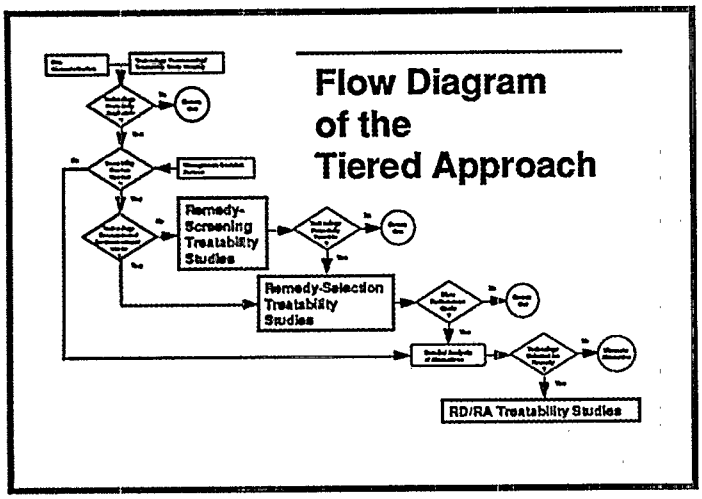
Treatability Studies Tiers and Corresponding Test Levels

- Remedy Screening -- Bench Tests
- Remedy Selection -- Bench- to Full-Scale Tests
- Remedial Design/Remedial Action -- Full-Scale Tests

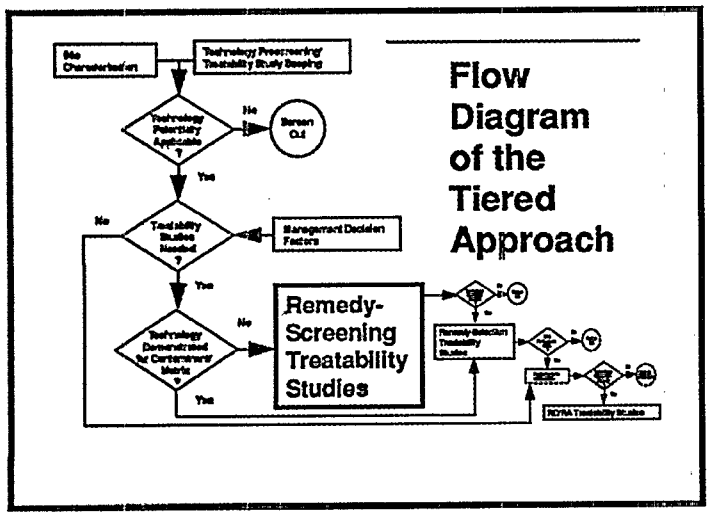
C


The Role of Treatability Studies in the RI/FS and RD/RA Processes

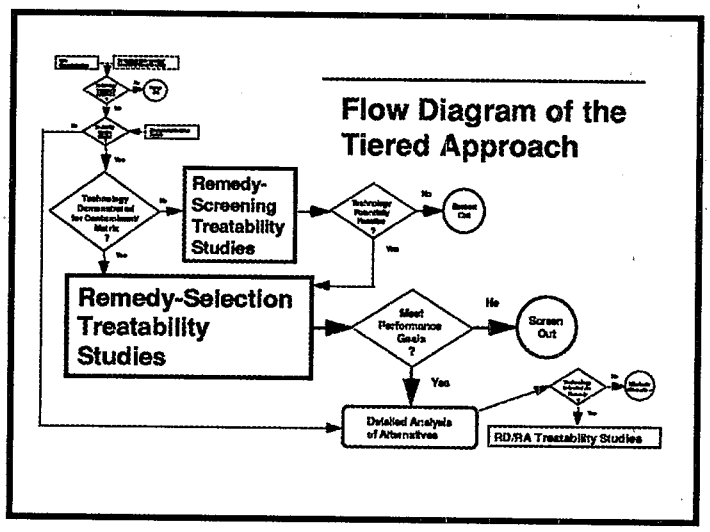
A


Flow Diagram of the Tiered Approach
Remedy-Screening Treatability Studies
Remedy-Selection Treatability Studies
RD/RA Treatability Studies

B


Flow Diagram of the Tiered Approach
Remedy-Screening Treatability Studies

C



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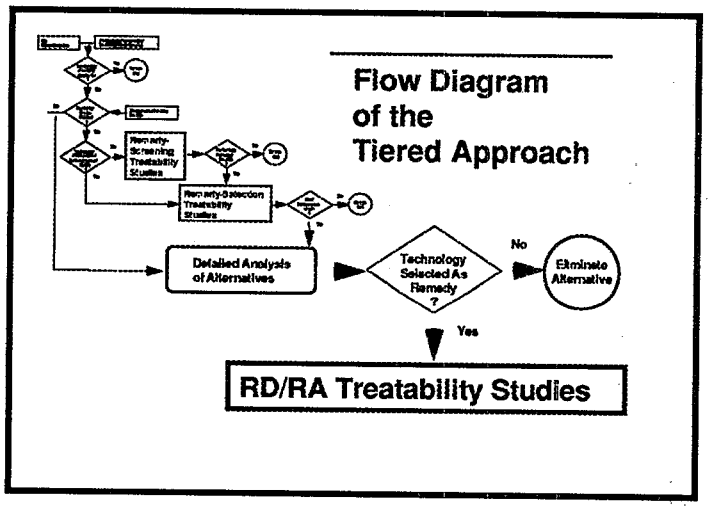


B

Treatability Study Tiers

1. Technology Prescreening and Treatability Study Scoping
2. Remedy Screening
3. Remedy Selection
4. Remedial Design/Remedial Action (RD/RA)

C

1. Technology Prescreening and Treatability Study Scoping

- Initiate as Soon as Possible
- Search Literature and Data Bases
- Consult Technology Experts
- Identify Treatability Study Sources
- Develop Preliminary Data Quality Objectives and Work Plan/Assignment

A

Literature Search/Expert Judgment

- Reports and Documents
  - Guidance for Conducting Remedial Investigations and Feasibility Studies
  - Superfund Treatability Clearinghouse Abstracts
  - The Superfund Innovative Technology Evaluation Program: Technology Profiles
  - Summary of Treatment Technology Effectiveness for Contaminated Soil

B

Literature Search/Expert Judgment

- Electronic Data Bases
  - RREL Treatability Data Base
  - OSWER Electronic Bulletin Board System (BBS)
  - Computerized On-Line Information System (COLIS)
  - Alternative Treatment Technology Information Center (ATTIC)

C

Literature Search/Expert Judgment

- EPA Personnel Consultations Through EPA RPM
  - Robert S. Kerr Environmental Research Laboratory Ground-Water Fate and Transport Technical Support Center Ada, Oklahoma
  - Risk Reduction Engineering Laboratory Engineering Technical Support Center Cincinnati, Ohio

A

2. Remedy Screening

- Study Scale: Bench
- Data Generated: Qualitative
- Process Type: Batch
- Waste Stream Volume: Small

B

2. Remedy Screening (cont.)

- Number of Replicates: Single/Duplicate
- Time Required: Days
- Cost Range: $10,000-$50,000

C

3. Remedy Selection

- Study Scale: Bench-Full
- Data Generated: Quantitative
- Process Type: Batch or Continuous
- Waste Stream Volume: Medium to Large

A

3. Remedy Selection (cont.)

- Number of Replicates: Duplicate/Triplicate
- Time Required: Days/Months
- Cost Range: $50,000-$250,000

B

4. Remedial Design/ Remedial Action

- Study Scale: Full
- Data Generated: Quantitative
- Process Type: Batch or Continuous
- Waste Stream Volume: Large

C

4. Remedial Design/ Remedial Action (cont.)

A

- Number of Replicates: Duplicate/Triplicate
- Time Required: Weeks/Months
- Cost Range: $250,000-$1,000,000

Treatability Study Test Objectives

B

- Site Cleanup Goals Are the Best -- But They Are Not Always Available

In the Absence of Cleanup Goals

C

- Levels That Provide Overall Protection of Human Health and the Environment
- Levels That Are in Compliance with ARARs
- Levels That Ensure a Reduction of Waste Toxicity, Mobility, or Volume
- Levels Acceptable for Delisting of the Waste
- Levels Set by the State or Region for a Similar Site

Special Considerations Discussed in the Guide

- Innovative Treatment Technologies
- Treatment Trains
- In Situ Treatment Technologies

A

Special Considerations Discussed in the Guide

- Generic vs. Vendor Treatability Studies
- PRP-Led Pre-ROD Treatability Studies
- Treatability Study Funding

B

Protocol for Conducting Treatability Studies Has 11 Elements

1. Establishing Data Quality Objectives
2. Identifying Sources for Treatability Studies
3. Issuing the Work Assignment
4. Preparing the Work Plan

C

Protocol for Conducting Treatability Studies Has 11 Elements (cont.)

5. Preparing the Sampling and Analysis Plan
6. Preparing the Health and Safety Plan
7. Conducting Community Relations Activities
8. Complying with Regulatory Requirements

A

Protocol for Conducting Treatability Studies Has 11 Elements (cont.)

9. Executing the Study
10. Analyzing and Interpreting the Data
11. Reporting the Results

B

1. Establishing Data Quality Objectives (DQOs)

- Precision, Accuracy, Representativeness, Completeness, and Comparability (PARCC)
- Remedy Screening -- Qualitative
- Remedy Selection -- Quantitative
- Remedial Design/Remedial Action -- Quantitative

C

2. Identifying Sources for Treatability Studies

- In-House vs. Contractors or Vendors
- Remedy Screening -- Simple and Usually Generic
- Remedy Selection -- More Complex and Sometimes Vendor-Specific
- Remedy Design/Remedial Action -- More Complex and Usually Vendor-Specific

A

3. Issuing the Work Assignment

1. Background
2. Test Objectives
3. Approach
4. Reporting Requirements
5. Schedule and Level of Effort

B

4. Preparing the Work Plan Involves 15 Components

1. Project Description
2. Remedial Technology Description
3. Treatability Test Objectives
4. Experimental Design and Procedures
5. Equipment and Materials

C

4. Preparing the Work Plan Involves 15 Components (cont.)

A

6. Sampling and Analysis Plan
7. Data Management
8. Data Analysis and Interpretation
9. Health and Safety
10. Residuals Management

4. Preparing the Work Plan Involves 15 Components (cont.)

B

11. Community Relations
12. Reports
13. Schedule
14. Management and Staffing
15. Budget

5. Preparing the Sampling and Analysis Plan (SAP)

C

- SAP = Field Sampling Plan (FSP) + Quality Assurance Project Plan (QAPjP)
- Remedy Screening -- Least Stringent
- Remedy Selection -- Moderately Stringent
- Remedial Design/Remedial Action -- Highly Stringent

6. Preparing the Health and Safety Plan (HSP) with 10 Components

1. Hazard Analysis
2. Employee Training
3. Personal Protective Equipment
4. Medical Surveillance
5. Personnel and Environmental Monitoring

A

6. Preparing the Health and Safety Plan (HSP) with 10 Components (Cont.)

6. Site Control Measures
7. Decontamination Procedures
8. Emergency Response Plan
9. Confined-Space Entry Procedures
10. Spill Containment Program

B

6. Preparing the Health and Safety Plan (cont.)

- Remedy Screening -- Relatively Minor
- Remedy Selection -- Skin, Eye, and Usually Respiratory Protection
- Remedial Design/Remedial Action -- Skin, Eye, Respiratory Protection; Decontamination and Emergency Procedures

C

7. Conducting Community Relations Activities

- Remedy Screening – Low Profile/Few Activities
- Remedy Selection –
  - Offsite: Generally Not Controversial and Low Profile/Few Activities
  - Onsite: May Be Controversial and High Profile/Significant Activities
- Remedial Design/Remedial Action – Low Profile/Few Activities

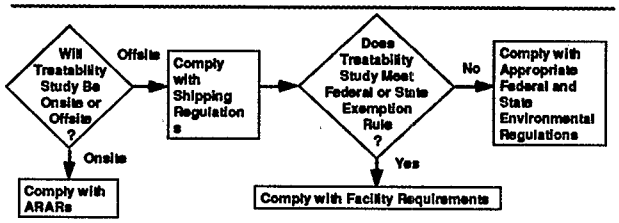
A

8. Complying with Regulatory Requirements

- Onsite
- Offsite
- Residuals Management

B

8. Complying with Regulatory Requirements: Regulatory Requirements for Onsite and Offsite Testing



C

8. Complying with Regulatory Requirements: Determinations of Onsite Testing

- Volume of Waste
- Test Duration
- Site Accessibility
- Availability of Mobile Laboratory or Treatment Unit and Onsite Utilities
- State and Community Acceptance

A

9. Executing the Treatability Study

- Field Sample Waste Streams for Characterization and Testing
- Conduct Treatability Tests
- Analyze Samples of Treated Waste and Residuals

B

10. Analyzing and Interpreting the Data

- Pre-ROD Data Interpretation
- Post-ROD Data Interpretation

C

10. Analyzing and Interpreting the Data--Pre-ROD Interpretation

1. Overall Protection of Human Health and the Environment
2. Compliance with Applicable or Relevant and Appropriate Requirements (ARARs)
3. Implementability
4. Reduction of Toxicity, Mobility, or Volume

A

10. Analyzing and Interpreting the Data--Pre-ROD Interpretation (cont.)

5. Short-Term Effectiveness
6. Cost
7. Long-Term Effectiveness
8. State Acceptance
9. Community Acceptance

B

10. Analyzing and Interpreting the Data--Post-ROD Interpretation

- Depends on the Use of the Remedial Design/Remedial Action Data
  - Prequalifying Vendors or Processes

  or
  - Implementing the Most Appropriate Remedies Prescribed in a Contingency ROD

  or
  - Supporting the Preparation of Detailed Design Specifications

C

11. Reporting the Results

- All Treatability Reports Are Submitted to the *RREL Treatability Data Base Repository*, Organized by the Office of Research and Development

Contact:

Mr. Glenn Schaul
RREL Treatability Data Base, U.S. EPA
ORD Risk Reduction Engineering Laboratory
26 West Martin Luther King Drive
Cincinnati, Ohio 45268

A

11. Reporting the Results: Treatability Report Format

- Introduction
- Conclusions and Recommendations
- Treatability Study Approach
- Results and Discussion
- References and Appendices

B

11. Reporting the Results: Treatability Report Format

1.0 Introduction
- 1.1 Site Description
- 1.2 Waste Stream Description
- 1.3 Treatment Technology Description
- 1.4 Previous Treatability Studies at the Site

C

11. Reporting the Results: Treatability Report Format (cont.)

A

2.0 Conclusions and Recommendations

- 2.1 Conclusions
- 2.2 Recommendations

11. Reporting the Results: Treatability Report Format (cont.)

B

3.0 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
- 3.5 Data Management
- 3.6 Derivatives from the Work Plan

11. Reporting the Results: Treatability Report Format (cont.)

C

4.0 Results and Discussion

- 4.1 Data Analysis and Interpretation
- 4.2 Quality Assurance/Quality Control
- 4.3 Costs/Schedules for Performing the Treatability Study
- 4.4 Key Contacts

11. Reporting the Results: Treatability Report Format (cont.)

A

References and Appendices

- References
- Appendices
  - -Data Summaries
  - -Standard Operating Procedures

REFERENCES FOR GENERIC TREATABILITY GUIDE

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13. U.S. Environmental Protection Agency. 1989b. 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, July 12. OSWER Directive 9380.3-01.

SOIL WASHING

GUIDE FOR CONDUCTING TREATABILITY STUDIES UNDER CERCLA: SOIL WASHING

A

Presentation Outline

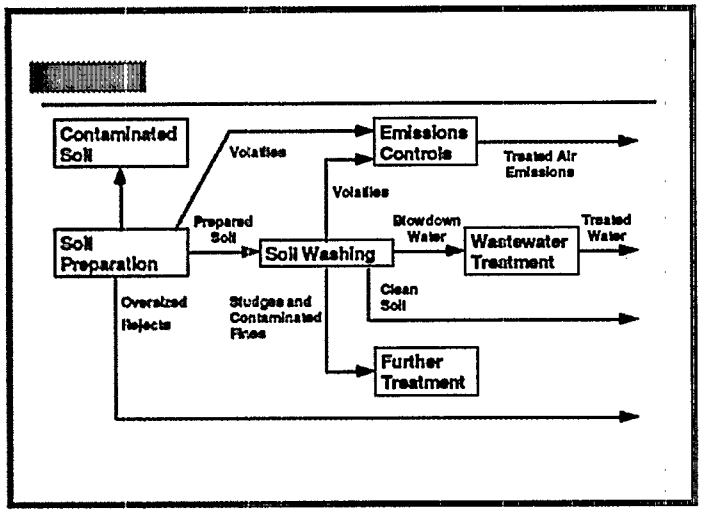
1.0 Introduction
2.0 Description of Soil Washing
3.0 Preliminary Screening
4.0 Technology Limitations
5.0 The Use of Treatability Studies in Remedy Evaluation
6.0 Sampling and Analysis Plans
7.0 Interpretation of Results
8.0 Remedy Evaluation Treatability Study Work Plans
9.0 References

B

Overview Description of Soil Washing

- Excavate Soil
- Pretreat Soil to Remove Large Objects and Soil Clods
- Wash Soil with Fluid(s) to Remove Contaminants (Usually Water)

C



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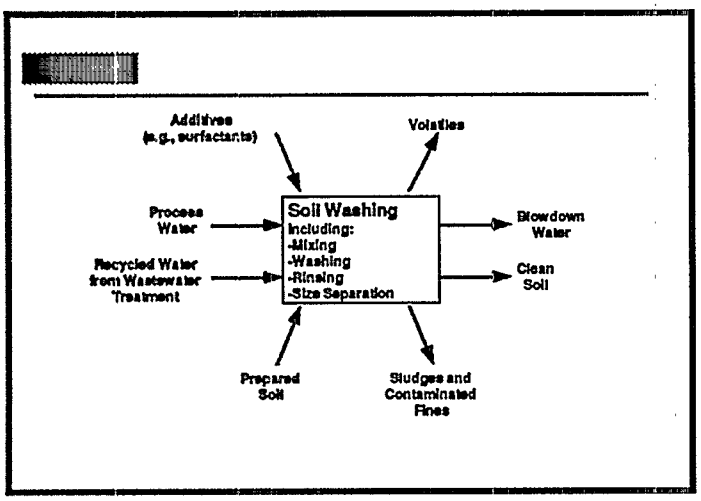


B

Measures of Effectiveness of Soil Washing

- Removal of Contaminants into Fluid
  and/or
- Concentrating Contaminants into a Portion of the Soil Volume

C

Current Use of Soil Washing

- Widespread in Europe; Limited in the U.S.
- Used at 16 Superfund Sites

A

Considerations for Determining the Appropriate Treatability Study Level

- Literature
- Expert Judgment
- Site Characteristics

B

Prescreening Determination

- If the Prescreening Results are only Marginally Favorable, then Usually Proceed to Screening Tests

C

Prescreening Factors

- Soil Characteristics
- Contaminant Characteristics and Distribution

A

Soil Washing Technical Limitations

Factors that Hinder Cost-Effective Soil Washing:

- Inappropriate Soil Particle Distribution for the Contamination
- Inappropriate Contaminant(s)
- Inappropriate Process Modifications

B

Inappropriate Soil Particle Distribution

- High Percentage of Silt, Clay, or Organic Matter
  - High Humic Content Impairs Contaminant Separation

C

Inappropriate Contaminant(s)

- High Concentration of Low Solubility Metals
- Hydrophobic Organic Compounds, Compounds with High Estimated Aqueous Distribution Coefficients (K_d)
  - e.g., K_d for PCBs is >10,000, which is High
  - e.g., K_d for TCE is 3, which is Low

A

Inappropriate Process Modifications

- Too Many Additives to Address Multiple Contaminants Present On Site
- Too Many Sequential Washings with Different Wash Formulations to Address Multiple Contaminants
- Additives Resulting in Wash Water Treatment Difficulties or Recycling Problems

B

Soil Characteristics

- Grain Size Distribution
- Clay Content
- Cation Exchange Capacity

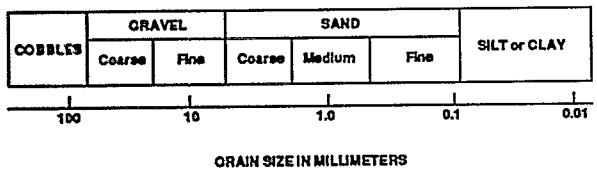
C

Grain Size Distribution

- Soils with Relatively High Percentages of Sand and Gravel (i.e., Soils with Particles $\geq$2 mm) Are More Amenable to Soil Washing

A

Particle Size Terminology



B

Clay Content

- The Higher the Percentage of Clay and Silt (i.e., Soil Particles with < 0.25 mm) in the Contaminated Soils, the Lower the Removal Efficiency of Soil Washing

C

Cation Exchange Capacity (CEC)

- Soil Washing is Most Effective for Soils with Relatively Low CEC's (i.e., with CEC's of Less than 50 to 100 meq/kg)

A

Contaminant Characteristics

- Water Solubility
- Miscability
- Reactivity with Wash Fluid
- Volatility and Density

B

Speciation of Metal Contaminants

- Metal Contaminants Have Different Species with Different Properties
- Examples of Forms of Metal Compounds with Different Properties
  - Oxides
  - Hydroxides
  - Nitrates
  - Phosphates
  - Chlorides
  - Sulfates

C

Remedy Screening

- Existing Information is Often Sufficient to Skip Remedy Screening
- This Stage Usually Employs Simple Lab Tests
- Typically, Indicator Contaminants Are Selected to Avoid the Necessity of Testing All Contaminants Present On Site

A

Jar Tests in Remedy Screening

- These Simple Tests Permit Chemical Analyses of the 3 Separated Layers:
  - Floatables Layer
  - Waste Water Layer
  - Solids Layer
- Settling Speed Provides a Rough Indicator of Particle Size Distribution

B

Jar Test Variables

- Using Different Dispersing Agents
- Using Sequential Washing Processes
- Heating Wash Water
- Adjusting the pH of the Wash Water
- Rinsing Cycle After Washing

C

Remedy Selection

- Key question: How Much Soil Requires Treatment to Meet the Clean-Up Goal(s)?
- Requires more Precision in Weighing, Mixing, and Particle Size Assessment than the Jar Testing in Remedy Screening
- Wash Water and Particles are Analyzed Quantitatively

A

Remedy Selection

Technical Aspects

- Soil to Wash Water Ratio
  - Standard: 1:3
- Wash Time Duration
  - Standard: 30 minutes
- Use of a Rinse Process
  - Rinse Water: Wash Water Ratio
- Type of Sieve
  - Gilson Wet Sieve or RO Tap Sieve

B

Sampling & Analysis Plan (SAP)

- Field Sampling Plan (FSP)
- Quality Assurance Project Plan (QAPjP)

C

Remedy Selection

Interpretation of Results

- If Soil Washing Removes ≥ 50% of Contaminants, then Soil Washing Should Continue Along the Remedy Evaluation Process
- If ≥ 90 Percent Reductions In-Bulk Contamination are Observed, then Remedy Design Tests are Warranted

A

Remedy Selection

Interpretation of Results

- If PCBs and Dioxins are Present, Test Only for PCBs During Remedy Screening Due to the Extremely High Cost of Assessing Levels of Dioxin
- If an Oily Layer Floats During Jar Tests, this Indicates the Presence of an Insoluble Organic Layer

B

Soil Washing Treatability Study Work Plan Elements

- 15 Elements in Any Treatability Work Plan
- 4 Elements that are Significantly Different from Generic Treatability Studies and Have Not Been Discussed Earlier in this Presentation

C

4 Treatability Study Work Plan Elements

1. Experimental Design
2. Schedule
3. Management and Staffing
4. Budget

A

Experimental Design:

Remedy Screening

- Most Important Factor is Particle Size Distribution

B

Particle Size Distribution Determination

Usually with a Series of 5 Sieves:

- Prescreening
  1. 3" Diameter Sieve
  2. #4 Sieve (4.750 mm)
- Screening
  3. #10 Sieve (2.000 mm)
  4. #40 Sieve (0.425 mm)
  5. #200 Sieve (0.070 mm)

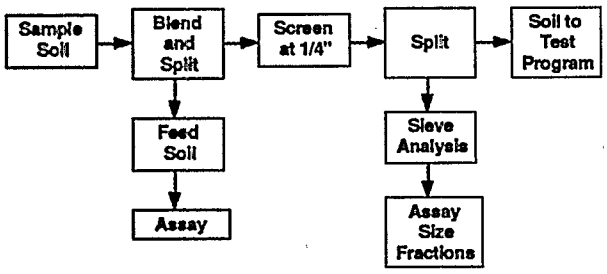
C

Ideal Soil for Soil Washing

- Soil Where Only 10-15 Percent of its Particles is Less than 0.07 mm

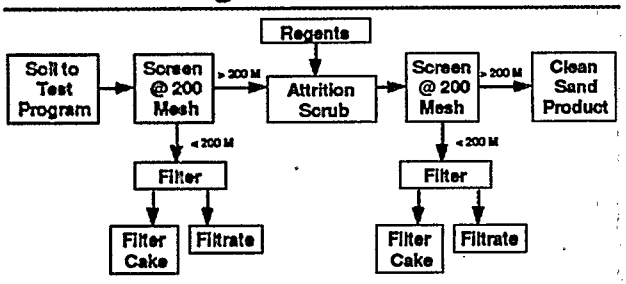
A

Soil Characterization Procedure



B

Test Protocol for Contaminated Soil Washing



C

Remedy Selection

- Need to Establish
  1. Percentage Contaminant Removal Achievable
  2. Particle Size Separation
  3. Contaminant Distribution in Soil

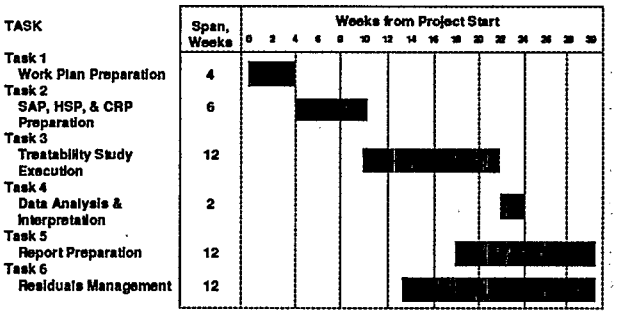
A

Remedy Selection

- Remedy Selection Outputs, Using Jar Tests from Remedy Screening to Approximate
  1. Wash Time
  2. Wash Water to Soil Ratio
  3. Rinse Water to Wash Water Ratio

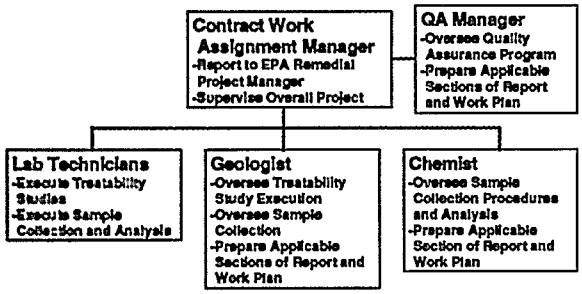
B

Example Project Schedule for a Treatability Study



C

Organization Chart



A

Major Cost Elements Associated with Remedy Selection Soil Washing Studies

COST ELEMENT	COST RANGE (thousands of dollars)
Initial Data Review	1 - 10
Work Plan Preparation	1 - 5
Field Sample Collection	1 - 10
Field Sample Chemical Analysis	5 - 25
Laboratory Setup/Materials	5 - 25
Treatability Test Chemical Analysis	5 - 20
Data Presentation/Report	2 - 5
TOTAL COST RANGE	20 - 100

B

Cost Components of Remedy Design Field Test of Soil Washing

1. Planning
2. Excavation
3. Design and Construction
4. Analytical Support
5. Management

C

Cost Components of Remedy Design Field Test of Soil Washing

6. Supplies
7. Lease or Rental of Remedy Design Unit
8. Labor
9. Implementation of Demonstration

A

Cost Components of Remedy Design Field Test of Soil Washing

10. Decontamination and Return of Remedy Design Unit
11. Site Closure
12. Laboratory Testing
13. Report Preparation

B

Cost Components of Full-Scale Soil Washing

1. Soil Excavation
2. Soil Transport
3. Soil Storage
4. Contaminant Containment
5. Soil Pretreatment

C

Cost Components of Full-Scale Soil Washing

A

6. Management of Soil Pretreatment Residuals
7. Wash Water Supply
8. Additive Supply
9. Soil Washing Facility
10. Temporary Soil Storage

Cost Components of Full-Scale Soil Washing

B

11. Wash Water Treatment Facility
12. Management of Used Wash Water
13. Further Management of Contaminated Soil Fraction
14. Further Management of Water Treatment Sludge

Cost Components of Full-Scale Soil Washing

C

15. Permitting and Legal Services
16. Engineering Design
17. Maintenance During Operation
18. Contingencies

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AEROBIC BIODEGRADATION

GUIDE FOR CONDUCTING TREATABILITY STUDIES UNDER CERCLA:
AEROBIC BIODEGRADATION, REMEDY SCREENING

Interim Guidance

A

Presentation Outline

- Introduction
- Description of Aerobic Biodegradation
  - In Situ Bioremediation
  - Solid-Phase Bioremediation
  - Slurry-Phase Bioremediation (Liquids/Solids Treatment)
  - Composting
- Remedy Screening
- Remedy Selection

B

Aerobic Biodegradation at Superfund Sites

- 22 Superfund Sites as of 1989
  - Matrices: Groundwater, Soils, Sludges, and Sediments
  - Pollutants: VOCs, Phenols, Creosotes, PAHs, and BTEX

C

Aerobic Biodegradation Processes

- In Situ
- Land Treatment
- Slurry-Phase
- Composting

A

Important Bioremediation Design Considerations

- Contaminant Characteristics
- Contaminant Bioavailability
- Indigenous Microbial Population

B

Important Bioremediation Design Considerations

- Hydrogeology
- Temperature
- Nutrients
- pH

C

Sources of Innoculum

- Indigenous Microbes
- Waste Water Sludge Microbes
- Microbes Specifically Cultured for the Site
- Proprietary Microbes from Vendors

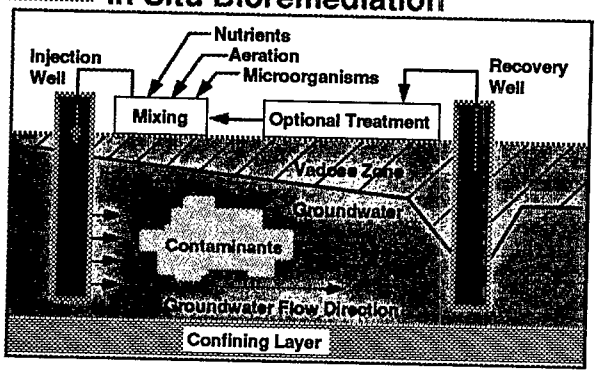
A

In Situ Bioremediation

- Soil is Treated in Place by Providing Optimal Subsurface Environmental Conditions for the Microbial Destruction of Pollutants

B

In Situ Bioremediation



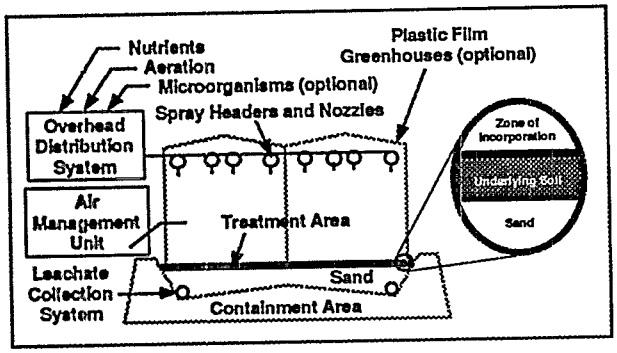
C

Land Treatment

- Cutivates Microbial Populations in Excavated Soils in Staging Areas to Destroy Pollutants
- Uses Conventional Farming Techniques to Provide Optimal Moisture, Nutrition, and Oxygen Levels

A

Land Treatment



B

Abiotic Removal Mechanisms Associated with Land Treatment

- Volatilization
- Leaching
- Photo-Decomposition

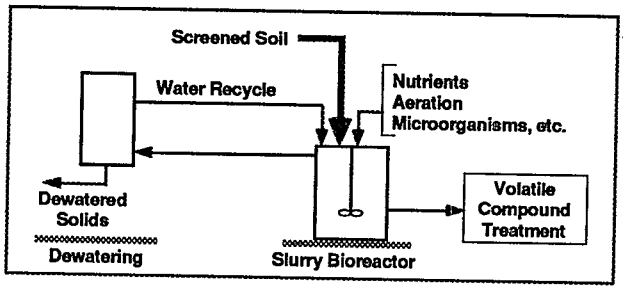
C

Slurry Phase

- Excavated Soil is Slurried in a Reactor with Large Quantities of Water to Maximize Contact Between Soil, Microorganisms, and Nutrients
- Nutrients, pH Adjusters, Surfactants, Microorganisms, and Electron Acceptors Can Be Added to the Water

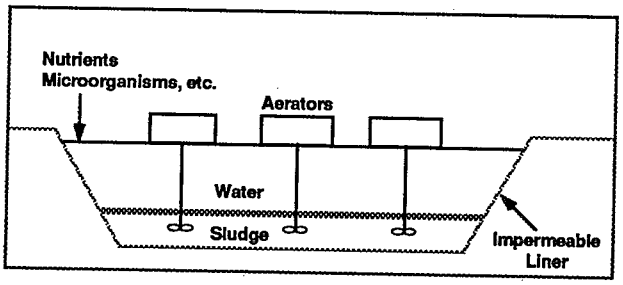
A

Above-Ground Slurry-Phase



B

Slurry-Phase in a Lagoon



C

Composting

- Soil is Incubated in Relatively Large Piles with Appropriate Amendments Added (Including: Nutrients, Moisture, Microorganisms, or Bulking Agents)
- Aeration is Achieved Either by:
  - Pushing or Pulling Air through the Pile
  - Mechanical Mixing

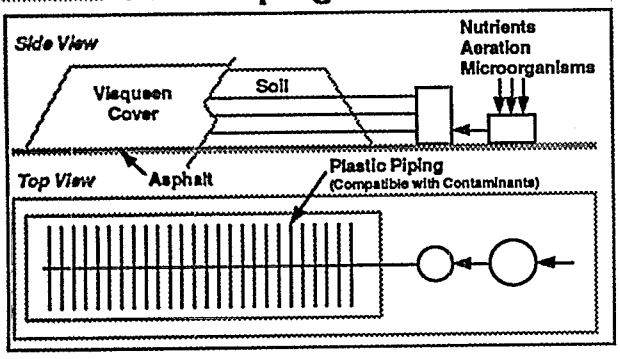
A

Basic Types of Composting

- Open Windrow
- Static Windrow
- In-Vessel (Reactor)
- Soil Heaping

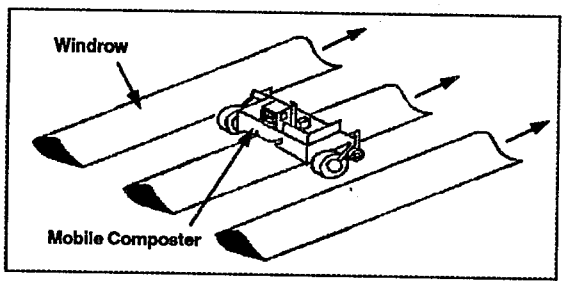
B

Soil Heaping



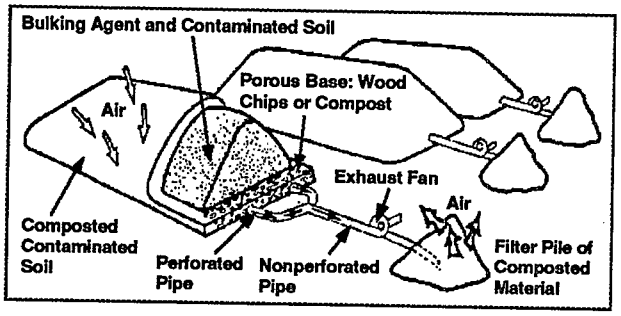
C

Open Windrow Composting



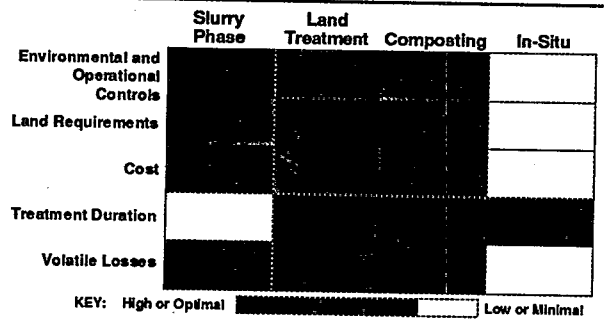
A

Static Compost Pile



B

Comparisons of Bioremediation Technologies



C

Goals for Treatability Studies

- Site Specific Potential for Bioremediation
- Design Data for Sequential Studies or Full-Scale Implementation
- Process Optimization

A

Reactor Requirements

- One Large Reactor
  - Subsampling with Time
- Multiple Reactors
  - Sacrifice Reactors with Time

B

Controls

- Necessary to Assess Abiotic Losses

C

Tiered Approach

- Remedy Screening
- Remedy Selection
- Remedial Design/ Remedial Action

A

Remedy Screening Objectives

- Optimize Conditions to Determine if Pollutants are Biodegradable
- Not Designed to Mimic Field Conditions

B

Key Features of Experimental Designs

- Reactor Type and Number
- Controls
- Analyses

C

Remedy Screening Reactor Types

- Shake Flask
- Soil Slurry Reactors
- Plate Counts

A

Questions to Be Answered in Remedy Screening

- Is Aerobic Biodegradation Feasible?
- Are Further Treatability Studies Warranted?

B

Remedy Screening Techniques

- Literature Review
- Microbial Population Assessment
- Soil Slurry Flask Tests

C

Abiotic Losses

- Volatilization
- Sorption
- Photo Decomposition
- Leaching

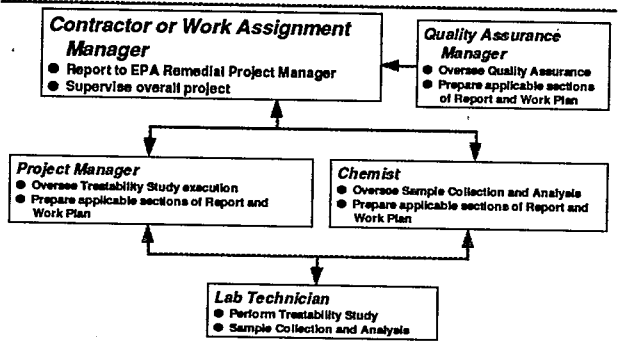
A

Sterilization Techniques for Controls in Remedy Screening

- Formaldehyde
- Metal Salts

B

Management and Staffing for Remedy Screening



C

Major Cost Elements Associated with Aerobic Biological Remedy Screening Treatability Studies

A

COST ELEMENT	COST RANGE (thousands of dollars)
Work Plan Preparation	1 - 5
SAP Preparation	1 - 5
Sample Collection	3 - 15
Laboratory Setup/Materials	2 - 10
Treatability Test Chemical Analysis	4 - 20
Data Presentation/Report	1 - 5
TOTAL COST RANGE	12 - 60

Remedy Screening Success

B

- A 20 Percent Contaminant Reduction Due to Aerobic Biodegradation
- Alternatives Measures
  - Toxicity Reduction
  - Presence of Healthy Microbial Population

Remedy Selection Success

C

- Cleanup Goals for the Site Are Achieved Within Desired Timeframe

Remedy Selection Goals

- Determine the Effects of:
  - Nutrient Loadings
  - Soil Volume Loadings
  - Microbial Innoculation on the Rate of Biodegradation
- Provide Scale-Up Data

A

Remedial Design/ Remedial Action

- Produce Data to Support Final Full-Scale Remedial Design/Remedial Action and Cost Figures

B

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28. 40 CFR, Section 796.3400.

SOIL VAPOR EXTRACTION

GUIDE FOR CONDUCTING TREATABILITY STUDIES UNDER CERCLA: SOIL VAPOR EXTRACTION

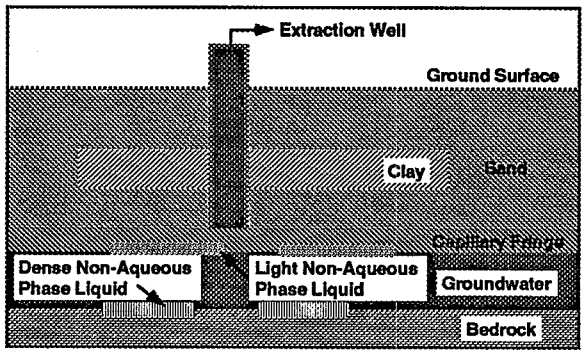
Interim Guidance

A

Presentation Outline

1.0 Introduction
2.0 Description of Soil Vapor Extraction
3.0 Preliminary Screening
4.0 The Use of Treatability Studies in Remedy Evaluation
5.0 Sampling and Analysis Plan
6.0 Interpretation of Results
7.0 Treatability Study Work Plan
8.0 Summary and References

B



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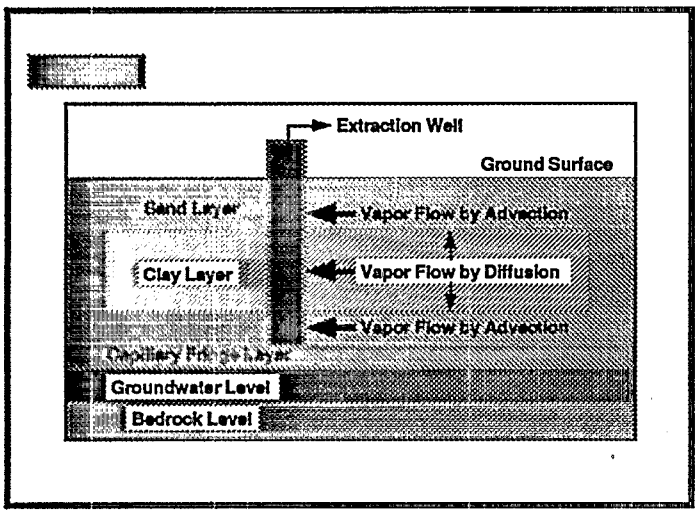
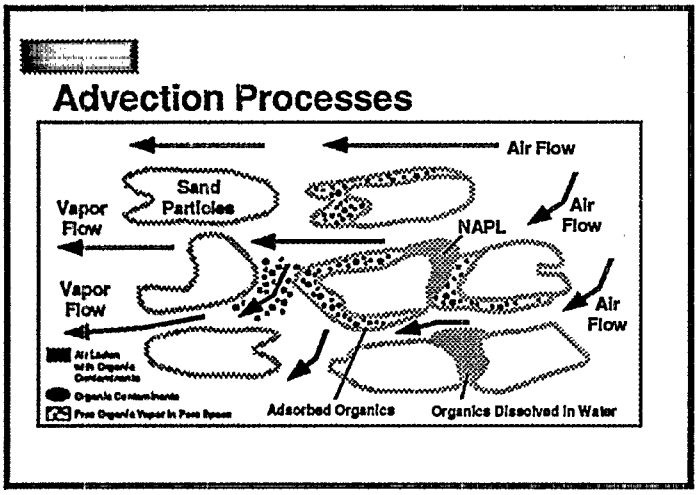
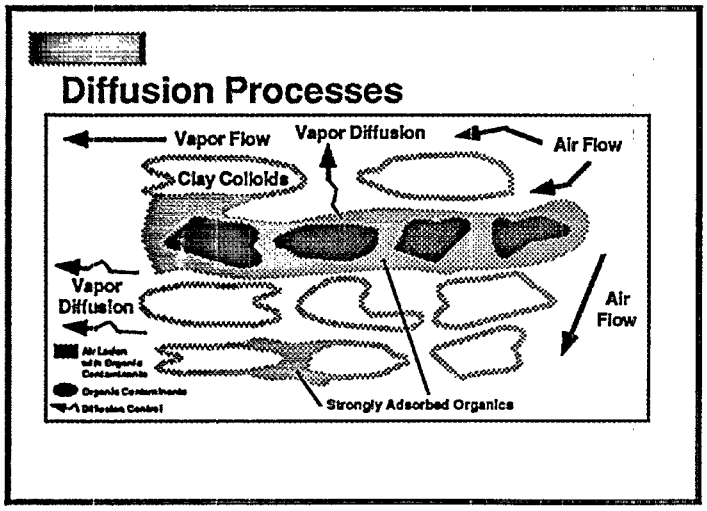

Extraction Well
Ground Surface
Sand Layer
Vapor Flow by Advection
Clay Layer
Vapor Flow by Diffusion
Vapor Flow by Advection
Groundwater Level
Bedrock Level

A

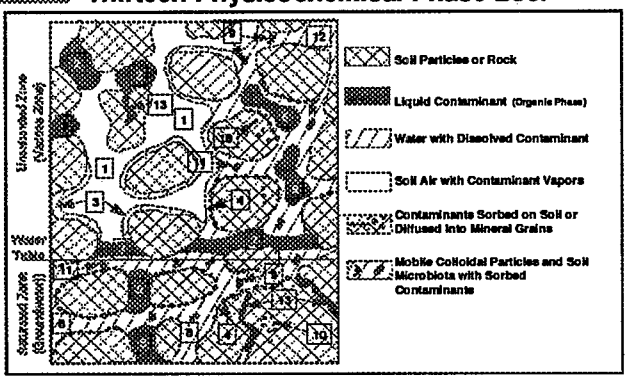

Advection Processes
Air Flow
Sand Particles
Vapor Flow
Air Flow
NAPL
Vapor Flow
Air Flow
Adsorbed Organics
Organics Dissolved in Water

B


Diffusion Processes
Vapor Flow
Vapor Diffusion
Air Flow
Clay Colloids
Vapor Diffusion
Air Flow
Strongly Adsorbed Organics

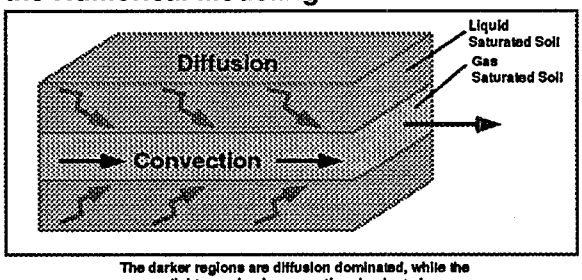
C

Thirteen Physicochemical-Phase Loci



A

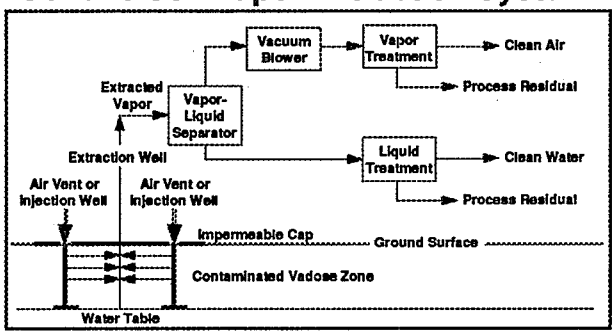
Conceptual Model Used for the Numerical Modeling



The darker regions are diffusion dominated, while the lighter region is convection dominated

B

Generic Soil Vapor Extraction System



C

Effectiveness of SVE

Demonstrated Effectiveness for:

- Halogenated Volatiles
- Nonhalogenated Volatiles
- Some Nonhalogenated Semivolatiles

A

Effectiveness of SVE

Potential Effectiveness for:

- Some Halogenated Semivolatiles
- Reactive Reducers

B

Effectiveness of SVE

Experts Assume Ineffective for:

- Inorganic Compounds
- Reactive Oxidizers
- Certain Organic Compounds, Including PCBs, Pesticides, Dioxins, Furans, Organic Cyanides, and Organic Corrosives

C

Preliminary Screening Factors

- Contaminant
- Soil
- Site

A

Preliminary Screening Factors

Contaminant

CHARACTERISTIC	POTENTIAL IMPACT	REMEDY PHASE
TYPE	SVE Suitability SVE Design	Screening, Selection, and Design
VAPOR PRESSURE AND HENRY'S LAW CONSTANT	Volatilization	Screening
DENSITY & WATER SOLUBILITY	Tendency to Migrate	Screening

B

Preliminary Screening

Soil

CHARACTERISTIC	POTENTIAL IMPACT	REMEDY PHASE
AIR PERMEABILITY	Movement through Soil	Selection
HUMIC CONTENT	Contaminant Volatilization Sorption of VOCs Water Table Modification	Selection
CLAY CONTENT	Structural Support Air Movement through Soil Need for Air Permeability Tests	Screening & Selection

C

Preliminary Screening

Soil (continued)

CHARACTERISTIC	POTENTIAL IMPACT	REMEDY PHASE
MOISTURE CONTENT	Air Movement through Soil Attracts VOCs Water Table Modification	Screening, Selection, and Design
TEMPERATURE	Contaminant Vapor Pressure	Screening, Selection, and Design
pH	Materials Selection	Selection & Design

A

Preliminary Screening Factors

Site

CHARACTERISTIC	POTENTIAL IMPACT	REMEDY PHASE
DISTRIBUTION AND QUANTITY OF CONTAMINANTS	Cost Definition of Contamination of NAPL Pools Pilot-Scale Verification	Selection
SOIL CONDITIONS AND CHARACTERISTICS	Contaminant Removal Rates	Selection

B

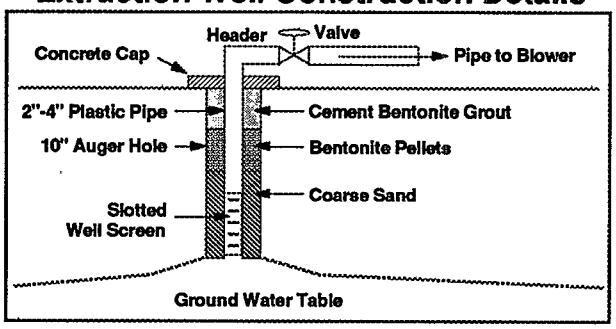
Preliminary Screening Factors

Site (continued)

CHARACTERISTIC	POTENTIAL IMPACT	REMEDY PHASE
ROCK FORMATION HETEROGENEITY	Well Design and Placement SVE Design Need for Air Permeability Tests Need for Pilot-Scale Verification	Selection
BURIED DEBRIS	Contaminant Removal Rates Need for Air Permeability Tests Need for Pilot-Scale Verification	Screening

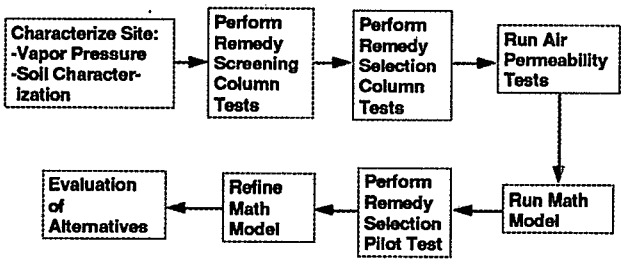
C

Extraction Well Construction Details



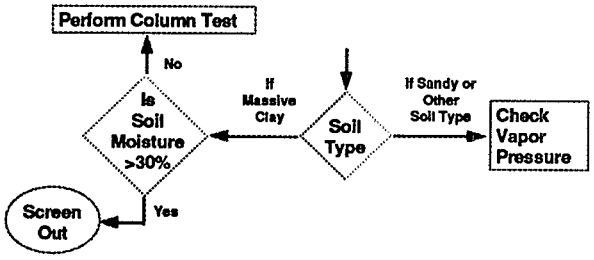
A

General Sequence of Events During RI/FS for SVE



B

Treatability Flow Chart
Soil Type



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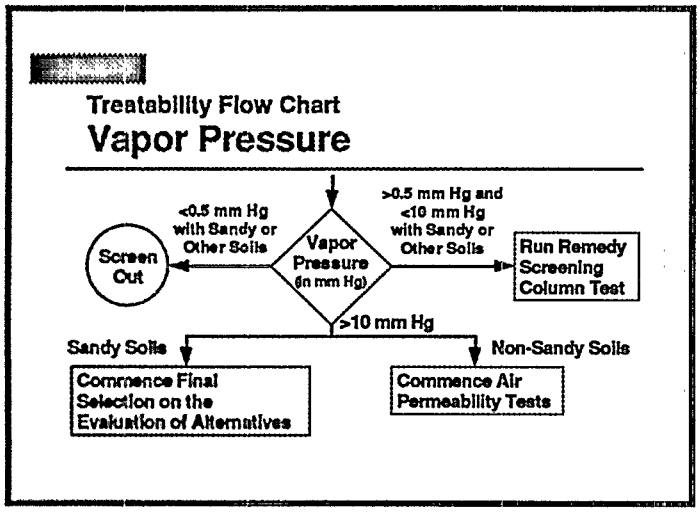
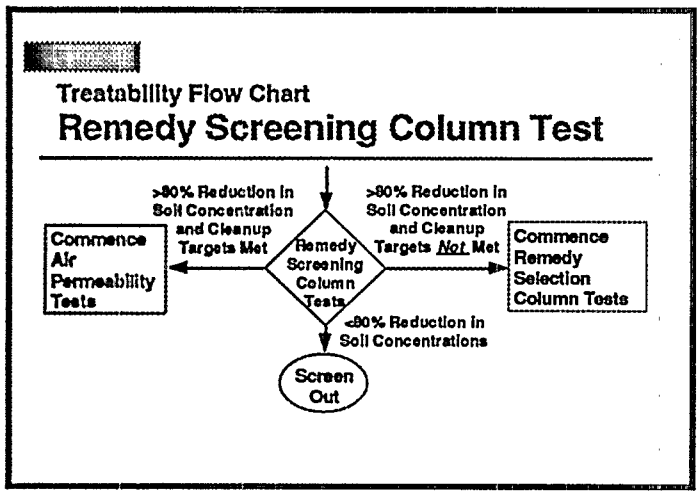
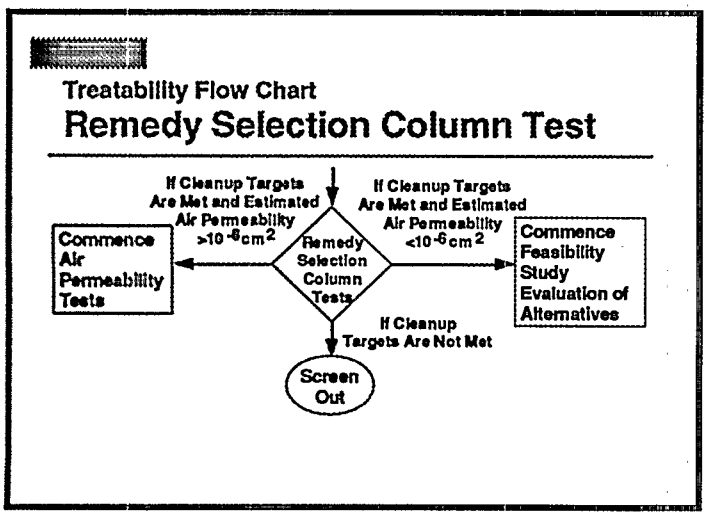

Treatability Flow Chart
Vapor Pressure
<0.5 mm Hg with Sandy or Other Soils
Screen Out
Vapor Pressure (in mm Hg)
>0.5 mm Hg and <10 mm Hg with Sandy or Other Soils
Run Remedy Screening Column Test
>10 mm Hg
Sandy Soils
Non-Sandy Soils
Commence Final Selection on the Evaluation of Alternatives
Commence Air Permeability Tests

A


Treatability Flow Chart
Remedy Screening Column Test
>80% Reduction in Soil Concentration and Cleanup Targets Met
Commence Air Permeability Tests
Remedy Screening Column Tests
>80% Reduction in Soil Concentration and Cleanup Targets Not Met
Commence Remedy Selection Column Tests
<80% Reduction in Soil Concentrations
Screen Out

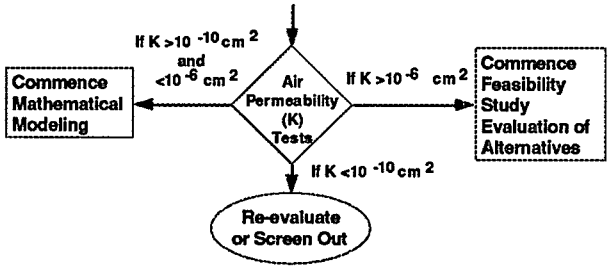
B


Treatability Flow Chart
Remedy Selection Column Test
If Cleanup Targets Are Met and Estimated Air Permeability >10-6cm2
Commence Air Permeability Tests
Remedy Selection Column Tests
If Cleanup Targets Are Met and Estimated Air Permeability <10-6cm2
Commence Feasibility Study Evaluation of Alternatives
If Cleanup Targets Are Not Met
Screen Out

C

Treatability Flow Chart

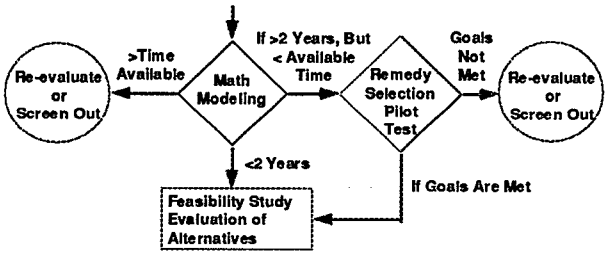
Air Permeability Tests



A

Treatability Flow Chart

Mathematical Modeling



B

6.0 Interpretation

SVE Is Evaluated During the Remedy Selection Phase as Follows:

- **Bench-Scale Column Tests Are Performed To Establish Whether SVE Can Meet Site Performance Goals**
- **Following Successful Column Tests for Remedy Selection, Field Air Permeability Tests Are Conducted To Check SVE Implementability**

C

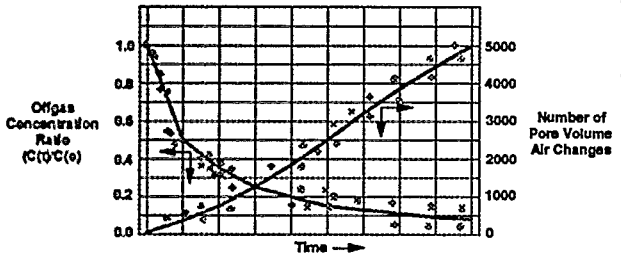
6.0 Interpretation (continued)

SVE Is Evaluated During the Remedy Selection Phase as Follows:

- Column Tests for Remedy Selection and Field Air Permeability Tests Are Supplemented with Mathematical Modeling
- If Warranted, Pilot-Scale Testing for Remedy Selection Is Performed

A

Hypothetical Column Test Data



Where: C(t) = indicator contaminant concentration at time="t"
C(o) = indicator contaminant concentration after 1 pore turnaround

B

Column Test Advantages

1. Accelerates the SVE process To Permit Evaluation of Maximum Contaminant Removal Potential.
2. Gives Order of Magnitude Information on the Partition Coefficients Needed for Mathematical Modeling.
3. Order of Magnitude Air Permeability Measurements May Be Obtained with "Undisturbed" Samples.

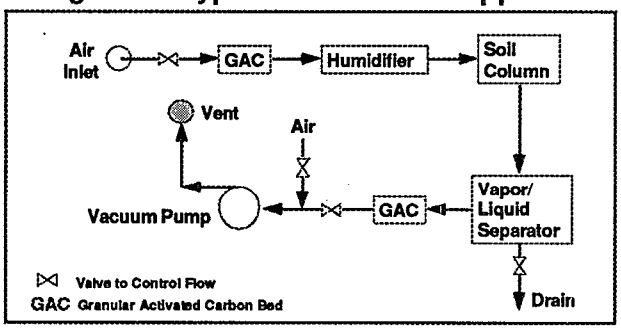
C

Column Test Limitations

1. Stripping Air Always Has Good Access to the Contaminants throughout the Column. Air Flow to Different Zones Varies Widely in the Field.
2. Diffusional Processes Are Not Properly Modeled.
3. More Accurate Air Permeability Results Must Be Obtained through Field Air Permeability Measurements.
4. Standard Procedures Must Be Formulated and Validated Against Field Data (preliminary draft stage)

A

Diagram of Typical Column Test Apparatus



B

Field Air Permeability Test Advantages

1. Provides the Most Accurate Air Permeability Measurements.
2. Permits Measurements of the Air Permeability of Several Geological Strata.
3. Measures the Radius of Influence in the Vicinity of the Testing Point.
4. When Coupled with Analytical Measurements, Gives Information about Initial Contaminant Removal Rates.
5. Provides Information for Designing a Pilot-Scale Test.

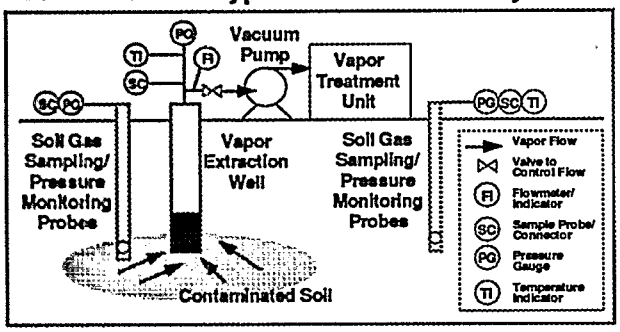
C

Field Air Permeability Test Limitations

1. May Give Low Air Permeability Measurements in Soil Zones Where Significant Water Removal May Later Take Place during the Operation of the SVE System.
2. Does Not Show the Location of NAPL Pools.
3. Requires a Health and Safety Plan and May Require Special Protective Equipment.
4. May Require an Air Permit on Superfund Sites.
5. Cannot Be Used To Measure Air Permeabilities in a Saturated Zone that Will Be Dewatered Prior to Application of the Technology.

A

Schematic for Typical Air Permeability Test



B

Mathematical Modeling Advantages

1. Provides Order of Magnitude Estimates of SVE Cleanup Times.
2. A Prediction of a Lengthy Cleanup Time Based on Mathematical Modeling Is Indicative that the SVE Process Is Not Applicable.
3. Provides Sensitivity Analyses for Critical Variables such as Air Permeability, Radius of Influence, Partition Coefficients, and Vacuum Applied.

C

Mathematical Modeling Limitations

1. Most Models Underestimate the Time Required for Cleanup. Prediction of a Short Cleanup Time Does Not Indicate that SVE Will Be Successful.
2. Different Models Must Be Used To Simulate Various Field Conditions. These Models Must Be Applied Carefully.
3. There Are Limited Field Data Available for Validation of the Mathematical Models.

A

Factors Affecting SVE Treatment Costs

Extraction Well Factors

- Well Design
- Number of Wells
- Depth of Wells
- Passive (Inlet) vs. Air Injection Wells
- Surface Seals

B

Factors Affecting SVE Treatment Costs

Treatment Factors

- Vapor/Liquid Separation
- Offgas Treatment
- Liquid (Water) Treatment

C

Factors Affecting SVE Treatment Costs

Other Factors

- Water Table Depression Pumps
- Operating Costs

A

Pivotal SVE Component Selection

SVE System Factors

COMPONENT AFFECTED	COMPONENT SELECTION FACTORS	DATA REQUIRED
WELL SPACING/ LOCATION	Radius of Influence	Pressure Profiles Mathematical Modeling Contaminant Distributions
NUMBER OF WELLS	Extent of Contamination	Depth to Bedrock Depth to Water Table
DEPTH OF WELLS	Depth to Impermeable Layer Location of Contaminants	Contaminant Distributions

B

Pivotal SVE Component Selection

SVE System Factors (continued)

COMPONENT AFFECTED	COMPONENT SELECTION FACTORS	DATA REQUIRED
PASSIVE (INLET) OR AIR INJECTION WELL	Air Flow Distributions	Air Permeability Tests Pilot Tests Mathematical Modeling
VACUUM PUMP OR BLOWER	Vacuum Level and Air-Flow Rate	Air Permeability Tests Pilot Tests Number of Vapor Extraction Wells
SURFACE SEALS	Air-Flow Distributions	Air Permeability Tests Pilot Tests
	Surface Water Infiltration	Mathematical Modeling, or Air-Flow Patterns Rainfall Permeability of Surface Soils

C

Pivotal SVE Component Selection

Treatment Factors

COMPONENT AFFECTED	COMPONENT SELECTION FACTORS	DATA REQUIRED
VAPOR/LIQUID SEPARATOR	Liquid (Water) Removal Rates	Moisture Content Vapor Flowrates
OFFGAS TREATMENT	Contaminant Removal Rates Contaminant Identities Moisture Content After Vapor/Liquid Separator	Air Permeability Tests Pilot Tests Moisture Content During Pilot Tests
LIQUID (WATER) TREATMENT	Site Water Removal Rates Treatability Factors	Site Hydrological Behavior Moisture Content in Offgass Contaminant Concentrations in Water Inorganic Chemistry Tests

A

Pivotal SVE Component Selection

Other Factors

COMPONENT AFFECTED	COMPONENT SELECTION FACTORS	DATA REQUIRED
WATER TABLE DEPRESSION PUMPS	Depth to Water Table Depth of Contaminants Water Infiltration Rates	Depth to Water Table Site Hydrological Behavior
OPERATING COSTS	Size of SVE System Cleanup Time Analytical Costs Residual Disposal Costs	All of the Above, Plus Cleanup Time Predictions

B

SVE Remedy Evaluation Test Elements and Their Relative Costs

COST ELEMENT	FIELD AIR PERMEABILITY TEST	BENCH-SCALE COLUMN TEST(S)**	PILOT-SCALE FIELD TEST**
Plan Preparation*	$	$	$
Mobilization/Demobilization			
SVE Vendor Equipment			
Materials	$	$	$$
Utilities	$	$	$$
Sampling and Monitoring	$	$	$$
Analyses	$	$	$$
Residuals Management	$	$	$$
Analysis Report Preparation	$	$	$$
ESTIMATED TOTAL COST	$	$	$$
	$	$	$
	$30,000-$50,000	$50,000-$100,000	≥$100,000

*Includes Work, Subcontractor, Sampling & Analysis, and Health & Safety Plans
**Includes Mathematical Model Data Interpretation and System Efficiency Analysis

C

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CHEMICAL DEHALOGENATION

GUIDE FOR CONDUCTING TREATABILITY STUDIES UNDER CERCLA

Chemical Dehalogenation

A

Presentation Outline

1.0 Introduction
2.0 Description of Chemical Dehalogenation
3.0 Technological Limitations
4.0 The Use of Treatability Studies in Remedy Evaluation
5.0 Treatability Study Work Plan
6.0 Data Interpretation
7.0 References

B

Chemical Dehalogenation

Can Be Applied to:

- Soils
- Sediments
- Sludges

C

The Chemical Dehalogenation Process Requires:

1. That a Chemical Reagent Be Applied Directly to the Contaminated Material
   and
2. When the Reagent Reacts with the Contaminant, that it Remove One or More Halogen Atoms from the Contaminant Molecule

A

The Chemical Dehalogenation Process Involves

Reactions between Reagents and Contaminant That Are Either:

1. *Substitution Reactions*
   or
2. *Elimination Reactions*

B

Dehalogenation Is Applicable to Soils Contaminated By:

- Halogenated Aromatic Contaminants
  - PCBs
  - PCDDs
  - PCDFs
  - Chlorobenzenes
  - Chlorinated Phenols
  - Halogenated Herbicides
  - Organochlorine Pesticides

C

Dehalogenation Is Applicable to Soils Contaminated By:

- Certain Halogenated Aliphatics
  - Ethylene Dibromide
  - Carbon Terachloride
  - Chloroform
  - Dichloromethane

A

Dehalogenation as a Portion of a Treatment Train

If Non-Halogenated Volatiles, Semi-Volatiles, or Metals Are Present on a Site, then Dehalogenation May Be Used in Conjunction with Other Technologies such as:

- Thermal Desorption
- Solvent Extraction
- Biodegradation

B

Examples of Direct Dehalogenation Process Types

- A PEG: Alkali Metal Polyethylene Glycolate
- BCD: Base-Catalyzed Decomposition

C

Dehalogenation Vendors

Dehalogenation Processes Are Largely Proprietary. Four Firms that Offer Full-Scale Dehalogenation Services:

- Galson Remediation Corp.
- Soil Tech
- Chemical Waste Management
- SDTX Technologies

A

Superfund Sites at Which Dehalogenation Was Selected in the ROD

- 1985 - Wide Beach Development; Brant, NY
- 1987 - Re-Solve; N. Dartmouth, MA
- 1988 - Sol Lynn/Transformers; Houston, TX
- 1990 - Myers Property; Hunterton County, NJ

B

Current Developments

Presently, a Base-Catalyzed Decomposition (BCD) Technology is under Development to Address:

- Chlorophenols
- Chlorinated Herbicides (e.g., Silvex)
- Organochlorine Pesticides (e.g., Diedrin)
- Dioxins and Furans
- PCBs

C

Parameters Needed to Prescreen Dehalogenation

- Effectiveness
- Implementability
- Cost

A

Effectiveness Data to Screen Dehalogenation

- Contaminated Media Type
- Volume of Contaminated Media
- Contaminant Type
- Contaminant Concentration
- Previous Dehalogenation Applications to Analogous Wastes

B

Implementability Data to Evaluate Dehalogenation

- Availability of the Process
- Administrative Requirements (e.g., Permits)
- Accessibility to the Site

C

Cost Data to Evaluate Dehalogenation

- Capital vs. Operation and Maintenance Costs
- Past Experience
- Engineering Judgment

A

Dehalogenation Performance Factors

- Soil Type Is Not Critical in Using Dehalogenation
- Effectiveness of Dehalogenation Process Depends on Thorough Mixing of Contaminated Material with Reagent
  - Requires Excavation
  - In Situ Treatments Usually Fail
- Optimization Factors
  - Soil Temperature
  - Reaction Duration
  - Reagent Ratio

B

Technical Limitations of Dehalogenation

- Quantity of Reagent May Be Prohibitive
- Energy Requirements May Be Prohibitive
- Treated Soil and Residuals May Require Extensive Post Treatment
- Uncharacterized Process Byproducts May Present Hazards
- Safety Hazards (Exposures, Explosions, and Fires) are Ever Present

C

Application of Tiered Approach to Dehalogenation Treatability Studies

- Literature Survey
- Remedy Screening
- Remedy Selection
- Remedial Design/Remedial Action

A

Literature Review

- Purpose:
  - Identify Potentially Applicable Dehalogenation Processes
  - Obtain Existing Information on Performance with Similar Characteristics, Compounds, Concentrations, and Site Conditions
- Objective: Determine Treatability Data Needs

B

Remedy Screening

- Purpose: Determine Feasibility for Application to Site's Contaminants/Matrix
- Objective: Achieve >90 Percent Reduction in Contamination
- Parameters Investigated: None, Testing is Conducted Under Severe Conditions
- Data Generated: Contaminant Concentrations Before and After Treatment

C

Remedy-Selection Testing

- Purpose: Generate Performance and Cost Data for Detailed Analysis of Alternatives
- Objective: Meet Site Cleanup Criteria for Target Contaminant(s)

A

Remedy-Selection Testing (cont.)

Parameters Investigated:

- Temperature
- Reaction Time
- Reaction Formulation and Loading
- Process-Specific Parameters
- Multiple Sample Types Representing Site Chemical/Physical Variability

B

Remedy-Selection Testing (cont.)

Data Generated:

- Relationship between Process Parameters and Contaminant Concentrations
- Characterizations of Product(s) and Residual(s)
- Capital and Operating and Maintenance Cost Estimates

C

Remedial Design/ Remedial Action Testing

A

- Purpose: Produce Scale-Up, Design, and Cost Data for Implementation of Remedy
- Objective: Optimize Process

Remedial Design/ Remedial Action Testing (cont.)

B

Parameters Investigated:

- Feed Rates (Continuous Processes)
- Number of Treatment Cycles (Batch Processes)
- Mixing Rates
- Heating Rates
- Other Equipment-Specific Parameters

Remedial Design/ Remedial Action Testing (cont.)

C

Data Generated:

- Materials-Handling Characteristics
- Reagent Recycling and Recovery Efficiency
- Energy and Chemical Usage
- Treatment Train Performance
- Residuals Treatment Performance

Dehalogenation Treatability Study Work Plan

- 15 Standard Elements in All Treatability Studies
- 7 of the 15 Elements Have Specific Components for Dehalogenation Treatability Studies that Have Not Been Discussed Yet

A

Seven Dehalogenation-Specific Work Plan Elements

- Test Objectives
- Experimental Design and Procedures
- Equipment and Materials
- Sampling and Analysis

B

Seven Dehalogenation-Specific Work Plan Elements

- Residuals Management
- Schedule
- Budget

C

Test Objectives

Test Objectives Consist of Meeting Quantitative Performance Goals

or

Making a Qualitative Engineering Assessment of the Process

A

Test Objectives: Remedy Screening

- Focus on the Degree of Reduction in Toxicity Achieved as a Determinant of Feasibility
  - Generally Above 90% for Target Contaminants

B

Test Objectives: Remedy Selection

- Generally Corresponds to the Site's Final Remediation Goals
  - Chemical-Specific Health-Based Applicable or Relevant and Appropriate Requirements (ARARs)
  - Reasonable Land-Use
  - Standard Exposure Pathways

C

Experimental Design and Procedures

- Remedy-*Screening* Treatability Studies Should Be Done under Severe Conditions to Avoid False Screen-Outs, Including:
  - Excess Reagent
  - High Temperatures
  - Extended Reaction Times

A

Experimental Design and Procedures

- Remedy Selection Design Requires Special Considerations:
  - Generating Sufficient Treated Product
  - Performing a Mass Balance
  - Assessing Reagent Recovery, Residuals Treatment, and Soil Pre- and Post-Treatment(s)

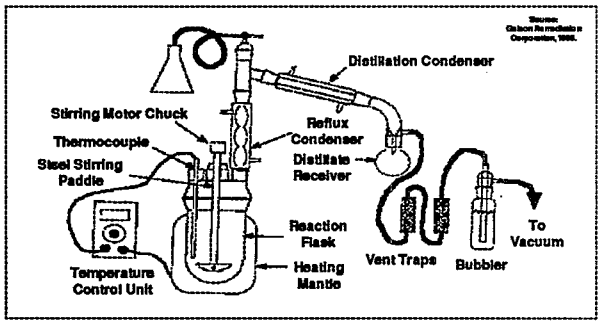
B

Equipment and Materials

- Remedy-Screening Studies Performed in a Batch System Using Off-the-Shelf Laboratory Glassware and Bench-Scale Equipment
- Remedy-Selection Studies Performed Using Bench-Scale and Occasionally Pilot-Scale Equipment
- RD/RA Studies Performed with Full-Scale Trailer-Mounted Equipment

C

Example Chemical Dehalogenation Bench-Scale Reactor



A

Sampling and Analysis
Available Remedial Investigation Data

- Spatial Distribution of Target Contaminants
- Contaminant Levels that Limit Testing and Disposal Options (e.g., Dioxins and PCBs)
- Non-Target Contaminants that May Interfere with Extraction and Analysis of Target Contaminants (e.g., Certain Solvents)

B

Sampling and Analysis
General Considerations

- Reactive Species
- Soil Type
- Soil Moisture Content
- Particle Size Distribution

C

Sampling and Analysis

Remedy Screening

- Single Analyses Are Usually Sufficient
- Limited to Target Contaminants
- Includes Soil and Other Treatment Fractions (Used Reagent, Rinse Water, Condensate, and Absorbent Traps)
- EPA or ASTM Methods Are Recommended (Although Vendor Modified Methods May Be Necessary)

A

Sampling and Analysis

Remedy Selection

- This Tier Requires Duplicate or Triplicate Tests
- Selection of Other Halogenated Contaminants for Additional Tests By Assessing:
  - Likely Products from Chemical Reactions
  - Relative Toxicity of Byproducts
  - Residuals Management Inhibitors

B

Sampling and Analysis

Pretreatment Waste Characterization Factors

- Moisture (May Dilute Reagent)
- pH
- Buffering Capacity
- Particle Size Distribution

C

Residuals Management

Includes Managing Six Types of Residuals

1. Waste Not Used in Testing Procedures
2. Treated Waste
3. Treatment Residual (Spent Reagent and Condensate)

A

Residuals Management

4. Laboratory Samples and Extracts
5. Used Containers
6. Contaminated Protective Clothing and Debris

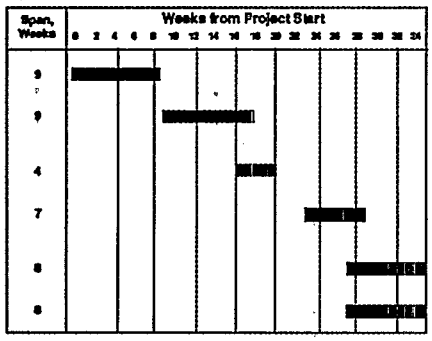
B

Residuals Management Considerations

- Types and Quantities
- Impact on Schedule
- Impact on Cost
- Responsibilities of Parties Involved (i.e., PRPs, EPA, and Testing Facility)

C

Example Project Schedule for a Two-Tiered Chemical Dehalogenation Treatability Study



A

Applicability of Cost Elements to Treatability Study Tiers

COST ELEMENT	REMEDY SCREENING	REMEDY SCREENING	REMEDY DESIGN
Labor	$$	$$	$$
Testing Equipment and Rental	$	$$	$$
Health and Safety	$$	$$	$$
Analytical Services	$$	$$	$$

$=Not Applicable under Low Cost Incurred, $=May Be Applicable under Intermediate Cost Incurred. $=Applicable under High Cost Incurred.

B

Applicability of Cost Elements to Treatability Study Tiers

COST ELEMENT	REMEDY SCREENING	REMEDY SCREENING	REMEDY DESIGN
Reagents	$	$	$$
Permitting and Regulatory	$	$$	$$
Sample Transportation	$	$	$$
Residual Management	$	$	$$

$=Not Applicable under Low Cost Incurred, $=May Be Applicable under Intermediate Cost Incurred. $=Applicable under High Cost Incurred.

C

Applicability of Cost Elements to Treatability Study Tiers

COST ELEMENT	REMEDY SCREENING	REMEDY SCREENING	REMEDY DESIGN
Site Preparation	0	0	$$
Utilities	0	$	$$
Mobilization/ Demobilization	0	$	$$
Air Emission and Effluent Treatment	0	$	$$
Decontamination of Equipment	0	$	$$

0=Not Applicable under No Cost Incurred. $=May Be Applicable under Interim-state Cost Incurred. $$=Applicable under High Cost Incurred.

A

Budget-Analytical Cost Considerations

- Number of Analyses
- Chemical and Physical Properties Measured
- Analytical Test Duration
- Specialty Analyses (e.g., Dioxins)

B

Data Interpretation

Long-Term Effectiveness and Permanence

What Is the Magnitude of Residual Risk?

- Target Contaminant Concentrations in Treated Product and Residuals
- Presence of Byproducts
- Bioassay Results on Treated Product

C

Data Interpretation

Reduction of Toxicity, Mobility, and Volume

What Is the Reduction in Toxicity?

- Percent Reduction in Target Contaminant Concentrations
- Bioassay Results Comparison Before and After Treatment

A

Data Interpretation

Reduction of Toxicity, Mobility, and Volume

What Is the Irreversibility of the Dehalogenation?

- Materials Balance Data, with Target Contaminant Concentrations in Treated Product and Residuals

B

Data Interpretation

Reduction of Toxicity, Mobility, and Volume

What Are the Risk Types and Quantities Posed by Treatment Residuals?

- Target Contaminant Concentrations in Treatment Residuals
- Presence of Byproducts in Treatment Residuals
- Bioassay Results on Treatment Residuals
- Treatment Residuals Volume

C

Data Interpretation

Short-Term Effectiveness

How Are the Community and Workers Protected During Remedial Actions?

- Physical and Chemical Properties of Waste Matrix and Treatment Residuals
- Reagent Formulation and Material Safety Data

A

Data Interpretation

Short-Term Effectiveness

How Long Will the Remedial Response Last?

- Reaction Time/ Throughput

B

Data Interpretation

Implementability

How Reliable Is the Process and What Is the Potential for Delays?

- Reliability and Schedule Delays During Testing
- Reaction Time and Throughput
- Physical Characteristics of Waste Matrix
- Contaminant Variability in Untreated Waste

C

Data Interpretation

Cost

What Are the Direct Capital Costs Determinants?

- Physical Characteristics of Waste Matrix
- Site Characteristics
- Reaction Time, Throughput, and Temperature
- Reagent Usage and Recovery

A

Data Interpretation

Cost

What Are the Operational and Maintenance Cost Determinants?

- Reagent Formulation, Loading, Usage, and Recovery
- Treated Product and Treatment Residual Volume and Characteristics
- Reaction Time, Throughput, and Temperature
- Physical Characteristics of Waste Matrix
- Materials Handling

B

Data Interpretation

Compliance with ARARs

What Are the Chemical-, Location-, and Action-Specific ARAR Determinants?

- Target Contaminant Concentrations in Treated Product and Residuals
- Bioassay Results for Treated Product and Residuals

C

Data Interpretation

Overall Protection of Human Health and the Environment

A

How Are Site Risks Eliminated, Reduced, or Controlled?

- Target Contaminant Concentrations in Treated Product and Residuals
- Byproduct Presence in Treated Product and Residuals
- Bioassay Results on Treated Product and Residuals

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SOLVENT EXTRACTION

GUIDE FOR CONDUCTING TREATABILITY STUDIES UNDER CERCLA:

SOLVENT EXTRACTION

Interim Guidance

A

Presentation Outline

1.0 Introduction
2.0 Description of Solvent Extraction (SE)
3.0 Preliminary Screening
4.0 Goals
5.0 Experimental Design
6.0 Sampling and Analysis
7.0 Data Analysis and Interpretation
8.0 Scheduling, Management, and Budgeting
9.0 Summary and References

B

Solvent Extraction

A Process that Uses Solvent(s) to Remove Hazardous Contaminants from:

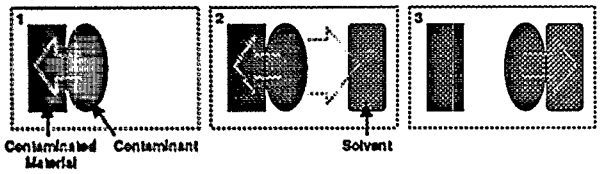
- Soils
- Sludges
- Sediments
- Ground Water*
- Surface Water*

*Possible, but uncommon.

C

Solvent Extraction

Is Based on the Contaminant's Higher Affinity for the Chosen Solvent than the Contaminated Material



A

Solvent Extraction Process

- An Ex Situ Process
  - Soils Are Excavated
  - Liquids Are Pumped
- Contaminated Material Removal Usually Requires Pretreatment and Posttreatment for SE to Work Efficiently

B

Solvent Extraction:

Pretreatment

Pretreatment Is Done to:

1. Optimize SE Performance
2. Protect Equipment
3. Increase the Variety of Equipment That Can Be Used

C

Solvent Extraction:

Pretreatment

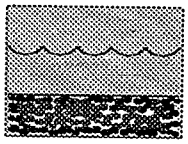
Pretreatment Decision Depends on:

1. Waste Characteristics
2. Whether SE Process is Batch or Continuous
3. Extraction Process
4. Soil Washing

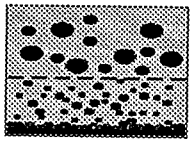
A

Solvent Extraction

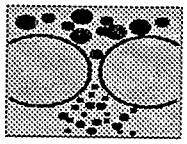
Solids Pretreatment



- Solid-Liquid Separation Removes Water, Which Can Impair Some SE Processes



- Screening Contaminated Material Protects Equipment from Larger Debris
  - This Type of Pretreatment Includes Classification and Flotation Processes



- Size Reduction Eliminates Debris and Increases Surface Area to Enhance Mixing
  - Too Much Reduction (i.e., Too Many Fines) Can Create Separation Problems

B

Solvent Extraction

Liquid Pretreatment

- Liquid Pretreatment Is Used to Enhance Pumping, Separate Constituents (Usually Solids), or Chemically Condition Waste
  - Pumping Enhancement Is Done with Either Water or Solvent
- Constituent Separation Techniques Include:
  - Filtering
  - Screening
  - Settling

C

Solvent Extraction

Liquids Pretreatment

- Chemical Conditioning (e.g., pH Adjustment) Depends on:
  - Waste Characteristics
  - Buffering Capacity of Waste Matrix
  - Treatment Equipment
  - Construction Materials

A

Types of Solvent Extraction (SE)

1. Standard SE
2. Near Critical Fluid/Liquified Gas SE
3. Critical Solution Temperature SE (CST)

B

Standard Solvent Extraction

Solvents Used for Standard Solvent SE Include:

- Alkanes
- Ketones
- Alcohols
- Other Solvents at Ambient Temperatures

C

Standard Solvent Extraction Process

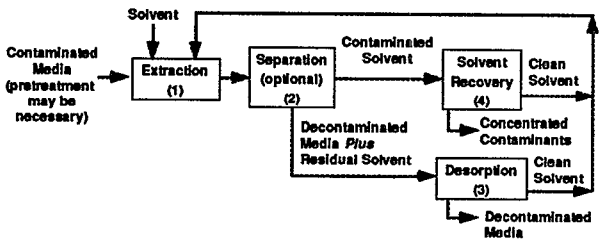
A

4 Basic Steps:

1. Extraction
2. Separation
3. Desorption
4. Solvent Recovery

Schematic of a Standard Solvent Extraction Process

B



Standard Solvent Extraction Process

Extraction

C

- Contaminated Media Are Mixed With Solvent
  - Pretreatment of Contaminated Media is Sometimes Necessary to Enhance Mixing
- Solvent Type and Contact Time are Selected through Treatability Studies

Standard Solvent Extraction Process

Separation

- This Optional Stage Includes Decanting the Liquid Phase from the Solid Phase
- The Liquid Phase Will Contain
  - Solvent
  - Fines
  - Contaminants
- Usually, the Solid Phase Will Contain Water

A

Standard Solvent Extraction Process

Desorption

- This Step Separates Any Residual Solvent from the Decontaminated Material Through Either
  - Vapor or Steam Stripping
  - Indirect Heating
- The Resulting Solvent Is Placed Back in the Extractor for Recycling
- The Resulting Solvent-Free Decontaminated Material Is Returned to the Site, Treated, or Disposed Of

B

Standard Solvent Extraction Process

Solvent Recovery

- This Step Involves Solvent Recovery Through Distillation
  - Distillate Is Sent to the Extractor for Reuse
  - Still Bottoms, with Concentrated Contaminants Require Further Treatment

C

Standard Solvent Extraction Process

Post Treatment

- Solvent Extraction Products Requiring Further Management
  - Concentrated Contaminants
  - Fines (Silts and Clays)
  - Separated Water
  - Side-Streams, Including Spent Solvents, Spent Activated Carbon, and Air Emissions

A

Standard Solvent Extraction Process

Post Treatment

- Typical Extraction Solvents Are Volatile or Biodegradable
  - Air Monitoring Is Used to Detect Problems
- The Presence of Metals or Other Inorganic Compounds Indicates a Need for Further Treatment
- Water from Solvent Extraction Processes Usually Is Adequately Treated at Standard Wastewater Treatment Plants

B

Variations on Standard Solvent Extraction

- Several Vendors Have Adapted SE to Different Site Situations, Such as Processes With
  - Lower Energy Requirements
  - Mixing and Distillation Enhancements
  - Specific Solvents
  - Extraction Enhancements

C

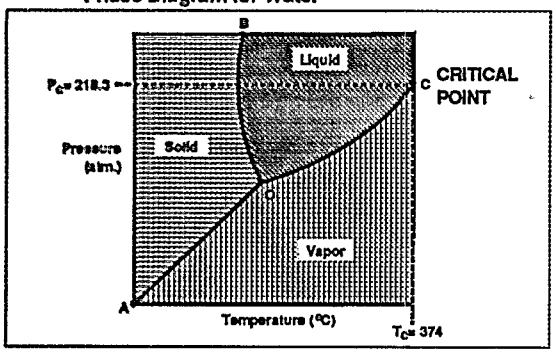
Near-Critical Fluid/Liquified Gas Solvent Extraction

- Often Termed Near-Critical Liquid (NCL) Solvent Extraction
- Similar to Standard Solvent Extraction, Except That It Uses Solvents Near Their Thermodynamic Critical Point
  - Thermodynamic Critical Point is the Combination of Temperature and Pressure Where Liquid and Gas Phase Are In Equilibrium
    - Exhibiting the Diffusity and Viscosity of a Gas *and* the Solvent Qualities of a Liquid.

A

Thermodynamic Critical Point for Water

Phase Diagram for Water



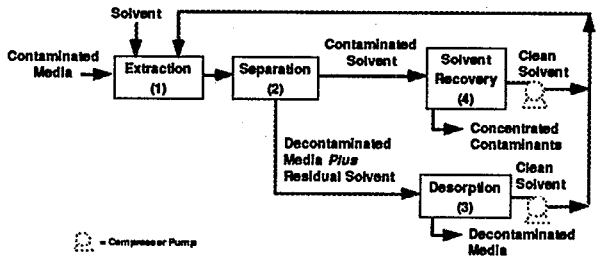
B

Properties of NCL Solvent Extraction

- Penetrates Like a Gas and Removes Contaminants Like a Liquid
- Operated at Elevated Pressure
- Address Solids and Liquids
- May Be a Continuous or Batch Process

C

Near-Critical Fluid/Liquified Gas Solvent Extraction Process Schematic



A

Examples of NCL Solvent Extraction

- Only Proprietary Units Are Available
- 2 Vendors of NCL Units
  - CF Systems
  - Sierra Environmental Services

B

Modifications to NCL Solvent Extraction

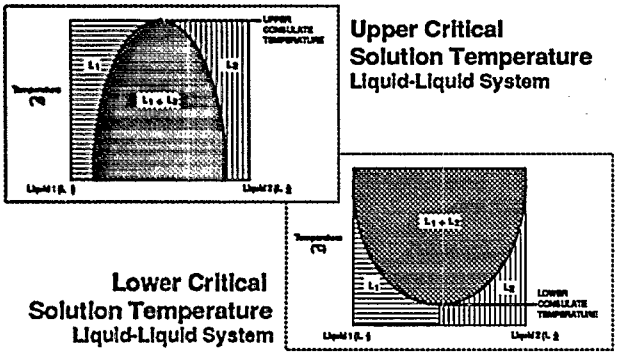
- There Are Bench-Scale Tests of This Method Using Super-Critical Fluids (SCFs)
  - SCFs Are Fluids Heated and Pressurized beyond Their Thermodynamic Equilibrium
- 3 SCF Methods under Exploration:
  1. Uses SCFs to Regenerate Spent Granular Activated Carbon
  2. Uses SCFs to Simultaneously Remove and Oxidize Contaminants
  3. Uses Nontoxic SCFs (e.g., Carbon Dioxide) to Remove Organic Contaminants

C

Critical Solution Temperature (CST) Solvent Extraction

- Employs Solvents with Extraction Capabilities That Are Enhanced under Nonambient Temperatures
- CST Solvent Extractions Are Liquid-Liquid Systems (Usually a Chemical Solvent and Water) Where the Mutual Solubilities of Each Solvent Increase as They Approach the CST (i.e., Both Solvents are Miscible in Each Other.)
- Three Types of CST Solvent Extractions with Either:
  - Upper Critical Solution Temperatures
  - Lower Critical Solution Temperatures
  - Upper and Lower Critical Solution Temperatures

A

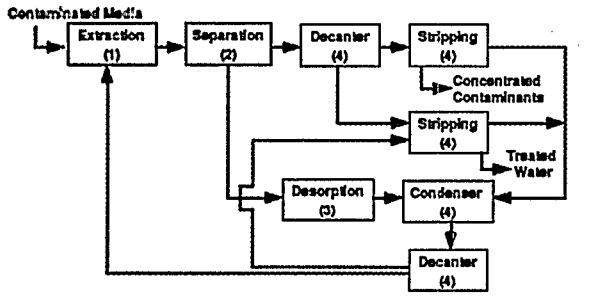


Upper Critical Solution Temperature
Liquid-Liquid System

Lower Critical Solution Temperature
Liquid-Liquid System

B

CST Solvent Extraction Schematic



C

CST Solvent Extraction Process

- Contains the Same 4 Basic Steps as Standard Solvent Extraction
- Solvent Recovery Step, However, May Be Much More Complex
  - Involves One or More Cycles of Decanting, Stripping, and Condensing

A

Use of Solvent Extraction Processes

- Promising for Organic Contaminant Removal
- SE Has Been Used at Full-Scale for 2 Superfund Sites
  - Tulsa, OK
  - Garden City, GA
- SE Has Been Selected at 5 Other Superfund Sites for Soils Contaminated with PCBs, PCPs, PAHs, and Other Organic Contaminants
  - These Sites Are Located in MA, ME, NJ, and TX

B

Preliminary Screening

- Includes:
  - Assessing Site-Specific Factors
  - Literature Search
  - Expert Judgment
  - Data Bases (e.g., RREL Treatability Data Base)

C

Most Important Prescreening Parameters:

- Contaminant Profile
- Contaminant Concentrations

A

Major Site Characterization Tests for Remedy Screening

PARAMETER	DESCRIPTION OF TEST	PURPOSE AND COMMENTS
ORGANICS	Varied	To Determine Concentration of Target or Interfering Constituents, Pretreatment Needs, Extraction Medium
GRAIN SIZE ANALYSIS/ PARTICLE SIZE DISTRIBUTION	Sieve Screening Using a Variety of Screen Sizes	To Determine Volume Reduction Potential, Pretreatment Needs, Solid/Liquid Separability

B

Major Site Characterization Tests for Remedy Screening

PARAMETER	DESCRIPTION OF TEST	PURPOSE AND COMMENTS
BULK DENSITY	Drive Cyclinder Method Sound-Cone Method	To Determine Throughput Capacity In Terms of Cubic Yards or Tons Per Hour
or		
SPECIFIC GRAVITY	Hydrometer or Pycnometer	

C

Major Site Characterization Tests for Remedy Selection

A

PARAMETER	DESCRIPTION OF TEST	PURPOSE AND COMMENTS
Total Organic Carbon (TOC) *or* Total Recoverable Petroleum Hydrocarbon	Combustion Infrared Spectrophotometer	To Determine the Presence of Organic Matter, Adsorption Characteristics of Soil
Moisture Content	Drying Oven at 110 °C in Situ, Nuclear Method	To Determine Pretreatment Needs. Water May Impede Some Extraction Processes

Contaminant Distribution

B

- Important to Assess Contaminant Distribution for Each Soil Type
  - Also "Hot Spots"
- Solvent Extraction May Be Applicable to Only Part of a Site.

Other Prescreening Contaminant Factors for SE

C

- pH
- Chemical Oxygen Demand
- Toxicity
- Viscosity

Other Important Contaminant and Residual Attributes

- Vapor Pressure
- Solubility in Specified Solvent(s)
- Henry's Law Constant
- Partition Coefficient
- Boiling Point

A

Solvent Extraction Limitations

- General Limitations Are Related to:
  - Contamination Mixture or Composition
  - Media
  - Process

B

Solvent Extraction Limitations

- Process Limitations:
  - Number of Extraction Cycles Needed
  - Ease of Recycling Solvent
  - Presence of Complex Hydrophillic *and* Hydrophobic Contaminants
  - Amount of Pretreatment Required

C

Qualities of the 3 Types of Solvent Extraction Vary

	Type of Solvent Extraction		
	STANDARD	NCF	CST
Ability to Process Fines and Clay	D	A	D
Ability to Process Wide Variety of Organics	A	D	D
Ease of Phase Separation	D	A	A
Energy Required	A	A	D

(A= Advantage D= Disadvantage)

A

Solvent Extraction Treatability Study Questions

- What Contaminant Will SE Leave Behind?
- Will Residual Contaminant Concentrations Meet ARARs and Risk-Based Clean-Up Levels?
- What Are the Physical, Chemical, and Contamination Differences Between Treated and Untreated Solids?
- What Impact Will Construction and Implementation of SE Have?

B

Solvent Extraction Implementation Questions

- Will Solvent Residuals in Soil and Water Make Residuals Treatment and Disposal Difficult?
- What are the Characteristics and the Volume of the Residuals that Will Be Produced?
- Are the Process Equipment and Solvent Readily Available?

C

Solvent Extraction Implementation Questions

- Can the Solvent Be Recovered and Recycled Economically?
- What Are the Necessary Pretreatment Steps (Specific to the Process Equipment and Solvent)?
- Will the Solvent Extraction System Chemicals React with the Solutes?

A

Solvent Extraction Long-Term Risk Issues

- What is the Magnitude of Risk From:
  - Treatment Residuals?
  - Side-Stream Residuals?
  - Other Treatment Train Processes?
  - Long-Term Measures (e.g., Site Access Limitations)?

B

Solvent Extraction Cost Advantages

- SE Concentrates Contaminants, thereby Reducing Treatment and Disposal Costs
- Reductions in Hauling, Treatment, and Disposal Costs Usually Make SE Cost-Effective

C

Solvent Extraction Process Cost Parameters Provided by Treatability Studies

- The Volume and Characteristics of Residual Wastewater and Sludge That Require Treatment or Disposal
- The Degree to Which Process Modifications Can Enhance the Efficiency of the Process
- The Degree to Which the Solvent and/or Contaminant Can Be Recovered and Recycled
- The Solvent-to-Feed Ratio
- The Number of Extraction Stages Necessary

A

Remedy Screening Is Not Always Necessary

- Prescreening Is Usually Sufficient to Initiate Remedy Selection Tests
  - If Organics Are Present, then Proceed with Remedy Selection Tests for Solvent Extraction
  - If Organics Are Not Present, then Do Not Proceed
- Existing Information Plus Expert Judgment Sometimes Substitute for Remedy Screening

B

Remedy Screening May Be Necessary, If:

1. The Waste Matrix Has Not Been Extracted
2. The Waste Matrix Contains a Wide Variety of Contaminants

C

Potential Remedy Screening Goals

A

1. To Confirm Solvent-Contaminant Compatibility
2. Solvent Extraction of 50% to 70% of Contaminants
3. To Eliminate Ineffective Treatment Technologies from Further Consideration

Remedy Selection Study Goals

B

1. Before and After Contaminant Concentrations in Treated Soil, Sludge, or Water
   - Typically 90% to 99% Removal
2. Design Information
3. Full-Scale Cost Estimates

Remedy Screening Experimental Design

C

- Important Physical Characteristics to Ascertain:
  - Contaminant Viscosity
  - Contaminant Specific Gravity
  - Soil Particle Site and Pore Size Profiles

Remedy Screening Experimental Design

- Other Important Data
  - Solvent(s) Solubility
  - Solvent(s) Vapor Pressure
  - Solvent(s) Henry's Law Constant

A

Remedy Screening Experimental Design

- Typical Remedy Screening Test for Soil Includes 6 Extraction Steps Using 5 kg of Soil, Standard Glassware, Centrifuge, Vacuum Filter, and Analyses
- An Alternative, Soxhlet Extraction, Uses Only 1 kg of Soil

B

Remedy Screening Tests

General Conditions

- Operate at Ambient Temperatures
- Use Hydrophillic Solvents for First Extraction
- Use Hydrophobic Solvents to Treat Residual in Soil after the First Extraction
- Select Solvent(s) after Identifying Contaminants

C

Examples of Hydrophillic Solvents

- Acetone
- Methanol
- Dioxane

A

Examples of Hydrophobic Solvents

- Hexane
- Kerosene

B

Using Indicator Contaminants Can Reduce Analytical Costs

- Indicator Contaminants Are Selected Based On:
  - Most Highly Toxic or Prevalent Contaminant
  - Most Representative of Chemical Contaminant Groups in the Soil
- If PCBs and Dioxins Are Present, PCB Tests Are Usually Used

C

Remedy Selection Experimental Design

- Bench-Scale Tests Generally Are Used for Remedy Selection
- Pilot-Scale Tests Are Used to:
  - Investigate Foaming Problems at Bench-Scale
  - Gain Community Acceptance
  - Better Define Costs

A

Remedy Selection Experimental Design

Considerations

- Solvent:Feed Ratios
- Extraction Mixing: Duration, Intensity, and Number of Cycles
- pH, Temperature, and Pressure
- Utility of Pre- and Post-Treatments

B

Remedy Selection Experimental Design

Benchmarks

- Typical Solvent:Feed Ratios Range from 2:1 to 5:1
- Typical Extraction Mixing Lasts from 10 to 30 Minutes

C

Equipment and Materials for Remedy Screening

1. Standard Laboratory Extraction Equipment (e.g., Soxhlet, Separatory Funnel, etc.).
   OR
   Specialized Solvent Extraction Equipment (e.g., High-Pressure Systems for Critical Fluids)
2. Top Loading Balance
3. Timer

A

Equipment and Materials for Remedy Screening

4. Sample Jars
5. Filter or Centrifuge
6. Magnetic Stirrer
7. Jar Mills

B

Equipment and Materials for Remedy Selection and Design

- Remedy Selection and Remedy Design Tiers Require Equipment and Materials Similar to Remedy Screening, Except at Different Scales.
  - Remedy Selection Generally Uses Bench-Scale
  - Remedy Design Uses Vendor-Specific Pilot-Scale

C

Sampling and Analysis Plan (SAP)

- SAP = Field Sampling Plan (FSP)
  + Quality Assurance Project Plan (QAPjP)
- Goal Is to Collect Representative Samples
- SAPs Are Site-Specific and Include:
  - Field Sampling
  - Waste Characterization
  - Treated Wastes and Residuals

A

Field Sampling Plan (FSP)

Contains:

- Number, Type, and Location of Samples
- Sample Numbering System
- Sample Collection Equipment and Procedures
- Chain of Custody Procedures
- Packaging, Labeling, and Shipping Procedures

B

Field Sampling Plan Questions

- Are Composite Samples Necessary?
- Are Representative Sample Sites Identified?
- Are Soils Heterogeneous or Homogeneous?
- Are Contaminants in Sediments, Sludges or Water?
- Are Worst-Case Samples Included?

C

Quality Assurance Project Plan Elements

- Experimental Description
- Quality Assurance Objectives
- Sampling Procedures

A

Quality Assurance Project Plan Elements

- Analytical Procedures and Calibration
- Data Reduction, Validation, and Reporting
- Quality-Control Reports

B

Data Analysis and Interpretation

Remedy Screening

At This Tier, Contaminant Concentrations in the Solids or Water Fractions Are Measured Before and After Treatment

- 50% to 70% Reduction Warrants Remedy Selection Tests
- Based on Duplicate Samples

C

Data Analysis and Interpretation

Remedy Selection

A

In Addition to Chemical Analyses, Many Process Variables Are Addressed in this Tier:

- Solvent:Solids Ratio
- Number of Extraction Stages and Solvent Sequences
- Type of Mechanical Agitation
- Extraction Temperature and Pressure
- System pH

Data Analysis and Interpretation

Full-Scale Considerations

B

1. Solvent Extraction Performance, Including Design Parameters
2. Residual Contamination in Solids, Used Solvent, and Soil Fines
3. Contaminant Concentrations in the End Product

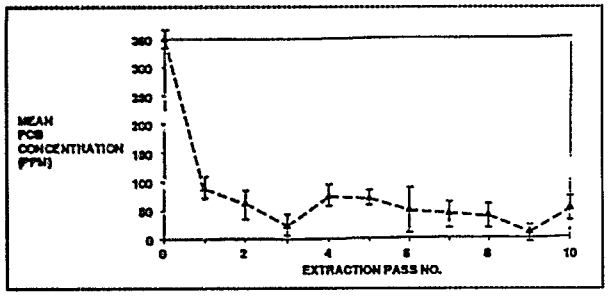
Data Analysis and Interpretation

Full-Scale Considerations

C

4. Risk Assessment for Worker and Community Hazards
5. Quantity of Oversized Materials
6. Quantity of Contaminated Water from Dewatering and Distillation Processes

Example of Pass-By-Pass PCB Concentration Plot



A

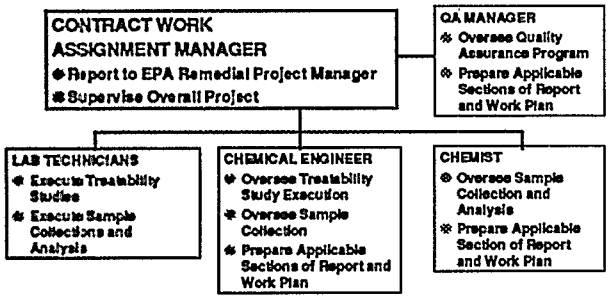
Data Analyses and Interpretation

Design Considerations

1. Material Throughput Volumes
2. Solvent Usage Per Ton Processed
3. Physical and Chemical Properties of Each Fraction to Design Management Systems

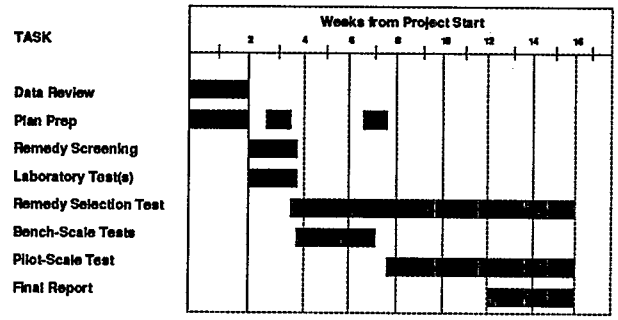
B

Example Organizational Chart



C

Example Project Schedule for a Solvent Extraction Treatability Study Program



A

Major Cost Elements for Remedy Selection SE Studies

Cost Element	Cost Range (Thousands of Dollars)
Initial Data Review	1 -10
Work Plan Preparation	1 - 5
Field Sample Collection	1 - 10
Field Sample ChemiCal Analysis	4 - 25
Laboratory Setup/Materials/Testing	4 - 25
Treatability Test Chemical Analysis	4 - 20
Data Presentation/Report/Remediation Cost Estimate	5 - 25
TOTAL COST RANGE	20 - 120

B

Major Cost Element Components

Pilot Scale

- Analytical
- Excavation
- Material Handling and Transport
- Pretreatment
- Treatment Cost and Throughput
- Residuals Management

C

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THERMAL DESORPTION

GUIDE FOR CONDUCTING TREATABILITY STUDIES UNDER CERCLA:

THERMAL DESORPTION

Interim Guidance

A

Presentation Outline

1.0 Introduction
2.0 Description of Thermal Desorption
3.0 Preliminary Screening and Technological Limitations
4.0 The Use of Treatability Studies in Remedy Evaluation
5.0 Test Goals and Experimental Design
6.0 Sampling and Analysis
7.0 Data Interpretation
8.0 Management and Budget
9.0 Summary and References

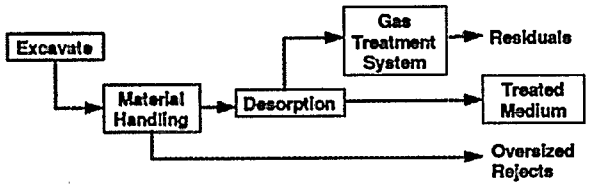
B

Thermal Desorption Process

- Thermal Desorption (TD) Is an Ex Situ Process Involving Excavation and Processing of Waste Materials
- TD Is a Physical Separation Process, *Not* a Decomposition Process
- TD Uses Direct or Indirect Heat to Vaporize Primarily Organic Contaminants from Soil, Sludge, or Sediments

C

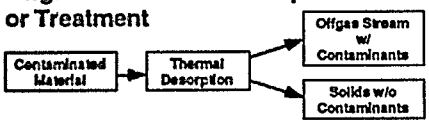
Schematic Diagram of Thermal Desorption



A

Advantages of Thermal Desorption

- Separates Contaminant from Medium into an Offgas-Stream for Subsequent Condensation or Treatment



- Reduces Waste Volume Requiring Treatment

B

Successful Organic Contamination Removal Considerations

- Contaminant Vapor Pressure
- Soil Characteristics
- Moisture Content
- Contaminant Thermal Properties
- Contaminant Concentrations

C

Excavation and Pretreatment

- Excavation Is Usually Done with Back Hoes and Belt Conveyors
- Pretreatment, Such as Screening, Creates a More Homogenous Material
  - Screened Objects Are Either Processed to Enable Thermal Desorption Processing or Are Addressed with a Different Remedial Technology

A

Thermal Desorption Process

Transfer Media

- Transfer Media Containing Vaporized Contaminants Removed by TD Include:
  - Air
  - Combustion Gas
  - Inert Gas

B

Offgas Issues

- Thermal Desorption Process Creates Contaminant Vapors, Water Vapor, and Dust
- Real Time Air Monitoring Is Generally Used to Manage Air Impacts

C

Fugitive Air Emissions Management Considerations

- Weather (e.g., High Winds)
- Aerodynamics (e.g., Wind Screens)
- Extent of Active Excavation Surface Area
- Control Agents (e.g., Foams, Water, Chemicals, or Covers)
- Site Enclosure Usage for Very Sensitive Sites (e.g., Sites Near Population Centers)

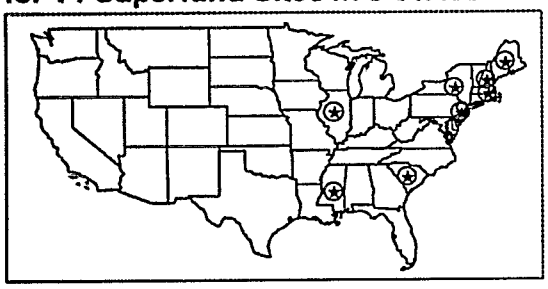
A

Offgas Vapor/Liquid Treatments

- Carbon Adsorption
- Catalytic or Thermal Oxidation
- Condensation
- Chemical Neutralization

B

Thermal Desorption Has Been Selected for 14 Superfund Sites in 8 States



C

Posttreatment

Since Thermal Desorption Can Alter Physical Characteristics of the Waste Material, a Thorough Geotechnical Evaluation Should Precede Back-Filling Material into the Site

A

Four Types of Thermal Desorption Units and Their Processing Capacities

	Processing Capacities (TPH)
Rotary Dryers	5 - 55
Thermal Screws	3 - 13
Vapor Extractors	10 - 73
Distillation Chambers	1 - 17

B

Rotary Dryers

This Unit Consists of Horizontal Cylinders, with Direct or Indirect Heat, That Move the Waste Either with an Incline or Rotation

- Direct Heat Method Blows Hot Gas Over Waste Medium
- Indirect Heat Method Blows Hot Gas Over the Rotary Drum Walls

C

Waste Residency Time in Rotary Dryers Depends on:

- Incline Angle
- Rotation Speed
- Turning Vane Pattern

A

Thermal Screw

This Unit Consists of Screw Conveyors or Hollow Augers with Hot Oil or Steam Circulated Through the Unit

- Unit Walls Are Also Heated
- Nitrogen or Combustion Gases Used to Vent the Unit

B

Thermal Screw Temperature Limitation Factors

- Heat Transfer Qualities of the Hot Oil
- Soil Characteristics
- Speed Material Is Conveyed Through the Unit

C

Thermal Screw Advantages

- Simplicity of Operation and Temperature Control
- Reduction in Fines, or Dust Generation

A

Vapor Extractor

This Unit Takes Classified Materials and Injects Hot Gases (1,000° -1,500°F) to Vaporize Contaminants and Fluidize the Medium

- Blades or Rollers Are Used to Enhance This Continuous Process
- Exit Gas Temperatures Range Around 320°F

B

Distillation Chamber

This Unit Transports Contaminated Material Through a Series of 3 to 5 Chambers with Increasing Temperatures

- The Distinct Temperature in Each Chamber Permits Segregation of Contaminants
- Vapors Are Flushed Through the System with Nitrogen
  - The Oxygen-Free Distillation Is Effectively Pyrolysis

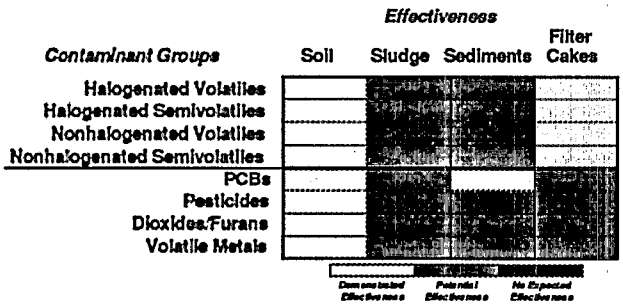
C

Preliminary Screening

- Site-Specific Factors
- Literature Search
- Expert Judgment

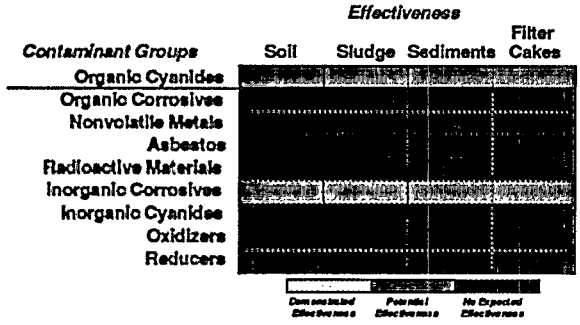
A

Effectiveness of Thermal Desorption on General Contaminant Groups



B

Effectiveness of Thermal Desorption on General Contaminant Groups



C

Thermal Desorption Is Effective in Separating:

- Refinery Wastes
- Coal-Tar Wastes
- Wood-Treating Wastes
- Creosote-Contaminated Soils

A

Thermal Desorption Is Effective in Separating:

- Pesticide-Contaminated Soils
- Mixed Radioactive and Hazardous Wastes
- Synthetic Rubber Processing Wastes
- Paint Wastes

B

Thermal Desorption May Be Appropriate for Only Part of the Site

- Profile the Different Contaminated Soils
- Profile Site "Hot Spots"
- Assess Need to Homogenize Contaminated Material to Improve Thermal Desorption Efficiency

C

Prescreening Sampling Considerations

- Surface Grab Samples May Miss Significant Variation in Subsurface Composition, Including:
  - Contaminants Levels
  - Soil Classifications
  - Total Organic Carbon
- Location and Concentration of VOCs and SVOCs Are Particularly Important
- Larger Soil Fractions Should Be Mapped for Possible Removal and Pretreatment

A

Prescreening Contaminant Assessment Factors

- Chemical Properties
- Physical Properties
- Concentrations
- Volatilities
- Densities

B

Key Prescreening Characteristics for Thermal Desorption Treatability Testing
Remedy Screening

PARAMETER	DESCRIPTION OF TEST	PURPOSE AND COMMENTS
ORGANICS	Varied	To Determine Concentration of Target or Interfering Constituents, Pretreatment Needs, and Extraction Medium
METALS	ICP Atomic Absorption Spectroscopy	To Determine the Potential Emissions of Volatile Metals and Inorganic Alkali

C

Key Prescreening Characteristics For Thermal Desorption Treatability Testing
Remedy Selection/Chemical

PARAMETER	DESCRIPTION OF TEST	PURPOSE AND COMMENTS
TOTAL ORGANIC CARBON (TOC) *or* TOTAL RECOVERABLE PETROLEUM HYDROCARBON *or* OIL & GREASE	Combustion Infrared Extraction for Sludge Samples	To Determine the Presence of Organic Matter and/or Adsorption Characteristics of Soil
TCLP	Extraction	To Determine Leachability of Organic and Inorganic Compounds in Liquid/Solid Residuals

A

Key Prescreening Characteristics For Thermal Desorption Treatability Testing
Remedy Selection/Physical

PARAMETER	DESCRIPTION OF TEST	PURPOSE AND COMMENTS
GRAIN SIZE ANALYSIS/ PARTICLE SIZE DISTRIBUTION	Sieve Screening Using a Variety of Screen Sizes	To Determine Volume Reduction Potential Pretreatment Needs
MOISTURE CONTENT	Drying oven at 110°C In Situ Nuclear Method	To Determine Pretreatment Needs and Medium Processing Rate
BULK DENSITY	Drive Cylinder Method Sand Cone Method Nuclear Method Hydraulic Cement Stabilized Waste	To Estimate Total Mass of Soil to Be Treated
pH	Soil pH	

B

Thermal Desorption

General Applicability

- Soils, Sludges, and Sediments
- VOCs, SVOCs, and Other Organics with High Boiling Points
- Generally Not Effective for Inorganics

C

Technical Factors Affecting Thermal Desorption Performance

- Maximum Bed Temperature
- Total Residence Time
- Organic and Moisture Content
- Contaminant Characteristics
- Waste Medium Properties

A

General Expense Factors for Thermal Desorption

- Waste Materials with High Organic Contamination Levels
- Waste Materials with High Moisture Levels
- Very High or Low pH Levels

B

Thermal Desorption

Solids

- Typical Thermal Desorption Systems Process Materials with 80% Solids
- Poor Thermal Desorption May Occur with Soils that:
  - Are Tightly Aggregated
  - Are Largely Clay
  - Contain Rocks or Fragments >38 mm
- Too Many Fines from Processed or Unprocessed Contaminated Material Can Stress Dust Control Systems

C

Evaluation of Thermal Desorption Against RI/FS Criteria

- What are Pre- and Posttreatment Contaminant Concentrations, Physical Features, and Chemical Characteristics?
- Will Residual Contamination Meet ARARs and Risk-Based Cleanup Levels?
- Will Treatment Create New Contaminants?
- What Are the Construction and Implementation Impacts?

A

RI/FS Implementation Issues

- Will Ambient Releases of Volatile Contaminants That Occur During Excavation and Classification Require Controls?
- Is There a Need for a Blending Program to Ensure Waste Hot Spots Can Be Accommodated by the Thermal Desorption System?
- Is the Water Content of the Waste/Sludge Too High or Highly Variable?

B

RI/FS Implementation Issues

- Has the Degree of Particulate Entrainment Been Determined, and Will the Particulate Need to Be Recycled?
- Have the Volumes and Characteristics of Residuals Been Approximated, and Are Residuals Treatment and Disposal Options Established?

C

RI/FS Implementation Issues

- What Are the Residual Risks after All Remedial Action?
- Are Long-Term Controls Adequate and Reliable?

A

RI/FS Cost Factors

- Ultimate Cleanup Achievable
- Volume and Characteristics of Residuals for Treatment or Disposal
- Degree to Which Medium Pretreatment or Process Modifications Can Enhance Thermal Desorption Efficiency
- Amount of Energy Required to Heat the Medium and Associated Fuel Costs

B

Remedy Screening Tier

- Determines Thermal Desorption General Applicability for All or Part of the Site
- Identifies Operating Parameters for Investigations in Later Tiers
- Can Skip This Tier if There Are Sufficient Existing Data
- Cost Range: $8,000 - $30,000

C

Remedy Selection Tier

- Establishes Whether Thermal Desorption Can Meet Site Cleanup Goals
  - Including Optimal Operating Conditions
- Cost Range: $10,000 - $100,000

A

Remedial Design/Remedial Action Tier Data Generation

- Specify Equipment Type for Full-Scale Unit
- Determine Feasibility of Thermal Desorption Based on Target Cleanup Goals
- Refine Cleanup Time Estimates
- Refine Cost Predictions

B

Remedial Design/Remedial Action Tier

- Possibly Unnecessary if Remedy Selection Phase Used a Pilot-Scale Unit for Tests
- Uses Vendor-Specific Equipment
  - Either an Onsite Small Scale Unit or a Mobile Unit
- Cost Range: $50,000 - $200,000

C

Remedy Screening

Experimental Design

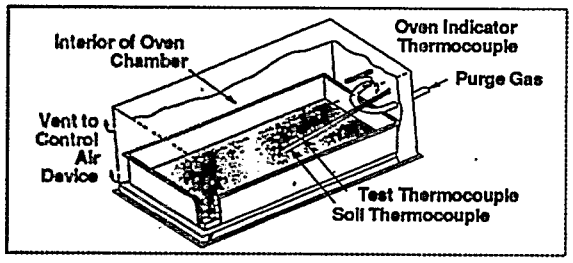
A

Several Possible Testing Systems, Including:

- Static Tray
- Differential Bed Reactor (DBR)

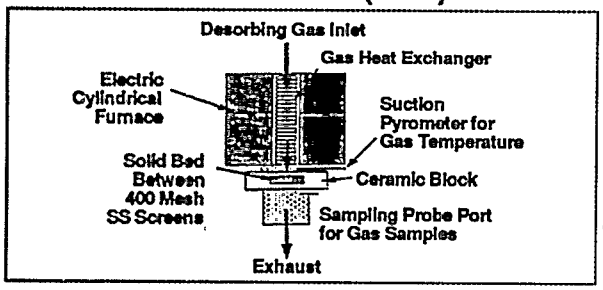
Cutaway View of Static Tray Test Oven with the Tray Insert

B



Cutaway View of Differential Bed Reactor (DBR)

C



Analytical Cost Reduction Selection Guidance for Remedy Screening

A

- 1 or 2 Low Volatility Contaminants
- 1 or 2 That Are Most Toxic or Most Prevalent
- Representatives of Chemical Groups
- Composite or Hot-Spot Samples
- Polar Contaminants

Experimental Design

Remedy Selection Tier

B

Critical Factors Generated:

- Time-at-Temperature
- Residual Contamination Levels as a Function of:
  - Heat Input
  - Bed-Mixing Characteristics

Remedy Selection Control Variables

C

- Moisture Content of Medium
- Contaminant Concentration in Medium
- Particle Size of Medium
- Treatment Temperature or Minimum Solids Temperature
- Time-at-Temperature or Total Residence Time

Remedy Selection Control Variables

- Medium Physical and Chemical Characteristics
- Thermal Properties of Contaminated Medium
- Degree of Agitation (Solid/Gas Mixing)
- Purge Gas Flow, Composition, and Temperature

A

Remedy Screening Equipment

- Muffle Furnace, Vapor Extractor, DBR, or Similar Devices
- Exhaust Hood (for Control of Fugitive Dust and Volatilized Compounds)
- Tray or Some Other Device to Hold Contaminated Media
- Thermocouples (to Record Medium and Gas Temperature)
- Rotameter (to Regulate Purge Gas Flow Rate)

B

Remedy Selection Equipment

- Rotary Dryer
- Thermal Screw
- Vapor Extractor
- Distillation Chamber
- Associated Offgas Controls for Each

C

Sampling and Analysis

A

Sampling Locations Should Be Based On:

- Previous Sampling
- Obvious Odors
- Residues

Required Analyses for Remedy Selection Tier

B

Sample Component	*Parameter* VOC/SVOC/pH	Moisture/ Ash/Oil/Grease/ Particle Size
Feed Stream	✔	✔
Treated Stream	✔	✔
Offgas/Condensate	✔	✘

✔ = Required ✘ = Not Required

Sampling Technique Sources

C

- EPA/OSW
- ASTM
- NIOSH

Thermal Desorption Residuals Requiring Analysis

- Treated Medium
- Condensate
- Particulate Control Dust

A

Thermal Desorption Residuals

- Residuals Should Be Analyzed for Target *and* Created Contaminants
- Since Thermal Desorption Is Vendor-Specific, and Encompasses a Wide Range of Technologies, Remedial Design/Remedial Action Tests Are Often Necessary

B

Field Sampling Issues

- Are There Adequate Data to Determine Sampling Locations Indicative of the More Contaminated Areas of the Site?
- Have Soil Gas Surveys Been Conducted?
- Are the Soils Homogenous or Heterogenous?
- Are Contaminants Present in Sediments or Sludges?
- Is Sampling of a "Worst-Case" Scenario Warranted?

C

Quality Assurance Project Plan Elements

- Number of Samples (Areas) to Be Studied
- Identification of Treatment Conditions (Variables) to Be Studied for Each Sample
- Target Compounds for Each Sample
- Number of Replicates Per Treatment Condition
- Criteria for Technology Retention or Rejection for Each Type of Remedy Evaluation Test

A

Quality Control Report Elements

- Assessments of Data Quality in Terms of Precision, Accuracy, Completeness, Method Detection Limits, Representativeness, and Comparability
- Limitations or Constraints on the Applicability of the Data
- Status of QA/QC Programs, Accomplishments, and Corrective Actions
- Results of Technical Systems and Performance Evaluation QC Audits
- Changes to the QA Project Plan

B

Remedy Screening

Key Results

- Temperature
- Treatment Time
- Initial Contaminant Concentrations
- Treated Medium Contaminant Concentrations

C

Remedy Screening

Key Parameters

- Soil Classification
- Contaminant Type
- Moisture Content
- Solid/Gas Mixing

A

Remedy Selection Performance Criteria

- Throughput Rate Expected for the Applicable Remedial Design/Remedial Action Thermal Desorption Device
- Material Handling System Design Requirements (Pre- and Posttreatment)
- Air Pollution Control System Design Requirements
- Need for Air Pollution Control Measures during Excavation, Transport, and Feeding

B

Data Interpretation

Remedy Screening:	To Establish the General Applicability of Thermal Desorption to the Site
Remedy Selection:	To Establish the Specific Applicability of Thermal Desorption to the Site
Remedial Design/ Remedial Action:	To Establish Support for Post-ROD Evaluation Criteria

C

Goals

- Address General Medium Pretreatment and Materials Handling Requirements
- Estimate Performance and Cost Data of Full-Scale Systems
- Verify That Thermal Desorption Can Meet Cleanup Levels at Normal Operating Conditions
- Define Heat Input Requirements
- Address General Offgas Treatment and Residuals Disposal Requirements

A

Remedy Selection Data

Requires Scaling Up Using Either:

- Past Experience
- Computer Model

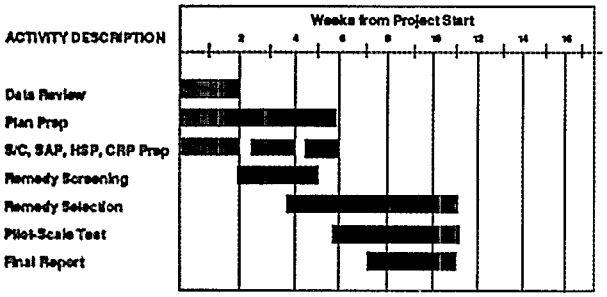
B

Example of a Scale-Up Computer Model

- GRI/NSF Thermal Treatment Model
  - Developed by University of Utah
  - Describes the Decontamination Process for a Solid Medium in a Rotary Dryer
  - Not Vendor Specific
  - Used in the Remedy Selection and RD/RA Tiers

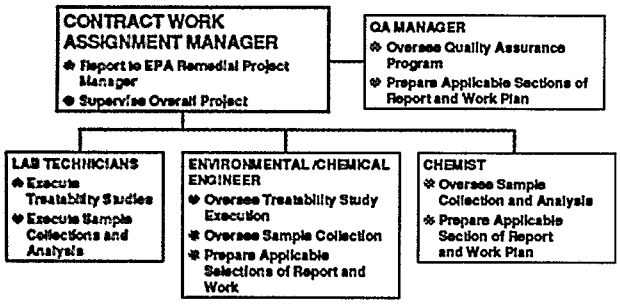
C

Example Project Schedule for a Solvent Extraction Treatability Study Program



A

Organizational Chart



B

Major Cost Elements for Remedy Selection Tier

Cost Element	Cost Range (Thousands of Dollars)
Initial Data Review	1 - 10
Work Plan Preparation	1 - 5
Sampling & Testing	3 - 6
Analysis, QA/QC Activities	3 - 20
Data Presentation/Report	2 - 5
Total Cost Range	$10,000 - $100,000

C

Cost Factors

Site Variability

Sites with Variable Conditions Are More Expensive to Remediate with Thermal Desorption Than Are Homogenous Sites. The Most Influential Variables Are:

- Media
- Contaminant Type
- Contaminant Concentrations
- Moisture

A

Remedy Selection Data Needed to Estimate Full-Scale Costs

- Medium Pretreatment and Materials Handling
- Moisture Content
- Contaminant Identification, Concentration, and Quantity
- Operating Temperature

B

Remedy Selection Data Needed to Estimate Full-Scale Costs

- Treatment Time
- Residual Contaminants and Contaminant Concentrations in the Treated Medium
- Offgas Treatment

C

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