7/1/95

SANDIA REPORT

SAND94–2611 • UC–~~510~~ 2000
Unlimited Release
Printed June 1995

Identification of Remediation Needs and Technology Development Focus Areas for the Environmental Restoration (ER) Project at Sandia National Laboratories/New Mexico (SNL/NM)

Mark D. Tucker, John M. Valdez, Mushtaq A. Khan

Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550
for the United States Department of Energy
under Contract DE-AC04-94AL85000

SF2900Q(8-81)

Issued by Sandia National Laboratories, operated for the United States Department of Energy by Sandia Corporation.

Printed in the United States of America. This report has been reproduced directly from the best available copy.

Available to DOE and DOE contractors from
Office of Scientific and Technical Information
PO Box 62
Oak Ridge, TN 37831

Prices available from (615) 576-8401, FTS 626-8401

Available to the public from
National Technical Information Service
US Department of Commerce
5285 Port Royal Rd
Springfield, VA 22161

NTIS price codes
Printed copy: A05
Microfiche copy: A01

SAND94-2611
Unlimited Release
Printed June 1995

Distribution
Category UC-510

Identification of Remediation Needs and Technology Development Focus Areas for the Environmental Restoration (ER) Project at Sandia National Laboratories/New Mexico (SNL/NM)

Mark D. Tucker
Site Restoration Technology Program Office
Sandia National Laboratories
Albuquerque, NM 87185-0715

John M. Valdez
Mushtaq A. Khan
IT Corporation
5301 Central Avenue NE, Suite 700
Albuquerque, NM 87108-1513

Abstract

The Environmental Restoration (ER) Project has been tasked with the characterization, assessment, remediation and long-term monitoring of contaminated waste sites at Sandia National Laboratories/New Mexico (SNL/NM). Many of these sites will require remediation which will involve the use of baseline technologies, innovative technologies that are currently under development, and new methods which will be developed in the near future. The Technology Applications Program (TAP) supports the ER Project and is responsible for development of new technologies for use at the contaminated waste sites, including technologies that will be used for remediation and restoration of these sites. The purpose of this report is to define the remediation needs of the ER Project and to identify those remediation needs for which the baseline technologies and the current development efforts are inadequate. The area between the remediation needs and the existing baseline/innovative technology base represents a technology gap which must be filled in order to remediate contaminated waste sites at SNL/NM economically and efficiently. In the first part of this report, the remediation needs of the ER Project are defined by both the ER Project task leaders and by TAP personnel. The next section outlines the baseline technologies, including EPA defined Best Demonstrated Available Technologies (BDATs), that are applicable at SNL/NM ER sites. This is followed by recommendations of innovative technologies that are currently being developed that may also be applicable at SNL/NM ER sites. Finally, the gap between the existing baseline/innovative technology base and the remediation needs is identified. This technology gap will help define the future direction of technology development for the ER Project.

Table of Contents

(this page left blank)

Section 1
Executive Summary

A. Introduction

The Environmental Restoration (ER) Project has been tasked with the characterization, assessment, remediation, and long-term monitoring of contaminated waste sites at Sandia National Laboratories/New Mexico (SNL/NM). The Technology Applications Program (TAP) supports the ER Project and is responsible for the development, transfer, and application of innovative technologies for remediation of those sites. This report has been written in support of that responsibility and its purpose is to accomplish four objectives:

1. Define the remediation needs of the ER Project. These needs were developed based on interviews with the task leaders responsible for the SNL/NM ER sites, and from the knowledge and expertise of TAP remediation engineers.

2. Review remediation unit operations considered the Best Demonstrated Available Technologies (BDAT). The purpose of this effort is to identify proven combinations of technologies (referred to as alternatives) in a framework that establishes a range of increasingly more complex solutions. A range of potential solutions are appropriate at this time due to the uncertainties associated with parameters such as future land use, risk-based decision making, and acceptance of remedial approach by the regulatory community.

3. Propose remedial alternatives based primarily on use of innovative technologies that are currently under development using the same conceptual framework as BDAT alternatives. This body of information helps focus the current areas of development and identifies potential technologies that may be more appropriate for application from the engineering optimization perspective.

4. Identify the technology gap between the remediation needs of the ER Project and the existing baseline/innovative technology base.

By identifying the gap between remediation needs and the existing baseline/innovative technology base, future development efforts by the Technology

Applications Program (TAP) and other organizations interested in supplying remediation technologies to the ER Project can be directed into technology development focus areas clearly aimed at solving problems for SNL/NM site remediation that cannot be adequately addressed by application of currently available technologies.

B. Identification of Remediation Technology Needs

The first objective of this report is to identify the remediation needs of the ER Project. The remediation needs were defined primarily by two groups of knowledgeable individuals. The first group of individuals were the individual task leaders who are responsible for oversight of various operable units in the SNL/NM ER Project. They were interviewed to determine their perspective concerning remediation technology needs. These interviews resulted in substantial information in this area. Specific problems identified include:

- Ex-situ separation technology for removing depleted uranium (DU) from soil.
- Technologies for excavation and remediation of buried waste sites using remote control/robotic devices.
- Technologies to remediate or contain soils contaminated with tritium.
- Enhancement of technologies for remediation of soils contaminated with organics using thermally enhanced soil vapor extraction (SVE).
- Technologies for destruction of organic contaminants.
- Remediation strategies for classified waste.
- Development of capping technologies for radioactive disposal sites in an arid environment.
- Development of containment systems for arid environment.
- Assistance to task leaders in planning and design of Voluntary Corrective Measures (VCM) that use new and innovative technologies.

The second group of individuals that provided information concerning remediation technology needs consisted of TAP engineers who are responsible for the development, transfer, and application of innovative technologies for the remediation of SNL/NM ER sites in coordination with the ER staff and management responsible for the investigation and remediation of these sites. This group of individuals has experience and expertise in the area of selecting the preferred remedial approach (in the regulatory context such as RCRA Corrective Measures Studies) and in the design and implementation of remediation technologies. Specific issues identified by this group include:

- Development of decision support tools designed to assist decision makers in selection of remedial process alternatives.
- Combining the characterization data requirements for nature and extent of contamination with those of site remediation data requirements.
- Replacement technologies for thermal treatment.
- Continuation of efforts to speed up the restoration of contaminated areas through the application of Corrective Action Management Units (CAMU) and the development of innovative technologies compatible with the application of CAMUs.
- Alternative technologies for the containment and isolation of mixed waste containing long-lived radionuclides and depleted uranium.
- Improvement of in-situ Soil Vapor Extraction (SVE) technologies.
- Development of biodegradation technologies for arid environment applications.
- Development of an improved technology for removal of mercury from soil.

Currently, because of the status of work in the ER Project, the focus of the task leader is primarily on characterization and assessment. It is not possible, at this time, to make decisions with absolute certainty concerning remediation technology needs or the direction of remediation technology development. A critical point made throughout the report is that this decision making process will be iterative in nature. As new information becomes available, previous conclusions will be revisited to test the validity of previous assumptions and to identify new areas of needs. However, since the ER Project has a relatively short lifetime, a highly iterative process of technology development will not be possible. Therefore, it is important that development of the remediation needs identified in this report be pursued in a timely manner.

C. Best Demonstrated Available Technology Remediation Alternatives

The second objective of this report is to identify currently available (baseline) remediation technologies (referred to as alternatives) that can potentially be applied at SNL/NM ER sites. The baseline alternatives recommended in this report have the potential to meet currently recognized performance requirements and regulatory constraints applicable to SNL/NM ER sites. The baseline alternatives consist of EPA defined Best Demonstrated Available Technologies (BDAT) and other technologies that have been sufficiently demonstrated to be considered baseline. An example of a performance requirement for baseline alternatives that treat organic wastes is the Destruction and Removal Efficiency (DRE) parameter outlined in RCRA. Another example of a performance requirement is the Land Disposal Restrictions (LDR) promulgated in the Hazardous and Solid Waste Amendments (HSWA) of RCRA. The LDRs require that hazardous waste must be processed to certain treatment standards before it can be disposed of in facilities such as landfills or injection wells. The treatment standard is usually expressed as a concentration of the contaminant in the final waste form. Definitions of alternatives consisting of BDATs are specified in accordance with RCRA regulations because it is anticipated that a portion of the contaminated material at SNL/NM ER sites is mixed, meaning that contaminants include a combination of hazardous (as defined by RCRA) and radioactive constituents.

Since a portion of ER waste is considered to be mixed and subject to the requirements of both RCRA and the Atomic Energy Act (AEA), management of these wastes will be subject to performance requirements such as DRE and LDR. Some discussion is necessary to understand the thought process that was applied to develop these alternatives. First, a grouping system based on the CERCLA General Response Action (GRA) concept has been applied. The GRA concept provides a logical framework for examining the merits of remediation alternatives relative to each other and against a formal set of evaluation criteria. The GRAs deemed appropriate for application at SNL/NM ER sites are:

- Containment
- In-Situ Treatment
- Removal, Treatment, and Disposal

Such a broad range of actions is needed at this time because many issues concerning the selection of a preferred action remain open. For example, future land use and residual risk (i.e., after the action) have not been determined. Second, since there are a large number of waste sites at SNL/NM, no attempt was made no examine each and every site in detail. Instead, sites were grouped by common characteristics such as the waste matrix and contaminant type found at a site. A total of five waste site categories were identified:

1. Soils - Organic Contamination
2. Soils - Radioactive and Inorganic Contamination
3. Debris - Mixed Waste or Hazardous Waste
4. Soils - Mercury Contamination
5. Groundwater - Organic, Inorganic and Radionuclide Contamination

Remediation alternatives were selected so that all waste sites in a specific category could be treated in a similar manner. More than one category can be applied to a specific site. For example, Waste Categories 1 and 2 might be applied to a landfill containing organic solvents and heavy metals.

This report presents fourteen remediation baseline alternatives of varying complexity and capability intended to meet the requirements of RCRA for the hazardous component of mixed waste. Table 1.1 presents a summary of these alternatives and the applicability of each alternative to the various generic waste categories defined above.

D. Innovative Technology Remediation Alternatives

The third objective of this report is to identify innovative remediation technologies that are currently under development that can potentially be applied to SNL/NM ER sites. The same assumptions used to develop BDAT based alternatives were also applied to the development of remediation alternatives based on innovative technologies. In addition, the following assumptions were also applied for this purpose:

1. The technologies selected can be applied with the limited site characterization information that is currently available for SNL/NM ER sites.
2. The technologies selected have been demonstrated at least at a pilot-scale and information is available for scale-up to a full-size system.

General Response Action	Alternative	Applicability by Waste Category
Containment	Alternative 1: Below Grade Vault	Waste Categories 1, 2, 3, and 4
	Alternative 2: Earth-Mounded Concrete Bunker	Waste Categories 1, 2, 3, and 4
In Situ Treatment	Alternative 3: Biodegradation	Waste Categories 1 and 5
	Alternative 4: Soil Vapor Extraction	Waste Category 1
	Alternative 5: Soil Mixing	Waste Categories 2, 3, and 4
	Alternative 6: Chemical Leaching	Waste Categories 2, 3, and 4
Removal, Treatment, and Disposal	Alternative 7: Incineration	Waste Categories 1 and 3
	Alternative 8: Thermal Desorption with Carbon Adsorption	Waste Categories 1 and 3
	Alternative 9: Sorting and Separation/Debris from Soil	Waste Category 3
	Alternative 10: Soil Washing of Contaminants from Soil	Waste Category 2
	Alternative 11: Mercury Distillation/Amalgamation	Waste Category 4
	Alternative 12: Pump and Treat with Air Stripping	Waste Category 5
	Alternative 13: Pump and Treat with Wet Air Oxidation	Waste Category 5
	Alternative 14: Pump and Treat with Granular Activated Carbon/Ion Exchange	Waste Category 5

Table 1.1: BDAT Alternatives for Use at SNL/NM ER Sites

3. The technologies selected appear to have the potential for treating a broad range of contaminants.
4. The technologies have the potential to lower the cost of remediation or are more efficient as compared to BDAT alternatives.

Table 1.2 provides a summary of innovative technology alternatives and the applicability of each alternative to the various generic waste categories which were previously defined. The intent of presenting this information is to begin to formulate decisions concerning potentially applicable innovative technologies and remediation alternatives. The alternatives defined below are not intended to represent the only choices available to decision makers but, instead, this list represents our assessment of logical choices given the information available at this time.

General Response Action	Alternative	Applicability by Waste Category
Containment	Alternative 1: Dry Barrier	Waste Categories 1, 2, 3, and 4
	Alternative 2: Permanent Isolation Surface Barrier	Waste Categories 1, 2, 3, and 4
	Alternative 3: Chemical Barrier	Waste Categories 1, 2, 3, and 4
In Situ Treatment	Alternative 4: Thermally Enhanced Vapor Extraction System	Waste Category 1
	Alternative 5: Electrokinetics	Waste Categories 2 and 5
	Alternative 6: In-Situ Vitrification	Waste Categories 1 and 2
	Alternative 7: Biodegradation in an Arid Environment, Solar Enhanced	Waste Categories 1 and 5
Removal, Treatment, and Disposal	Alternative 8: Steam Reforming	Waste Categories 1 and 3
	Alternative 9: Reverse-Burn Gasification	Waste Categories 1 and 3
	Alternative 10: Joule Heated Melter	Waste Categories 1, 2, 3, and 4
	Alternative 11: Plasma-Arc Furnace	Waste Categories 1, 2, 3, and 4
	Alternative 12: Mercury Removal by Thermal Volatilization	Waste Category 4
	Alternative 13: Mercury Control/Separation Processes	Waste Category 4
	Alternative 14: Sorting/Separation, Chemical Extraction, Precipitation, and Solidification	Waste Categories 1, 2, and 4
	Alternative 15: Catalytic Extraction Processing	Waste Categories 1, 2, and 4
	Alternative 16: Membrane-Media Extraction	Waste Category 5
	Alternative 17: Photocatalytic Oxidation	Waste Category 5
	Alternative 18: Super Critical Water Oxidation	Waste Categories 1 and 5

Table 1.2: Innovative Alternatives for SNL/NM ER Sites

E. Technology Development Focus Areas

The final objective of this report is to identify the technology gap between the remediation needs of the ER Project and the existing baseline/innovative technology base. This technology gap will represent areas where TAP and other organizations should focus technology development programs in order to enable the ER Project to remediate contaminated waste sites at SNL/NM economically and efficiently. Since it is very expensive to develop new remediation technologies, it is not conceivable that TAP can conduct all of these efforts. However, TAP can influence other development efforts in such a way that SNL/NM ER remediation needs will be met.

Based on the needs of the SNL/NM ER Project and the existing baseline/innovative technology base, Table 1.3 presents information identified in this report where technology development efforts are required. At this point in time, it is believed that development of the technologies listed in the table in conjunction with the existing baseline/innovative technology base will meet the future needs of the remediation portion of the ER project.

Category	Technology	Description
Remediation Technology Development Needs	Separation of Depleted Uranium from Soil	Separation of widely dispersed DU from surface soils
	Robotics for Excavation and Remediation	Use of robotics to increase the efficiency and safety at waste sites
	Tritium Containment	Containment and in-situ stabilization of soils contaminated with tritium
	Extraction of VOC and SVOC Contaminants	Improvement of current technologies (such as Soil Vapor Extraction) for remediation of VOCs and SVOCs
	Biodegradation in Arid Site Application	Technologies to apply biodegradation methods to arid waste sites
	Organics Destruction	Technologies for the destruction of organics that meet the technical capabilities of incineration
	Capping Technologies	Improved capping technologies for application at arid waste sites
	In-situ Stabilization of Heavy Metals	Methods to manipulate the geochemical state of heavy metals to render them immobile in the environment
	Horizontal Subsurface Barriers	Methods for the emplacement of subsurface barriers to isolate waste from the underlying saturated zone
Remediation Support Development Needs	Remediation Technologies for Classified Waste	Strategies that will change properties of classified waste materials to render them unclassified
	Decision Support Tools (DST)	Development of DSTs to assist decision makers in the selection of remedial processes
	CAMU Technologies Selection	Strategies to select and apply innovative technologies in the CAMU process

Table 1.3: Summary of Technology Development Focus Areas

(this page left blank)

Section 2
Overview of SNL/NM ER Project

A. Introduction

The Environmental Restoration (ER) Project is tasked with the characterization, assessment, remediation, and long-term monitoring of approximately 225 sites at Sandia National Laboratories/New Mexico (SNL/NM) that may potentially contain contaminated material. Most of these sites are located at Kirtland Air Force Base in Albuquerque, NM. However, there are also ER sites located at the Tonapah Test Range in Nevada and other federal facilities on which SNL/NM activities were conducted. An overview of ER waste sites can be found in the SNL/NM Program Implementation Plan (PIP).[2.1]

The Technology Applications Program (TAP) supports the environmental restoration effort at SNL/NM and is responsible for the development, transfer, and application of innovative technologies to meet the needs of the ER Project. The purpose of this report is to identify and recommend innovative remediation and restoration alternatives that should be developed by TAP and other organizations for future use by the ER Project. To accomplish this purpose, the overall remediation needs of the SNL/NM ER Project have been defined to the extent possible given current understanding of past practices and site characterization. The existing (baseline) technologies that can best meet as many of those needs as possible have been identified. Developing technologies from a variety of technical sources have also been surveyed and specific recommendations concerning those technologies that will best meet the SNL/NM ER Project needs have been identified. Remediation needs that cannot be met by application of baseline technologies or the developing technologies represent a technology gap that must be filled in order to accomplish restoration of SNL/NM ER sites. Future development by TAP will focus on the technology gap that is defined in this report. This focus will be subject to change and refinement as site characterization and other pertinent information becomes available.

Since there are a large number of waste sites at SNL/NM, it is difficult to assess the remediation needs of the ER Project on a site-by-site basis. Due to the amount of effort required to develop remediation alternatives and similarities shared by many SNL/NM ER sites, general categories of waste sites have been developed and each waste site has been placed in one or more specific category. Five categories of waste sites have been identified and are summarized in Table 2.1.

Category	Title	Description
1	Soils - Organic Contamination	Surface or subsurface contamination of soils from organic compounds such as TCE, TCA, HE, PCBs and petroleum hydrocarbons
2	Soils - Radionuclide and Metal Contamination	Surface or subsurface contamination of soils from metals and radionuclides such as Be, Pb, Ag, Li, Ba, Cd, Cr, Al, U, Cobalt-60, Cesium-137, and Pu
3	Debris - Hazardous or Mixed Waste	Debris contaminated with hazardous organic compounds, metals or radionuclides
4	Soils - Mercury Contamination	Surface or subsurface soils contaminated with mercury
5	Groundwater	Groundwater contaminated with organic compounds, metals, or radionuclides

Table 2.1: Waste Site Categories

Remediation technology needs will be developed so that all waste sites in each category may be treated in a similar manner. Remediation technologies have been grouped by General Response Actions (GRA). GRAs may be defined as a family of alternatives sharing similarities in approach and intent. The following GRAs are considered appropriate for actions involving active site remediation at SNL/NM.

- Containment
- In-Situ Treatment
- Removal, Treatment, and Disposal

Remediation alternatives (consisting of combinations of remediation technologies), both baseline and innovative, will be grouped into these GRA categories for convenience and also to communicate the idea that the selection of a preferred remediation alternative will span the breadth of increasingly complex choices. More than one GRA may be applied to a specific contaminated site. Application of a GRA to a contaminated site is based on parameters such as future land use, residual risk level, regulatory and public acceptance.

The remediation needs of the ER Project defined in this report and the remediation technologies that have been recommended for use at SNL/NM sites are based on three important assumptions. The first assumption is that all ER sites at SNL/NM will be restored using baseline technologies whenever possible. Innovative technologies will only be used when no baseline technologies can adequately remediate a site based on technical or economic considerations. The second assumption used in this report is that only innovative technologies that have been demonstrated at least at a pilot-scale will be recommended for use at SNL/NM. Innovative technologies that are not ready to go to a full-scale demonstration will not be considered and recommended. Finally, the third assumption is that all remediation technologies that have been recommended in this report have been selected based on the best available information. TAP is not necessarily excluding a particular technology for future consideration just because it is not mentioned in this report. As more information becomes available, alternative remediation technologies may be selected. This approach is consistent with regulatory guidance directing responsible parties to iterate through previous assumptions, conclusions, and recommendations as additional site characterization, risk assessment, and programmatic information becomes available.

This report first presents a summary of the remediation needs of the ER Project. These needs were derived from two sources, interviews of the ER task leaders and the combined experience of TAP personnel. Next, alternatives consisting of baseline technologies, including EPA defined Best Demonstrated Available Technologies (BDAT) that apply to the remediation needs of the ER Project, are presented. Information about the existing remediation technology base was obtained from EPA and DOE documents. [2.2-2.27] Then, examples of remedial alternatives consisting of innovative technologies that TAP personnel believe may be appropriate for remediation of SNL/NM ER sites are presented. Finally, the gap between the existing baseline/innovative technology base and the remediation needs of the ER Project is identified. This technology gap represents areas where the baseline technologies and the innovative technologies that are currently under development are inadequate to meet the remediation needs of the ER Project. This gap must be filled by the further development of new technologies or enhancement of existing technologies in order to meet the remediation needs of the ER Project and will be the basis for technology development for the ER Project. Coordination of this technology development effort will be the responsibility of the TAP. This document is not intended to replace reports such as the RCRA Corrective Measures Study (CMS) that formally document the process of selecting a preferred remediation alternative for RCRA sites. The intent is to aid in the initiation of development efforts in a timely manner in order to be ready for future site remediation.

A tremendous volume of information concerning description and selection of remediation technologies is available to the personnel responsible for defining the preferred remediation approach. The intent of this report is not to summarize potentially applicable technologies, but to begin the decision making process for selecting the BDAT or innovative technologies that are most likely applicable given current understanding of the sites and to define development focus areas where the existing baseline/innovative technology base is deficient. Each section of this document presents a list of resources used by TAP personnel in the preparation of this report. This list of resources is a cross-section of the type of information available and is not intended to serve as the sole source of data concerning remediation technologies. The purpose of the resource list is to provide assistance to the reader of this report in obtaining any additional data concerning remediation technologies that may be required as better information about specific ER sites is developed.

B. Resources

2.1. Sandia National Laboratories/New Mexico, 1993; *Environmental Restoration Program Implementation Plan.*

2.2. EPA, 1989; *Requirements for Hazardous Waste Landfill Design, Construction, and Closure*, EPA/625/4-89/022.

2.3. EPA, 1991; *Innovative Hazardous Waste Treatment Technologies: A Developer's Guide to Support Services*, EPA/540/2-91/012.

2.4. EPA, 1992a; *Innovative Treatment Technologies: Overview and Guide of Information Sources*, EPA/540/9-91/002; PB92-179001.

2.5. EPA, 1992b; *Literature Survey of Innovative Technologies for Hazardous Waste Site Remediation: 1987-1991*, EPA/542/B-92/004.

2.6. EPA, 1993a; *Remediation Technologies Screening Matrix and Reference Guide*, EPA/542/B-93/005.

2.7. EPA, 1993b; *Selected Alternative and Innovative Treatment Technologies for Corrective Action and Site Remediation*, EPA/542/B-93/010.

2.8. EPA, 1993c; *Federal Publications on Alternative and Innovative Treatment Technologies for Corrective Action and Site Remediation, Third Edition*, EPA/542/B-93/007 or PB94-144557.

2.9. EPA, 1993d; *The Superfund Innovative Technology Evaluation Program: Technology Profiles, Sixth Edition*, EPA/540/R-93/526.

2.10. EPA, 1993e; *Synopses of Federal Demonstrations of Innovative Site Remediation Technologies, Third Edition*, EPA/542/B-93/009 or PB94-144565.

2.11. DOE, 1993a; *Mixed Waste Integrated Program: Technical Area Status Report for Waste Destruction and Stabilization*, DE-AC01-93EW30030, DOE/MWIP-4.

2.12. DOE, 1993b; *Mixed Waste Integrated Program: A Technology Assessment for Mercury-Containing Mixed Wastes*, DE-AC05-840R21400, DOE/MWIP-9.

2.13. DOE, 1993c; *Mixed Waste Integrated Program: Technical Area Status Report for Chemical/Physical Treatment, Volume I*, DE-AC05-840R21400, DOE/MWIP-8.

2.14. DOE, 1993d; *Mixed Waste Integrated Program: Technical Area Status Report for Chemical/Physical Treatment, Volume II*, DE-AC01-EW30030, DOE/MWIP-8.

2.15. DOE, 1994a; *Rocky Flats Compliance Program: Technology Summary*, DOE/EM-0123P.

2.16. DOE, 1994b; *Robotics Technology Development Program: Technology Summary*, DOE/EM-0127P.

2.17. DOE, 1994c; *Underground Storage Tank Integrated Demonstration (UST-ID): Technology Summary*, DOE/EM-0122P.

2.18. DOE 1994d; *Mixed Waste Integrated Program: Technology Summary*, DOE/EM-0125P.

2.19. DOE 1994e; *Pollution Prevention Program: Technology Summary*, DOE/EM-0137P.

2.20. DOE, 1994f; *Heavy Metals Contaminated Soils Project, Resource Recovery Project, and Dynamic Underground Stripping Project: Technology Summary*, DOE/EM-0129P.

2.21. DOE, 1994g; *Supercritical Water Oxidation Program (SCWOP): Technology Summary*, DOE/EM-0121P.

2.22. DOE, 1994h; *Efficient Separations and Processing Integrated Program (ESP-IP): Technology Summary*, DOE/EM-0126P.

2.23. DOE, 1994i; *In Situ Remediation Integrated Program: Technology Summary*, DOE/EM-0134P.

2.24. DOE, 1994j; *VOCs in Non-Arid Soils Integrated Demonstration: Technology Summary*, DOE/EM-0135P.

2.25. DOE, 1994k; *Minimum Additive Waste Stabilization (MAWS): Technology Summary*, DOE/EM-0124P.

2.26. DOE, 1994l; *VOCs in Arid Soils: Technology Summary*, DOE/EM-0136P.

2.27. Wing, N.R., 1993; *Permanent Isolation Surface Barrier: Functional Performance*, Westinghouse Hanford Company, WHC-EP-0650.

2.28. McCulla, W.H., Herrington, L., Palmer, B., and Mauro, B.R., 1993; *Treatment Technology Catalog, Index: DOE EM-351 Applied Technology Program*, Los Alamos National Laboratory.

2.29. Martin Marietta Energy Systems, Inc., 1992; Mixed Waste Disposal Site Feasibility, SEC Donohue Environment and Infrastructure.

Section 3
Definition of SNL/NM Remediation Needs

A. Introduction

The primary objective of this report is to develop an understanding of the path for future development efforts of remediation technologies intended to be applied at SNL/NM ER Sites. In order to complete this objective, a clear definition of the remediation needs of the ER Project was first developed which is contained in this section of the report. Two primary groups of individuals provided the bulk of the information to define the remediation needs of the ER Project. These two groups included the ER Project task leaders, who are ultimately responsible for all activity which takes place on their particular contaminated sites, and TAP remediation engineers, who are responsible for assisting ER staff in the development, transfer, and application of innovative technologies for the ER Project. The next two sections present the remediation needs developed by each of these groups.

B. Task Leader Defined Needs

All task leaders in the SNL/NM ER Project were interviewed during January/February 1994. One purpose of these interviews was to determine the remediation needs at each ER site. Although these interviews provided significant information, all remediation needs were not identified partially due to the lack of site characterization data and also because current effort is focused on characterization and assessment. A summary of task leader defined needs are listed below.

1. Ex-situ separation technology for removing depleted uranium (DU) from soil. Many of the SNL/NM ER sites are a result of weapons testing programs. Widely dispersed DU is a major concern for the ER Project and technologies are needed for safe, economic remediation DU contaminated soils.

2. Technologies for excavation and remediation of buried waste sites using remote control/robotic devices. Robotic/remote control devices are needed to assist in the remediation of sites where there is a high risk to the health and safety of workers.

3. Technologies to remediate or contain soils contaminated with tritium. Technologies are needed to prevent or minimize the migration of tritium in the vadose zone soils by containment or stabilization methods.

4. Technologies for remediation of soils contaminated with organics using thermally enhanced soil vapor extraction (SVE). SVE has been used at many sites to remediate soil contaminated with volatile organic compounds. However, in some cases this method is slow due to site conditions. Recent enhancements to SVE, including thermal extraction and pulsed pumping, claim to improve the performance of this method while reducing the time required for remediation. These methods need to be investigated to determine their applicability to SNL ER sites.

5. Technologies for destruction of organic contaminants. Remediation of sites contaminated with organics generally rely on two types of technologies: 1) destruction typically by incineration as is mandated by Land Disposal Regulations (LDR) standards for many types of contaminants, or 2) concentration using technologies such as condensation and adsorption (with granular activated carbon). Both approaches have inherent drawbacks: socioeconomic issues for incineration, such as public distrust and NIMBY (Not In My Backyard), and need for additional treatment for concentration technologies (concentration does not result in destruction of organic contaminants; the contaminants are merely collected and the problem is transported elsewhere). Technologies capable of destroying organics that are acceptable to groups having concerns with incineration need to be developed.

6. Remediation strategies for classified waste. Innovations are needed for remediation activities at sites where classified materials were disposed. Specifically, innovative technologies capable of altering the classified nature of such materials (i.e., shape and/or chemistry) must be developed for certain ER sites.

7. Development of capping technologies for radioactive disposal sites in an arid environment. The high desert climate poses unique challenges for the development of caps designed to protect human health and the environment by eliminating source to receptor pathways. Another issue to be addressed in the

design of this type of cap is longevity. RCRA type caps have an uncertain design lifetime and a maintenance period of 30 years. This may not be adequate for isolation of long half-life radionuclides. Also, capping may be appropriate where the potential risks of exposure outweigh the benefit of removal. Adequate risk assessment methods should be developed to examine capping/removal options.

8. Development of containment systems for arid environment. This effort is similar to the cap development program except that the focus is also on the development of horizontal and vertical subsurface barriers. Materials testing is also an important area of development for assessment of containment performance.

9. Assistance to task leaders in planning and design of Voluntary Corrective Measures (VCM) that use new and innovative technologies.

C. TAP Remediation Engineer Defined Needs

The task leader focus as noted above is justifiably concentrated in site characterization and risk assessment at this time. The schedule defining ER Project milestones indicates that remediation will not begin until July 1995 (assuming current schedules are maintained, and remediation begins after acceptance of the RCRA CMS, also assuming that VCMs are not part of this analysis). Due to the current lack of hard data necessary for Corrective Measures Implementation (as specified by RCRA), all needs for development effort defined here will be subject to an iterative process of reassessing past assumptions and conclusions as new information becomes available.

Therefore, the concepts defined here are qualified with the intention of pursuing development efforts in a proactive manner using the information concerning SNL/NM ER site past practice to extrapolate towards future remediation needs instead of waiting until complete site characterization is accomplished. A summary of the TAP remediation engineer developed needs include:

1. Development of decision support tools designed to assist decision makers in selection of remedial process alternatives. Many possible courses of action for remediation of any type of ER site are available to the decision maker. A computer based decision support tool capable of providing budgetary cost estimates and risk evaluations for selected remedial actions (both traditional and

innovative approaches) including a measurement of uncertainty would result in significant cost savings. Software architecture may be similar to that used in TAP projects such as PRECIS (Probabilistic Risk Evaluation and Characterization Investigation System) and BOSS (Borehole Optimization Sampling System). The intent would be to link characterization, risk assessment, and cost models/data in addition to remediation alternative information in such a manner that allows analysis for remedial alternatives with regard to quantifiable parameters.

2. Combining the characterization data requirements for nature and extent of contamination with those of site remediation data requirements. The intent here is to collect not only the relevant data needed to meet regulatory requirements, but to also understand the specific data requirements for designing site remediation/clean-up. For example, it is typical to report the presence of radionuclide contamination in the form of activity. This potentially leads to the need for additional characterization for selection of the remedial approach because activity does not define speciation. Carbon-14 (as an example) may exist in the form of an elemental particulate, as part of an organic molecule, or as part of an inorganic compound (e.g., a carbonate). Each of these species will require totally different approaches for remediation. Similarly, contaminated soil properties such as grain size, density, effective particle shape, magnetic properties, friability, solubility, conductivity, adsorptive properties, and hardness have an impact on the selection process for remediation alternatives.

3. Replacement technologies for thermal treatment. Using principles of organic chemistry, development effort is needed to identify and assess performance of new approaches capable of meeting thermal performance (e.g., in destruction and removal efficiency) with comparable cost and technical complexity, yet without difficulty of permitting as is encountered with technologies such as incineration.

4. Continuation of efforts to speed up the restoration of contaminated areas through the application of Corrective Action Management Units (CAMU) and the development of innovative technologies compatible with the application of CAMUs. Innovative technologies may offer performance based advantages over application of conventional technologies in the CAMU concept. Otherwise, while the regulations indicate that innovative approaches are encouraged, actual

permission to apply such an approach is difficult to obtain because of lack of performance data.

5. Alternative technologies for the containment and isolation of mixed waste containing long-lived radionuclides and depleted uranium. These technologies may include the use of horizontal and vertical subsurface barriers and may be implemented in conjunction with directional/horizontal drilling.

6. Improvement of in-situ Soil Vapor Extraction (SVE) technologies. SVE has been used successfully at many sites but can often be slow and not completely effective. Recent enhancements, such as thermal methods, should be developed for use at SNL/NM ER sites.

7. Development of biodegradation technologies for arid environment applications. Bioremediation has been used at humid sites for many years. However, its application at arid sites has been limited.

8. Development of improved technologies for removal of mercury from soil. Current methods are energy intensive.

D. Programmatic/Management Needs

Other areas of needs include the development of a decision process for remediation so that roles and responsibilities are clearly defined. While this particular focus is not technical in nature, it is clear that decision making has a strong impact on the efficiency and effectiveness of the remediation engineering effort.

Currently, the remediation (including preliminary studies in preparation for site clean-up) effort may be categorized into four areas:

1. Efforts underway for remediation at VCM sites.

2. Literature research by groups interested in understanding what technologies are available and appropriate for application at SNL/NM.

3. DOE OTD work, an example of which is a demonstration of thermally enhanced vapor extraction, which is being conducted by the Environmental Restoration Technologies Department at SNL/NM on the Chemical Waste Landfill in TA-III.

4. Efforts initiated by TAP focusing on development, transfer, and application of innovative technologies in the area of remediation (in addition to risk assessment, characterization, and long term monitoring).

Some of these efforts were initiated during a period of time when the focus was not necessarily on fast, industry-like remediation efforts. With new initiatives for faster, safer, more efficient, and cost-effective restoration efforts being demanded at high levels (especially championed by Thomas Grumbly, DOE Assistant Secretary for Environmental Restoration and Waste Management) it is imperative that the current approach be reassessed and strategic changes in the current management be implemented. Some suggestions include:

1. Increase the scope of effort for TAP or a select group of remediation engineers to include participation in all remediation decisions. This can and should include participation in efforts such as future land use decisions, type of data collected during site characterization (e.g., expand current efforts to include remediation technology design needs and hydrogeologic parameters).

2. Include TAP or a select group of remediation engineers in the decision making process for site remediation on a proactive basis. It is a benefit to the ER Project to involve this group at this stage for both consistency (similar sites border each other yet may be managed differently under the current management structure) and efficiency purposes.

3. Select ER Sites posing the highest risk to human health or the environment and pursue remediation as an expedited action (such as through the CAMU process).

E. Resources

3.1. DOE, 1993; *Technology Needs Crosswalk Report*, Prepared by Chem-Nuclear Geotech, Inc., DE-AC04-86ID12584.

Section 4
Baseline Remediation Technologies

A. Introduction

In order to control the process of treatment and disposal of hazardous waste, the Environmental Protection Agency has developed land disposal restrictions for hazardous wastes. These land disposal restrictions have been developed under two environmental laws including the Resource Conservation and Recovery Act (RCRA) and the Safe Drinking Water Act (SDWA). All of the ER sites at SNL/NM fall under the land disposal restrictions. The main purpose of the land disposal restrictions is to discourage the placement of untreated hazardous waste in or on the land when better treatment or destruction alternatives exist.[4.1]

The basic idea of the land disposal restrictions is relatively simple. For each hazardous waste, the EPA has developed treatment standards that protect human health and the environment when the wastes are disposed of on or under the land. The land disposal restrictions include wastes that are placed in landfills, surface impoundments, waste piles, injection wells, land treatment facilities, salt domes or salt bed formations, underground mines or caves, concrete vaults or bunkers.

The treatment standards established by the EPA require that one of two alternatives be used. The first alternative is to treat the waste by using one or more specified treatment technologies. The second alternative is to treat the waste so that each hazardous constituent in the waste has been reduced to certain concentration limits. When the second alternative is used, the waste can be treated by any technology but the EPA assumes that the waste is treated with the Best Demonstrated Available Technology (BDAT). The concentration of any hazardous constituent in the treatment residual must be less than or equal to the concentration obtained by using the BDAT. For example, incineration is the BDAT for many organic solvents. Although organic solvents may be treated by any technology, the concentration of the solvent in the residual must be less than the concentration in the residual of a typical incinerator (i.e., ash and off-gas treatment scrubber water).[4.1]

This section contains a description of baseline technologies that are recommended for use at SNL/NM ER sites. The baseline technologies consist of both EPA defined BDATs and other technologies that have been sufficiently demonstrated to be considered baseline (e.g., barriers such as the RCRA cap and slurry walls). All of the remediation techniques that are described in this section have proven to be effective at sites at which they have been employed. Waste treatment technologies specified here are proven in treating waste to meet the land disposal restrictions. These baseline technologies should be used unless better, cheaper, safer or faster treatment processes can be developed and demonstrated.

B. Baseline Technology Alternatives

The baseline technologies described in this section are divided into the three previously defined general response actions (GRA). These GRAs include 1) containment, 2) in-situ treatment, and 3) removal, treatment and disposal. As discussed previously, selection of a GRA is based on parameters such as future land use plans, residual risk (i.e., after implementation of the action), and acceptance by the regulatory agencies and stakeholders such as the public. Each baseline treatment technology alternative that is described in this section is presented in a standard format. First, a brief description of the technology is given. Then, the specific waste categories where treatment may be used are listed. The waste categories are defined in Table 2.1. Finally, a process schematic for the technology is presented. The process schematic is an illustration intended to help the reader understand how a particular technology may be utilized at an SNL/NM ER site. However, the formal design of the system for field application may vary considerably from the schematic. More information for each baseline technology can be found in the resources that are compiled at the end of this section.

GRA: Containment

Similar to treatment technologies, various containment and isolation technologies have been evaluated for the containment of hazardous, radioactive and mixed wastes. Siting, waste classification, compliance with various regulations and regulatory/public approval are additional factors that need to be considered in order to implement containment technologies.

For hazardous wastes, a landfill design consisting of a double liner and a leachate collection and removal system to control run-on and run-off are minimum requirements as specified by RCRA. For low-level radioactive wastes, several designs have been developed and some designs have been implemented as containment measures (e.g., DOE's UMTRAP and FUSRAP efforts). Furthermore, since many DOE facilities have substantial quantities of mixed wastes, several studies have been performed by the DOE and its contractors to come up with feasible methods for the containment of mixed wastes. There is also an existing EPA/NRC joint conceptual design for a Mixed Waste Disposal Facility.

The siting, design, construction, operation and closure of mixed waste containment at federal facilities has to meet the requirements of RCRA and DOE orders (usually the hazardous component of the mixed waste is regulated under RCRA and the radioactive component the mixed waste is regulated under the AEA through DOE Orders). It may also be necessary to consider the NRC standards for commercial low level waste disposal promulgated under 10 CFR 61.[4.2]

Since it is quite likely that the contaminated material exists in a mixed waste form at SNL/NM, the containment alternatives may need to address the requirements of both the radioactive and hazardous components. A brief description of these requirements is given below.

- Radioactive Component.

  In the past, NRC permitted commercial low level waste (LLW) disposal included shallow land burial (SLB). The Low-level Radioactive Waste Policy Amendments Act (LLRWPAA) of 1985 required NRC to identify containment/disposal for LLW that were different from SLB. As a part of LLRWPAA, DOE was required to aid in the development of LLW disposal alternatives. Greater Confinement Disposal (GCD) technologies were developed in response to the requirements of LLRWPAA. GCD technologies are defined as techniques for disposal of waste that use natural and/or engineered barriers and provide a greater degree of isolation than that of SLB (DOE Order 5820.2).

  GCD technologies for LLW containment/disposal incorporate design features to meet the performance objectives as defined in DOE Order 5820.2A. The design basis is governed primarily by the concept of waste isolation. The waste should be isolated such that the associated radioactivity is given sufficient time to decay to a level at which no member of the public would be exposed to an effective dose equivalent above that specified in the performance objectives (25 mrem/year, DOE 5820.2A). DOE also requires a 5 year post-closure care period and an institutional control period of 100 years for LLW disposal facilities (DOE Order 5820.2A).[4.3]

- Hazardous Component.

  RCRA regulations, including land disposal restrictions, govern the disposal/containment of the hazardous component. The design and operating basis for hazardous waste disposal is effective waste isolation accompanied by systems for detection and collection of potential releases. Design requirements for land disposal units include double liners, a leachate collection and removal system, and run-on and run-off control systems (40 CFR 264.301). Also required by RCRA is a wind dispersion control mechanism.

  Closure of a RCRA permitted land-based unit, specifically landfills and surface impoundments, must satisfy the RCRA requirements promulgated under 40 CFR 264. One of the primary closure requirements is the installation of a RCRA cap or cover. The RCRA cap or cover recommended by EPA in their guidance document "Final Covers on Hazardous Waste Landfills and Surface Impoundments" is a multilayer design described below:[4.3]

  - A top layer consisting of two components:
    1. A vegetated or armored surface component, selected to minimize erosion and, to the extent possible, promote drainage off the cover.
    2. A soil component with a minimum thickness of 60 cm (24 in.) comprised of top soil and or fill soil as appropriate.

  - Either a soil drainage layer (with a flexible membrane liner and protective bedding) that will effectively minimize water infiltration into the low permeability layer, or a drainage layer consisting of geosynthetic materials with equivalent performance characteristics.

  - A two component low permeability layer, lying wholly below the frost zone, that provides long-term minimization of water infiltration into the underlying wastes, consisting of a flexible membrane layer, a compacted soil component and a maximum in-place saturated hydraulic conductivity of 1×10^{-7} cm/sec.

The general performance standards specified in 40 CFR 264 state that disposal units must be closed in a manner that minimizes the need for further maintenance. A 30 year post closure period for land-based units is required by RCRA.

Mixed waste streams, regardless of the radioactivity classification, require disposal methods equivalent to GCD technologies which have been modified to meet RCRA design requirements.[4.2] In view of this requirement, suitable GCD technologies are identified and described below as alternatives.

Alternative 1 - Below Grade Vault (BGV)

Alternate name: Underground Vault

BGVs involve placing the contaminated waste material in an engineered structure constructed below grade. Several structural designs have been proposed for BGVs. Generally, the structures consists of concrete floors, walls and roofing. Also, like other containment technologies, earthen covers are used to provide additional barriers against infiltration, exposure to radiation and inadvertent intrusion. Structural stability is provided by the disposal material itself. BGVs are usually designed with a number of cells which can be closed and isolated when filled with contaminated waste material. This design reduces the amount of precipitation accumulation within the vault during operation and reduces the potential for radiation exposure to the operations personnel. Use of run-on and run-off control systems as required under RCRA will further reduce the collection of surface water resulting from precipitation.

Since BGVs consist of concrete floors and a drainage system, the double liner and leachate collection and removal systems may not be required. Exceptions to the double liner and leachate collection and removal system are allowed if it is demonstrated to the EPA Regional Administrator that alternate designs coupled with location characteristics are equally effective in preventing migration of any hazardous constituent into the groundwater or surface water. Cell floors of the BGV are slightly sloped to floor drains to facilitate drainage of any liquid that might enter the unit. Cell drains are directed to a sump that has a liquid monitoring and removal system. Any liquid collected is tested and, if necessary, treated and properly managed. In this context, the concrete cell and drainage, collection, monitoring and removal system could serve as the primary leachate collection and removal system in terms of RCRA requirements. An additional secondary containment barrier could be provided to meet RCRA's secondary containment requirements. For BGVs, the concrete structure also provides the principal barrier to radionuclide release with an additional barrier provided by the earthen cover. The final covers or caps must meet or exceed the minimum standards of RCRA and for which guidance documentation is available.[4.2]

Also, in addition to run-on and run-off controls, wind dispersion mechanisms must be incorporated as part of the construction, operation, closure, and post closure of BGVs to meet RCRA standards.

Application:
Waste Categories 1, 2, 3 & 4 (Table 2.1)
Process Schematic:

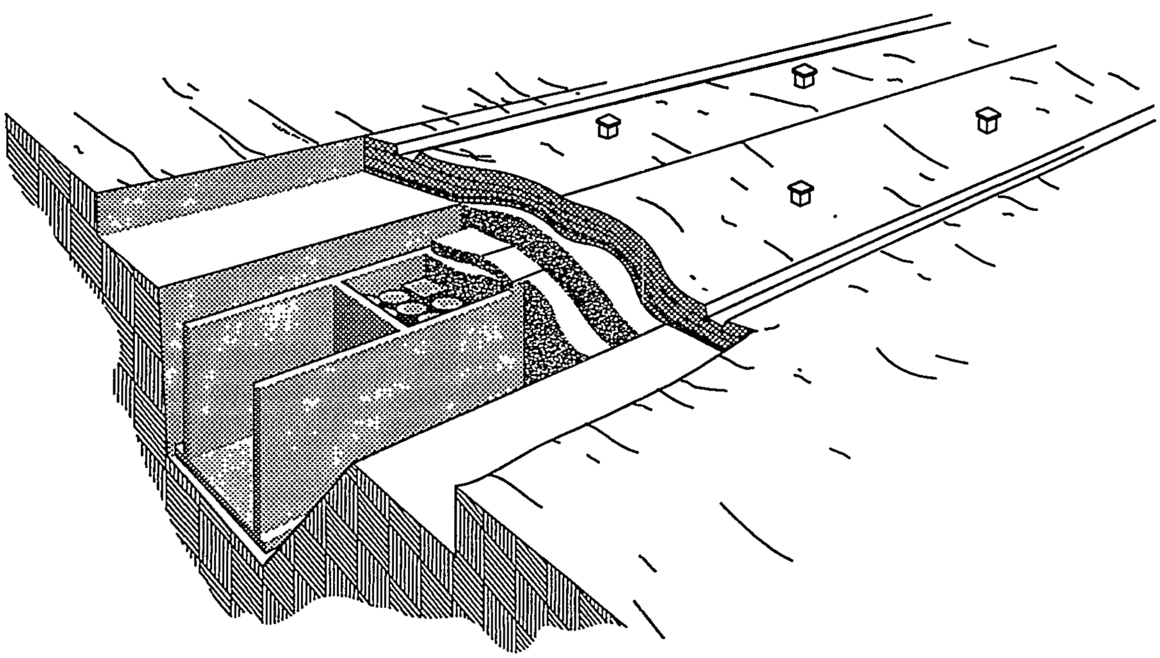


Figure 4.1: Below Grade Vault

Alternative 2 - Earth-Mounded Concrete Bunker (EMCB)

Alternate Name: Earthen Covered Tumulus with Concrete Bunker.

The EMCB or tumulus can be constructed above grade over the waste or used in combination with a below grade bunker for waste classes requiring greater isolation. Below grade bunkers are similar to BGVs. These structures are usually used for containerized or stabilized waste forms. A variation of this alternative is to construct the tumulus over waste placed on a concrete slab. Alternatively, the tumulus can be constructed over the concrete bunker above or below grade. An earthen cover is placed over the tumulus following the operational closure of the unit. Short-term stability is provided by backfilling with sand around the waste forms within the above grade tumulus. Void spaces within the below grade bunker are filled with concrete which solidifies to form a concrete monolith. A double liner and leachate collection and removal system would be required for management of the leachate. The joint EPA/NRC Mixed Waste Disposal Facility guidance can be used for design of this alternative. The earthen cover for closure of the tumulus must meet or exceed the RCRA requirements for which guidance documentation is referenced above. In this case, compliance with the RCRA requirements of run-on and run-off control and wind dispersion control mechanisms is also required.[4.3]

Application:

Waste Categories 1, 2, 3 & 4 (Table 2.1)

Process Schematic:

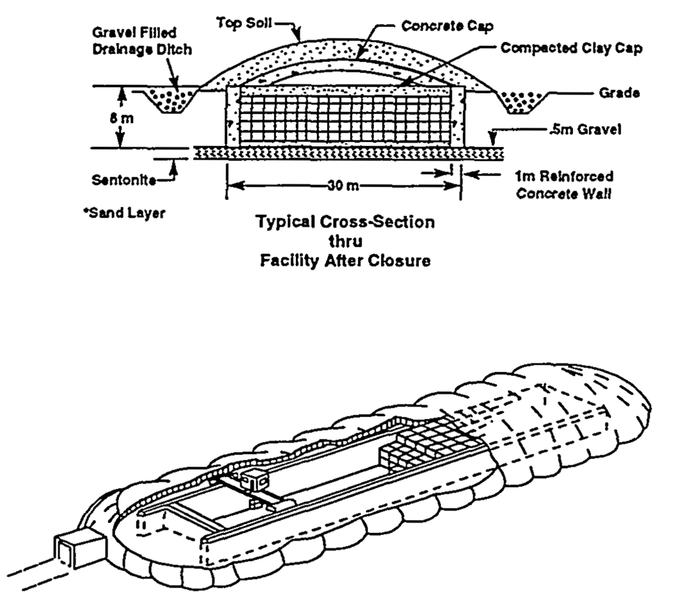


Figure 4.2: Earth-Mounded Concrete Bunker

GRA: In Situ Treatment

The general response action of *in-situ treatment* will consist of alternatives that can be used to destroy or immobilize a hazardous constituent without removing it from its present location in the surface soil, subsurface soil, or groundwater. In addition, *in-situ treatment* can apply to alternatives that remove a hazardous constituent from its present location with minimum disturbance to the matrix where it is located.

Alternative 3 - Biodegradation

Alternate Names: Aerobic and Anaerobic Bioventing, Bioremediation

This alternative consists of the introduction of nutrients, oxygen and bacterial culture (if needed) into the area of contamination (soil or groundwater) to enhance the biodegradation of organic compounds. The nutrients may be introduced in liquid or gaseous form through surface infiltration or a series of injection wells. Typically, bioremediation has been used to destroy organic constituents but it may also be used to reduce certain heavy metals and metalloids to insoluble forms in order to control their mobility. This alternative has a fairly broad applicability for organic contaminants and, since it is considered a natural process, is usually supported by the public. However, this method is highly dependent on site conditions and some wastes are difficult or slow to degrade.[4.4]

Application:
Waste Categories 1, 5 (Table 2.1)
Process Schematic:

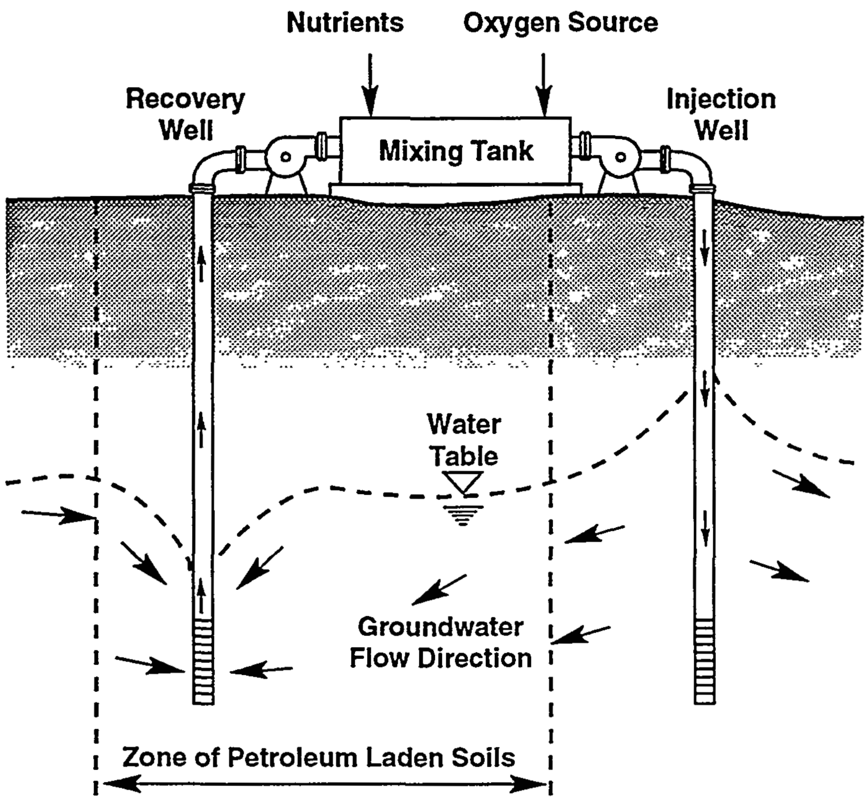


Figure 4.3: Bioremediation of Contaminated Groundwater

<u>*Alternative 4 - Soil Vapor Extraction (SVE)*</u>

Alternate Name: Soil Venting

This alternative consists of a system to apply a vacuum to a series of extraction wells resulting in air flow through the contaminated vadose zone. As the air moves through the soil, volatile contaminants move from the soil and pore water to the air. The contaminants in the extracted air and water may be treated using an emission control system such as activated carbon or catalytic oxidation.[4.4] This process works well in porous, sandy soil. Good performance has been demonstrated in soils with permeability ranging from 10^{-4} to 10^{-8} cm/s. The technology is relatively simple and reliable with minimal disturbance to the contaminated soil. However, the process is limited to volatile organic contaminants and in some situations, can be relatively slow.

Application:

Waste Category 1 (Table 2.1)

Process Schematic:

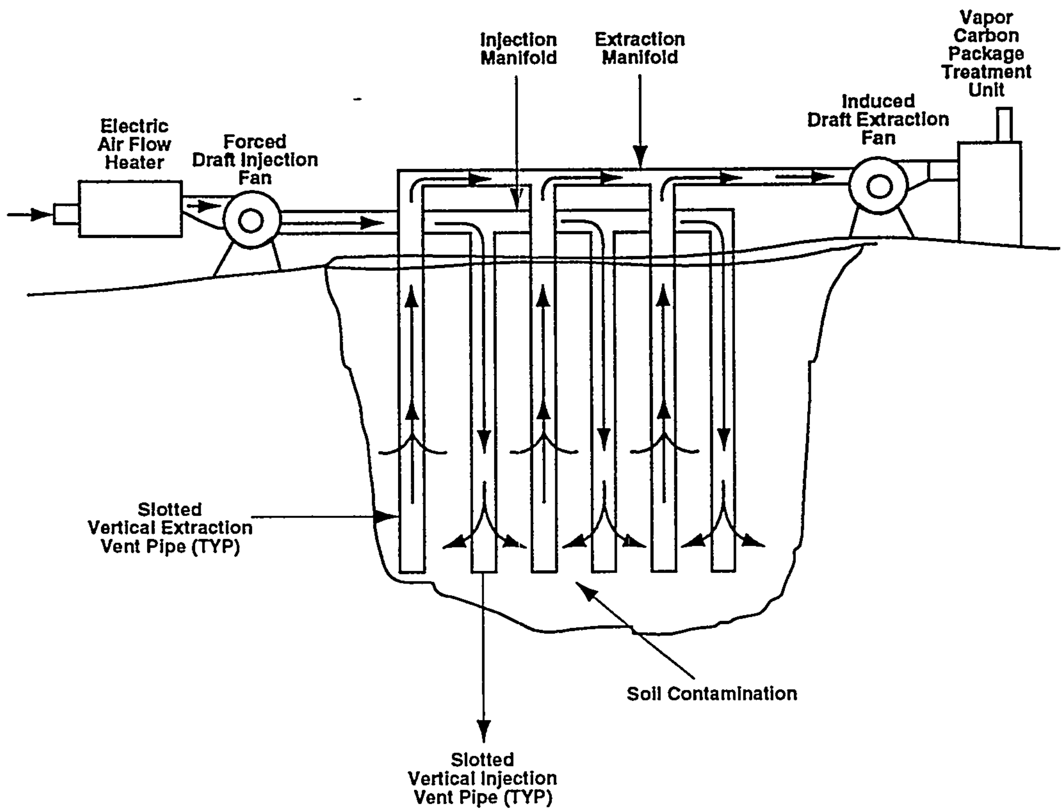


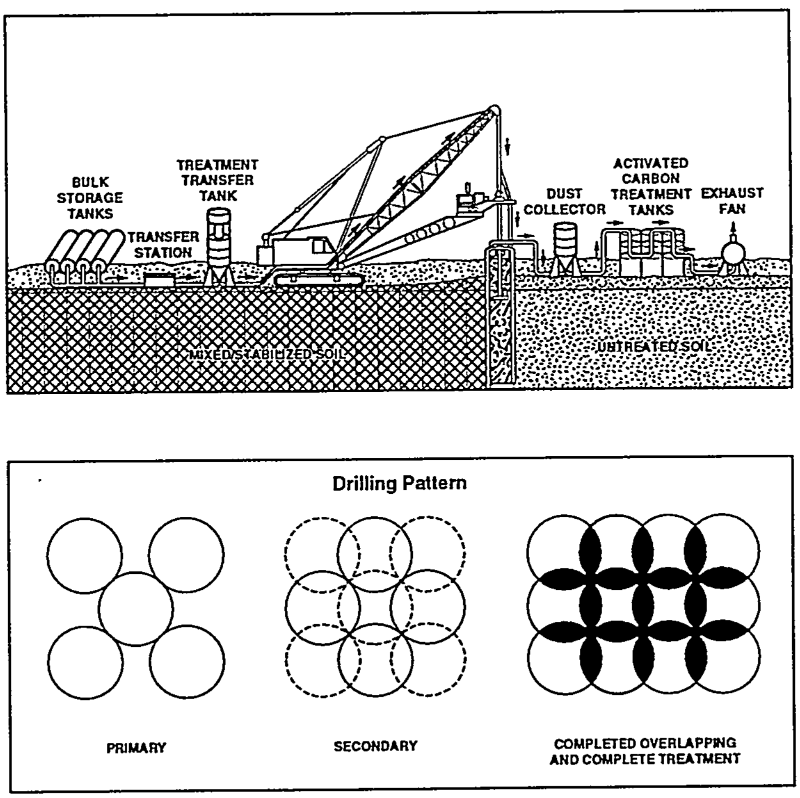
Figure 4.4: Generalized Schematic of Soil Vapor Extraction

Alternative 5 - Soil Mixing

Alternate Name: Hydraulic Soil Mixing

Soil mixing is a technology to stabilize a contaminant within the soil matrix. An auger is drilled into the soil and then is extracted to approximately one-half the depth of the hole. After the auger is partially extracted, it is reinserted while initiating injection of the stabilization material (e.g. bentonite, cement polymers, and mixtures). Reinsertion continues until the auger reaches the bottom of the hole. The process is repeated in a predetermined pattern until the entire contaminated volume of soil has been stabilized. This process does not generate hazardous waste since drill cuttings are not removed from the hole during the drilling process.

Application:
Waste Categories 2, 3, & 4 (Table 2.1)
Process Schematic:



• Reproduced/adapted from information supplied by GEOCON Inc. Pittsburg, PA.

Figure 4.5: Typical Soil Mixing System

Alternative 6 - Chemical Leaching

This alternative makes use of chelators, lixiviants, saponifiers or other reagents to dissolve contaminants such as heavy metals and metalloids into process water. The process water infiltrates through the contaminated vadose zone and is recovered by horizontal wells. Filtration, evaporation, sedimentation or other treatment processes are then used to remove the contaminant from the extracted process water. Use of this alternative is dependent on the ability to drill horizontal wells under the area of contamination. The above-ground water treatment system could be skid-mounted and used at several sites.

Application:

Waste Categories 2, 3, & 4 (Table 2.1)

Process Schematic:

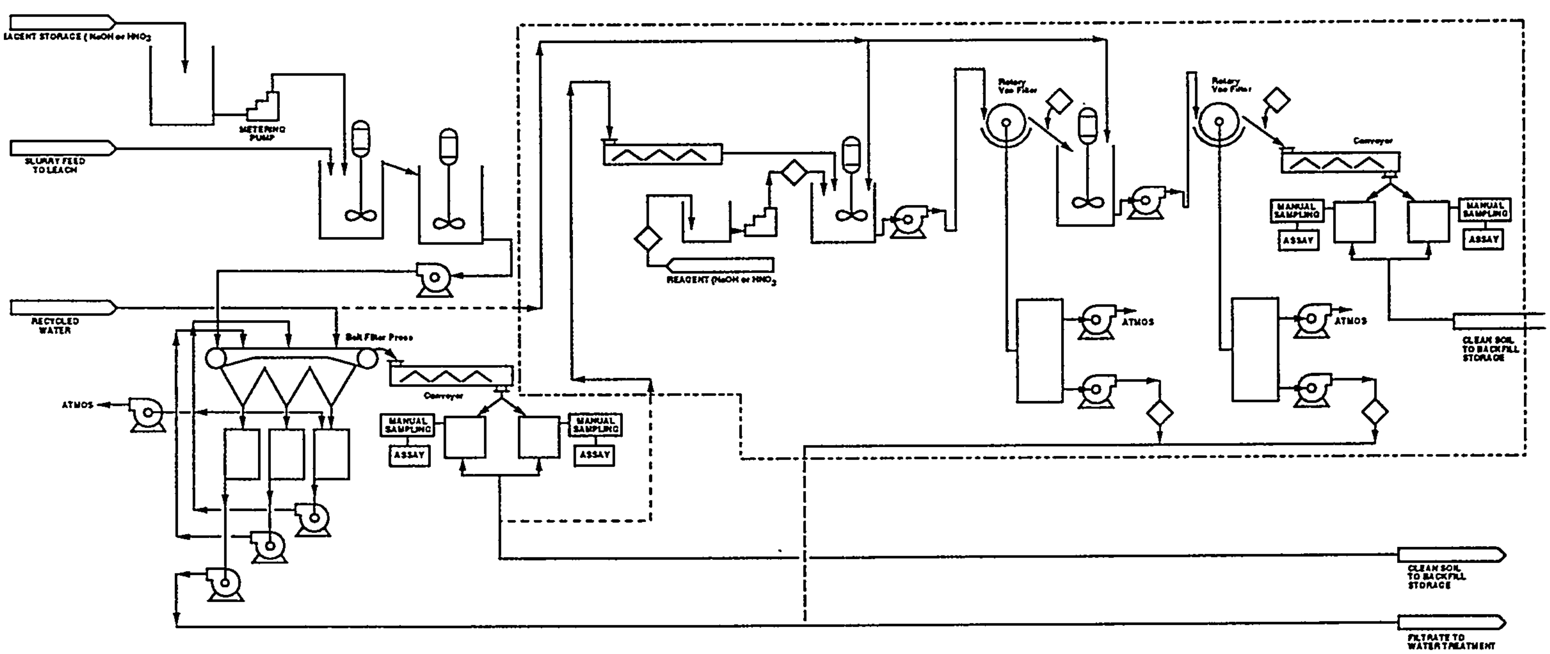


Figure 4.6: Chemical Leaching

GRA: Removal, Treatment and Disposal

The general response action of *removal, treatment, and disposal* will consist of alternatives that may be used to remove a hazardous constituent from its present matrix and treat it with an ex situ process followed by proper disposal. In the context of this report, removal will be defined as the use of a grader (for surface contamination) or a backhoe and front-end loader (for subsurface contamination) to physically displace the contaminated soil to a treatment facility or process. Removal may also include dust suppression and site restoration with actions such as replacement of soil, re-establishment of native grasses, bushes and trees, and the necessary short-term irrigation. Also in the context of this report, disposal will be defined as all legal, approved options and may include Corrective Action Management Units (CAMU), on/off-site landfills, and disposal at other DOE facilities.

Since excavation of soil and debris wastes component is common to all of the alternatives in this GRA, a discussion of this component is presented in the following subsection. Worker health and safety is a significant factor in the decision to excavate contaminated materials that are explosive, reactive, or highly toxic. Excavation can also become cost prohibitive at great depths and in complex hydrogeologic environments.

- Loading and Casting Excavation: This is accomplished by using a conventional earth removal equipment potentially ranging in size from a 1/4 cubic yard backhoe up to a 220 cubic yard dragline.[4.5] The basic types of excavation equipment that are suitable for use at SNL/NM sites are:
  - Backhoes
  - Cranes with attachments
  - Bulldozers and front end loaders

- Hauling Excavation: Hauling excavation is used for on-site and off-site transportation of excavated material. Hauling equipment includes scrapers and haulers. Sometimes bulldozers and front end loaders can also be used for hauling.

Generally, equipment used for different types of excavation is as follows:

- Surface soil: scrapers (self propelled, self loading and push loading).
- Shallow depth excavation: bulldozers and front end loaders.
- Deep excavation: back hoes and cranes with attachments.
- Soil handling, staging & hauling: front end loaders, backhoes and hauling trucks.

For the scope of this effort, disposal is assumed to be feasible at approved engineered disposal facilities and may include CAMUs, on-site, off-site facilities such as other DOE facilities and commercially licensed facilities (e.g., EnviroCare, Utah)

Alternative 7 - Incineration

Incineration uses high temperatures from 870 to 1200°C to mineralize organic compounds to CO_2, and water. Three common incinerator designs are rotary kilns, infrared furnaces, and fluidized bed incinerators. Well designed incinerators can achieve a destruction and removal efficiency (DRE) greater than 99.99% for many organic constituents and can be designed to achieve a DRE of 99.9999% for refractory organics such as PCBs and dioxins. Incineration is effective in treating soils, sediments, sludges, liquids and gases. This process is relatively expensive and has often met with great public resistance.[4.4]

Application:

Waste Categories 1, 3 (Table 2.1)

Process Schematic:

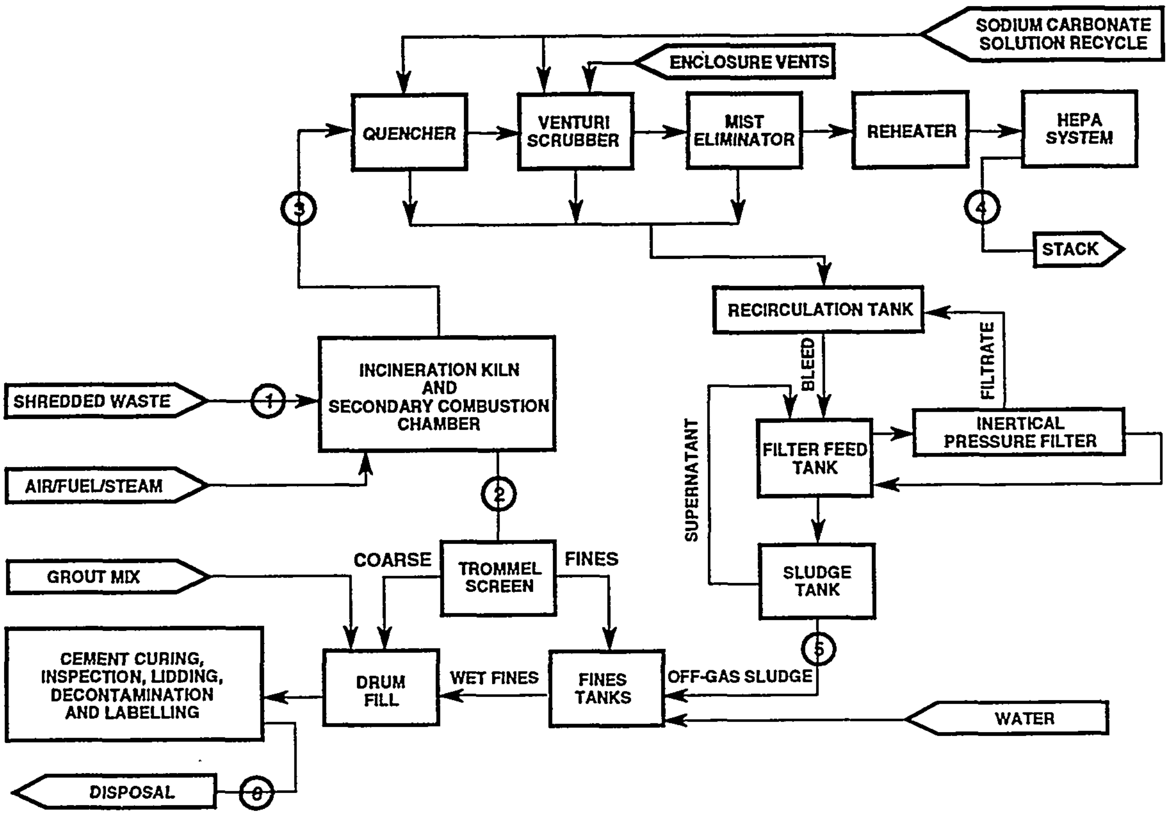


Figure 4.7: Incineration

<u>*Alternative 8 - Thermal Desorption with Carbon Adsorption*</u>

This alternative encompasses a wide variety of processes that vaporize volatile and semi-volatile organics from soil. Thermal desorption principally involves low temperature heating (as compared to incineration) so that volatilization, rather than combustion of organics occurs. Two general types of desorption systems are used. Direct-fired systems use a fuel burner as a heat source to the primary soil-heating chamber. This type of system resembles a rotary kiln incinerator and is operated at a temperature of less than 425°C. Indirectly heated systems transfer heat through metal surfaces to the waste and produces a lower volume of exhaust gas. After desorption, the volatile organics are removed from the air stream by carbon adsorption or a catalytic oxidation process. Since this process operates at lower temperatures than incinerators, less fuel is used and volatilization of some metals (such as lead, copper, cadmium, and zinc) is avoided. Even though these systems operate at lower temperatures than incinerators, some metals (such as mercury and arsenic) may volatilize and the system must be designed to handle this situation.[4.4]

Application:
Waste Categories 1, 3 (Table 2.1)
Process Schematic:

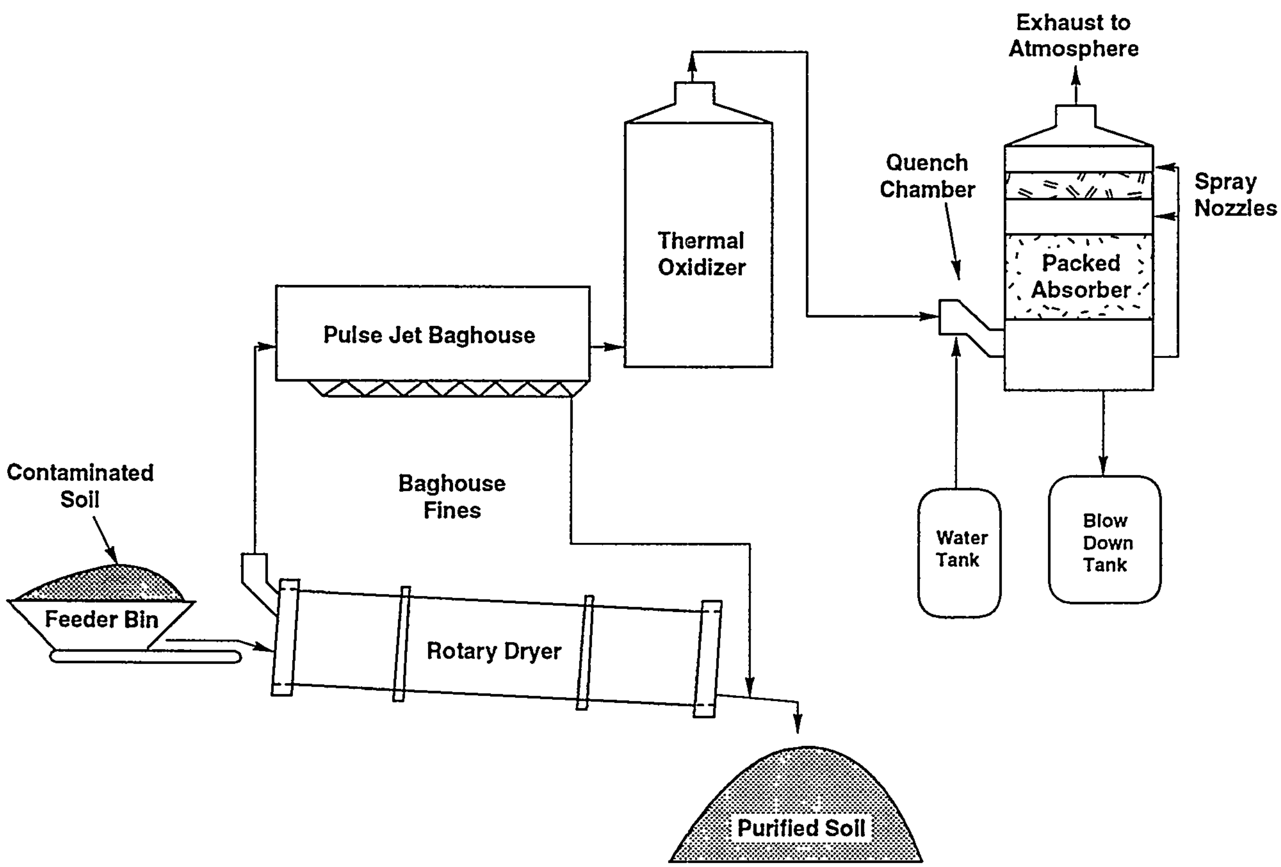


Figure 4.8: Typical Thermal Desorption System
(Courtesy of Southwest Soil Remediation, Inc.)

Alternative 9 - Sorting and Separation/Debris from Soil

This alternative separates contaminated soil from debris. Several different methods could be used. One method uses a high-pressure aqueous detergent solution to blast contaminated soil from debris. The soil is collected and subjected to a soil washing system to remove organic and inorganic contaminants (see Alternative 10). The detergent solution is continually cleaned and recycled through the system.[4.6] Another method uses vibratory screens or trommels as an initial step to separate the contaminated soil from debris. In both methods, a pretreatment process may be required to remove large items that could interfere with subsequent treatment. This alternative may also achieve volume reduction.

Application:

Waste Category 3 (Table 2.1)

Process Schematic:

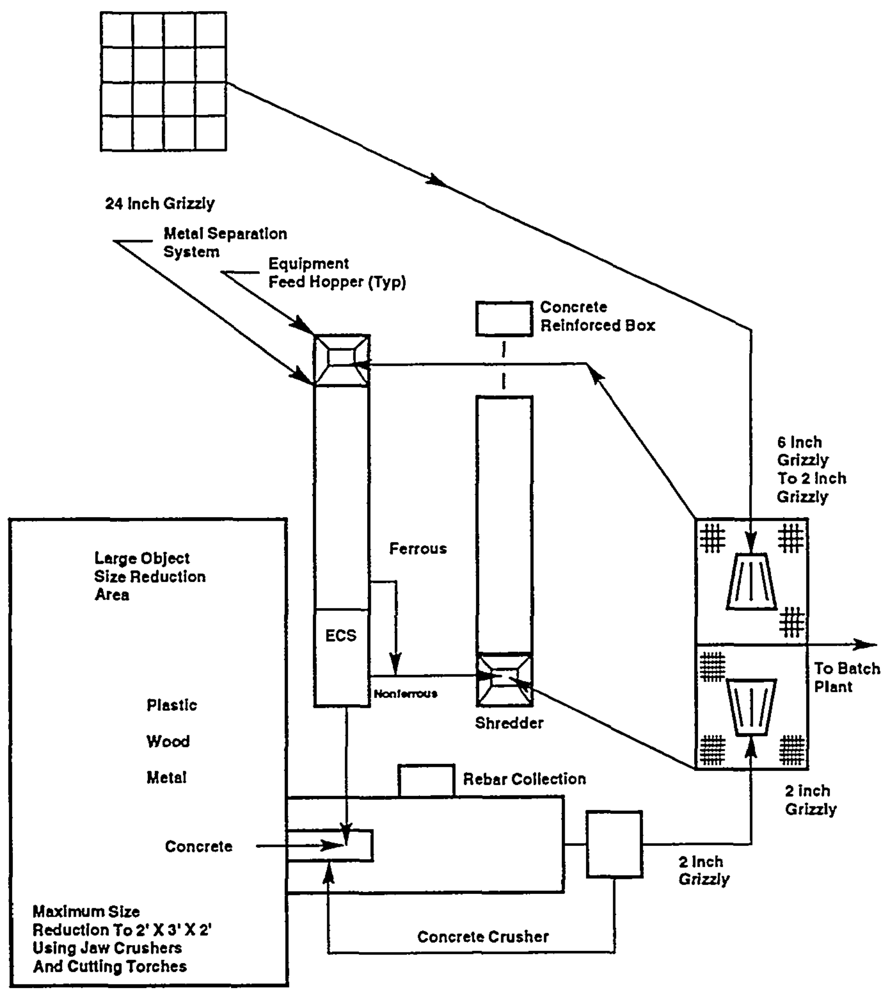


Figure 4.9: Sorting and Separation of Debris from Soil

Alternative 10 - Soil Washing of Contaminants from Soil

Soil washing is a physical or chemical process used to separate the contaminated fraction from the bulk soil. It is actually a volume reduction process and is often used for pretreatment. Most contaminants, such as heavy metals, have a tendency to adhere to the organic carbon and fine-grained soil fraction (silt and clay) instead of the coarse-grained fraction (sand and gravel). Physical processes can separate fine-grained soil from coarse-grained soil using density and size differences or by abrasive scouring. Chemical processes, making use of leaching agents, surfactants, pH adjustment, or a chelating agents, can also be used to desorb and solubilize contaminants in the wash water. Soil washing can remove between 90 to 99% of contaminants but is highly dependent on soil characteristics.[4.4] However, soil washing technologies do create large quantities of secondary wastes.

Application:

Waste Category 2 (Table 2.1)

Process Schematic:

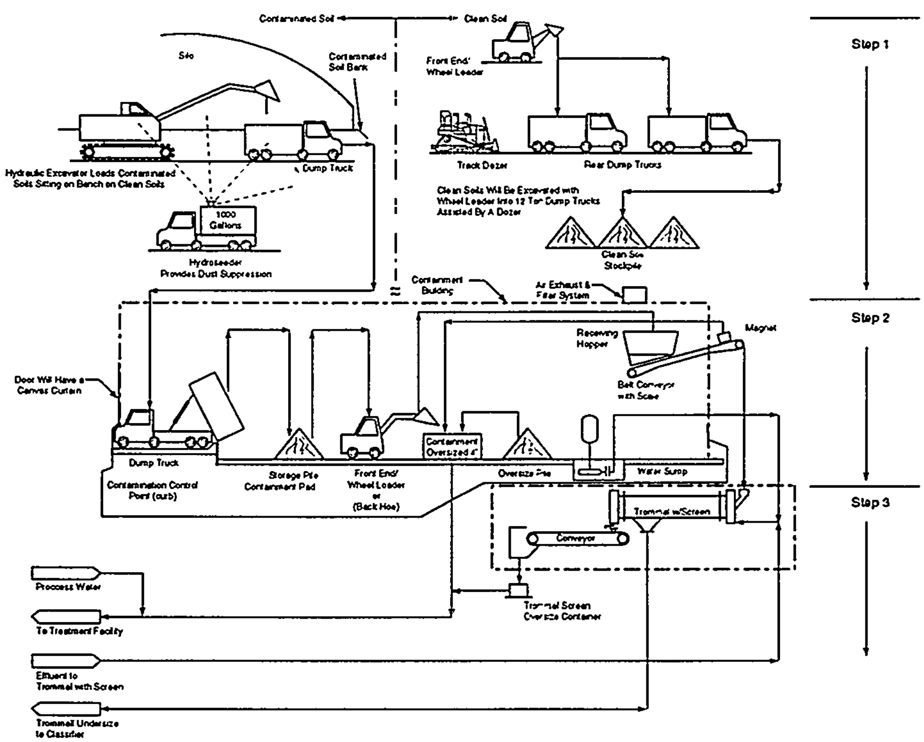


Figure 4.10: Schematic of Typical Soil Washing Operation

Alternative 11 - Mercury Distillation/Amalgamation

This process is used to separate mercury from soil. In the distillation process, the contaminated soil is heated to vaporize the mercury. Either vacuum distillation or batch steam distillation may be used. The mercury is collected in a condenser as the pure metal. If mercury is the only contaminant, the soil may be replaced in the previous location. This process is relatively simple and well demonstrated but has high energy costs.[4.7] A schematic of this process is shown in Figure 4.11.[4.8]

Application:

Waste Category 4 (Table 2.1)

Process Schematic:

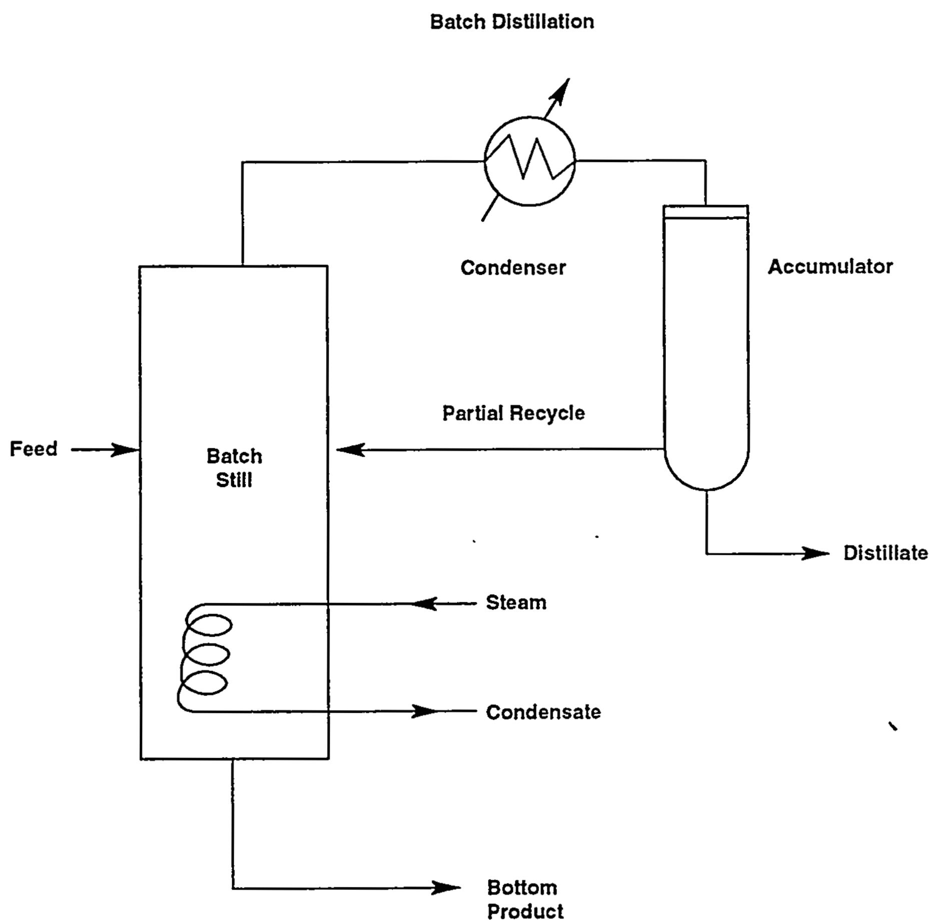


Figure 4.11: Conceptual Schematic of Mercury Distillation

Alternative 12 - Pump and Treat with Air Stripping

In this system, contaminated groundwater will be removed from the aquifer by a series of extraction wells. Volatile organic compounds (VOC) will be removed from the extracted groundwater by an air stripper. In the most common air stripper design, atmospheric air flows countercurrent to water in a tower-like structure. VOCs are removed from the water and pass to the air stream according to Henry's Law. The organic compounds are removed from the air stream by Granular Activated Carbon (GAC). GAC is commonly used for the adsorption of organic materials from both air and water. Activated carbon has an extremely large surface area to volume ratio and is able to adsorb large quantities of dissolved and particulate organic substances, and some inorganic materials into the interstices of the carbon particles. In this treatment system, a continuous stream of air (with the VOCs) from the air stripper will flow through a fixed column of activated carbon to remove the organic contaminants.[4.9] Contaminants remaining in the water phase will be removed by chemical reduction, precipitation and filtration. Treatment residues (such as spent GAC and precipitate) will be solidified in cement and disposed in an approved manner. The treated groundwater will be returned to the aquifer or discharged to the sewer system. Pump and treat systems have been used at many sites. However, the systems typically must operate for a long period of time and complete remediation of the aquifer is not usually possible due to the sorption of the contaminants on the soil matrix.

Application:

Waste Category 5 (Table 2.1)

Process Schematic:

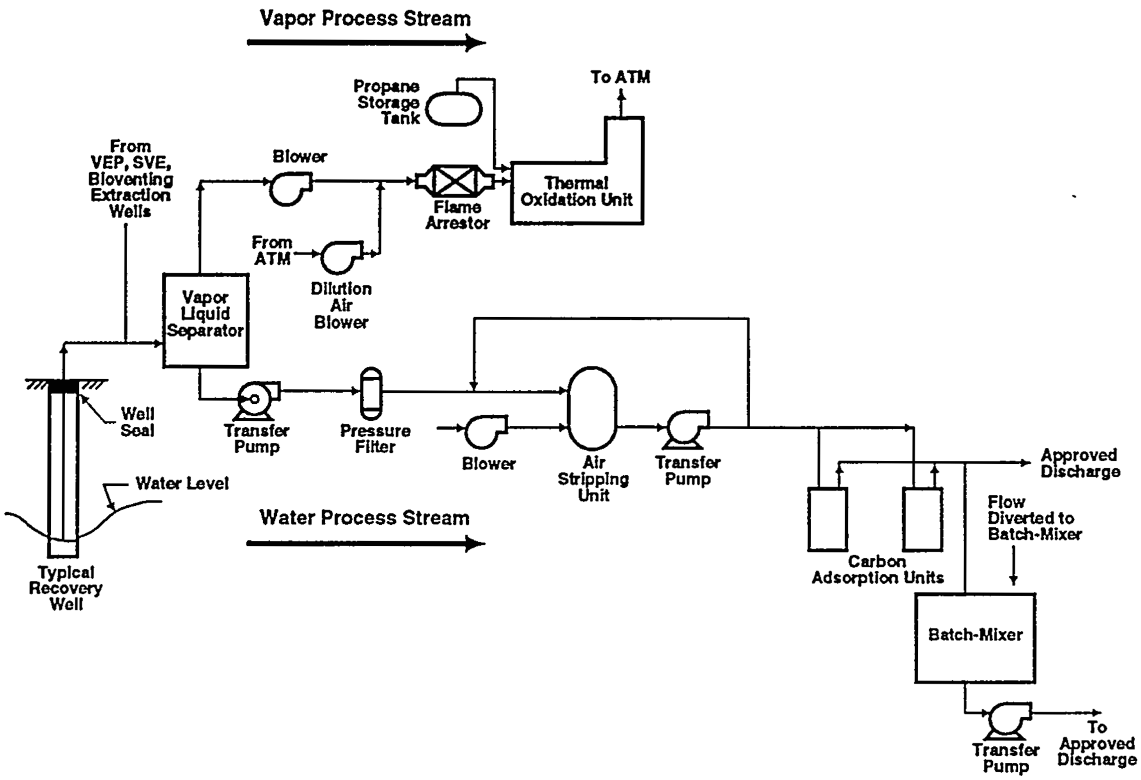


Figure 4.12: Typical Pump and Treat Operation with Air Stripping

<u>*Alternative 13 - Pump and Treat with Wet Air Oxidation*</u>

In this system, contaminated groundwater would be removed from the aquifer by a series of extraction wells and treated with Wet Air Oxidation. Wet Air Oxidation (WAO) is a liquid phase process to remove organics from water.[4.10] The water is first pressurized and then heated to approximately 250 to 300°C depending on the type of waste. Compressed air or oxygen is injected into the waste stream and organic compounds are oxidized to carbon dioxide and water. Other contaminants, such as heavy metals, will be removed by processes such as reverse osmosis and filtration. Waste treatment residues will be solidified by a cement-based process and disposed of in an approved manner. Problems with pump and treat systems are discussed under Alternative 12.

Application:
Waste Category 5 (Table 2.1)
Process Schematic:

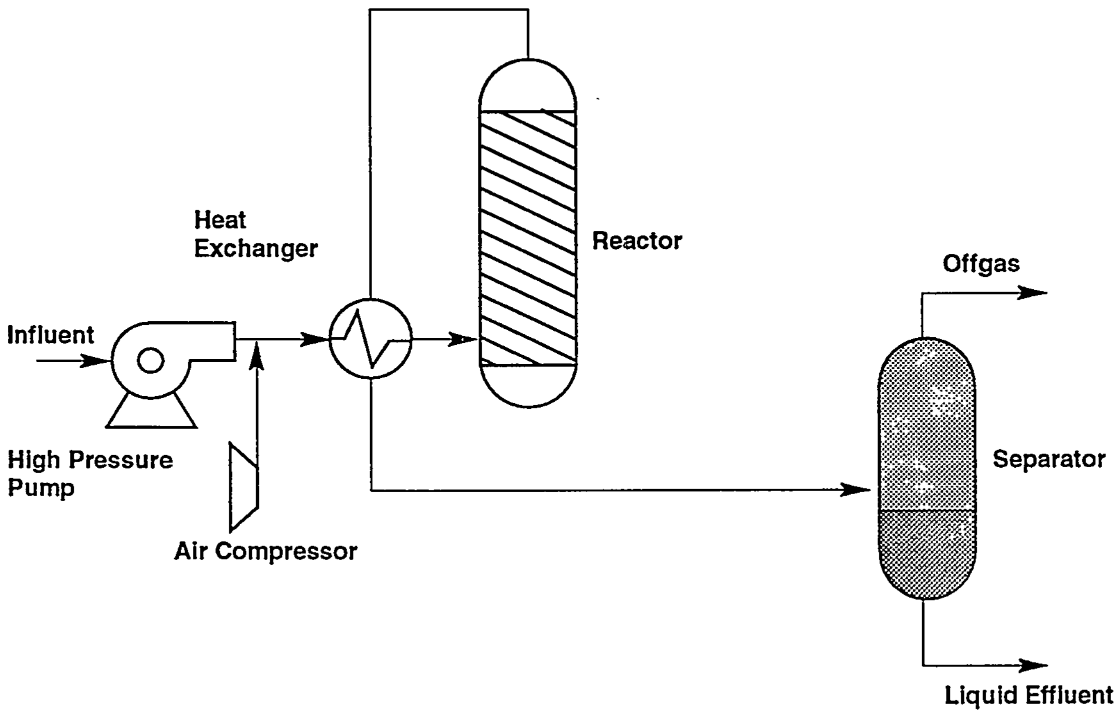


Figure 4.13: Conceptual Schematic of Wet Air Oxidation

<u>*Alternative 14 - Pump and Treat with Granular Activated Carbon/Ion Exchange*</u>

In this system, contaminated groundwater will be removed from the aquifer by a series of extraction wells. Granular Activated Carbon will be used to remove organic compounds from the aqueous solution. Ion exchange will be used to remove heavy metals from the extracted groundwater. Ion exchange is a reversible exchange of ions between liquid and solid phases. Ions, held by electrostatic charge to functional groups of an ion exchange resin, are replaced with ions of similar charge in solution. Ion exchange systems can be designed to be selective in the removal of specific ions. Since the reactions are reversible, the ion exchange resin may be regenerated by a strong acidic or brine solution. The extracted and treated groundwater will be returned to the aquifer or discharged into the sewer system. Problems with pump and treat systems are discussed under Alternative 12.[4.9]

Application:

Waste Category 5 (Table 2.1)

Process Schematic:

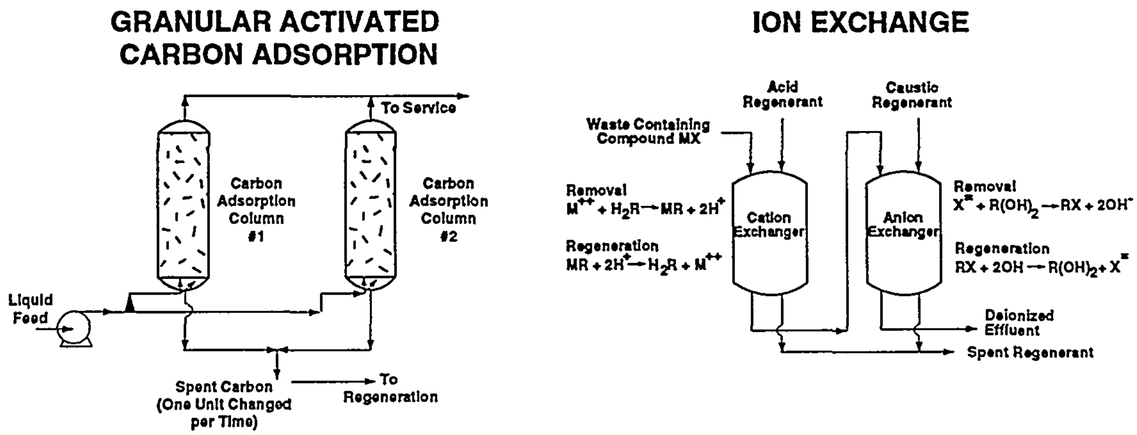


Figure 4.14: Conceptual Schematics of Granular Activated Carbon and Ion Exchange

C. Resources

4.1. McCoy, 1992; *The RCRA Land Disposal Restrictions: A Guide to Compliance*, McCoy and Associates, Inc., Lakewood, CO.

4.2. Martin Marietta Energy Systems, Inc., 1992; *Mixed Waste Disposal Site Feasibility*, SEC Donohue Environment and Infrastructure, December, 1992.

4.3. EPA, 1989; *Final Covers on Hazardous Waste Landfills and Surface Impoundments*, EPA/530-SW-89-047.

4.4. EPA 1991; *Innovative Treatment Technologies: Overview and Guide to Information Services*, EPA/540/9-91/002.

4.5. EPA, 1985; *Handbook: Remedial Action at Waste Disposal Sites*, EPA/625/6-85/006.

4.6. EPA 1993; *Synopses of Federal Demonstrations of Innovative Site Remediation Technologies, Third Edition*, EPA/542/B-93/009.

4.7. EPA 1990; *Best Demonstrated Available Technology: Background Document for Mercury-Containing Wastes D009, K106, P065, P092, and U151*, EPA/530-SW90-059Q or PB90-234170.

4.8. Bechtel, 1992; *Mixed Waste Treatment Project Process Systems and Facilities: Design Study and Cost Estimates*, Lawrence Livermore National Laboratory.

4.9. Wentz, C.A., 1989; *Hazardous Waste Management*, McGraw-Hill, Inc., New York, NY.

4.10. Jackman, A.P. and Powell R.L., 1991; *Hazardous Waste Treatment Technologies*, Noyes Publications, Park Ridge, NJ.

Section 5
Innovative Remediation Technologies

A. Introduction

This section identifies innovative alternatives that can potentially meet remediation needs of the ER project but have not been demonstrated to such an extent that they may be considered baseline. The innovative technologies identified here are based upon the following:

- Technologies that can be applied with the limited site characterization information that is currently available for SNL/NM ER sites.
- Technologies that have been or are being demonstrated by EPA or DOE at least at a pilot-scale level and adequate information is available for scale-up to a full-scale level.
- Technologies that have the potential for treating a broader range of contaminants than the BDAT alternatives identified in the previous section.
- Technologies that have the potential to lower the cost of remediation or are more efficient as compared to BDAT alternatives.

In response to the complexities associated with environmental restoration (especially at sites contaminated with radioactive materials) several government agencies and their operations/management contractors have been actively involved in programs for development, testing and implementation of innovative technologies. These programs include:

1. The U.S. Environmental Protection Agency (EPA) Superfund Innovative Technology Evaluation (SITE) Program.

2. The U.S. Department of Energy (DOE) Office of Environmental Restoration and Waste Management (ERWM) - Office of Technology Development (OTD).

A summary of each of these programs is presented in the following sections.

1. EPA SITE Program

Figure 5.1 illustrates the various components of the EPA SITE Program as defined in EPA SITE Program Technology Profiles.[5.1] The components that are relevant to the ER Project are described below.

- Demonstration Program: Conducts and evaluates demonstrations of promising innovative technologies to provide reliable performance, cost, and applicability information. Under this program the technology is field-tested on hazardous waste materials. Engineering and cost data are gathered on the innovative technology so that potential users can assess the technology's applicability to other sites. Data collected during the field demonstration are used to assess the performance of the technology, the potential need for pre-and post processing of the waste, applicability to types of wastes and waste matrices, potential operating problems and approximate capital and operating costs.
- Emerging Technology Program: Provides funding to developers to continue research efforts from the bench and pilot-scale levels to promote the development of innovative technologies.
- Technology Transfer Program: Disseminates technical information on innovative technologies to remove impediments for using alternative technologies.

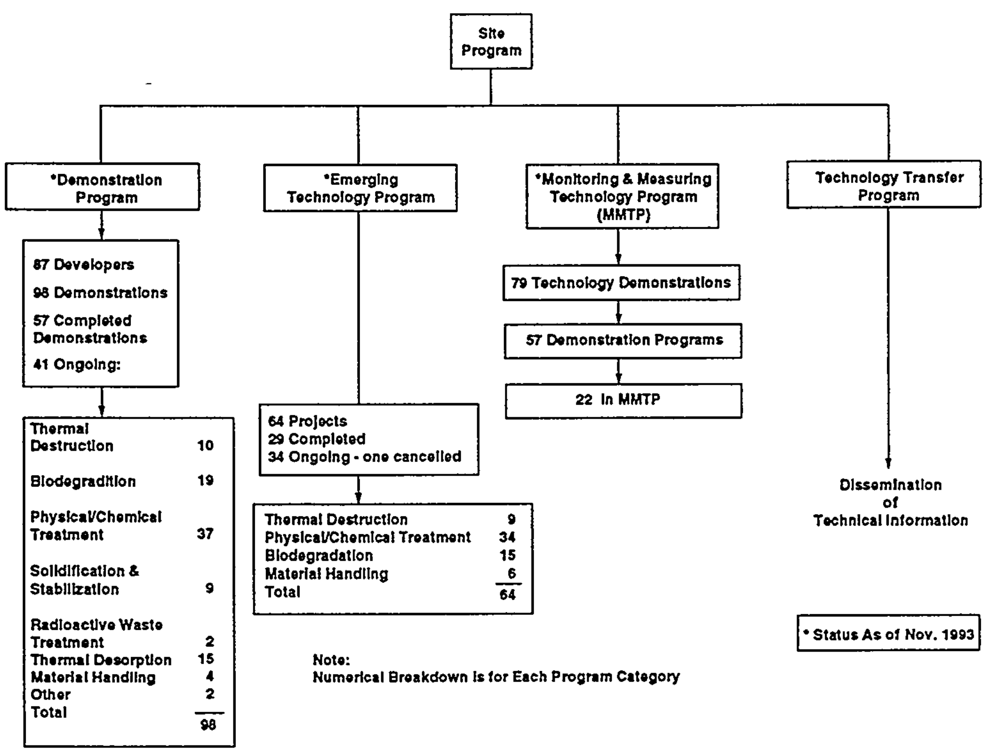


Figure 5.1: SITE Program Summary

2. DOE OTD Programs

Figure 5.2 illustrates the various components of the DOE OTD. The only component programs that are considered applicable to this effort are Treatment & Remediation Technology Systems and Innovative & Crosscutting Programs which are illustrated in further detail in Figure 5.3. The DOE/OTD is currently undergoing reorganization so most references are outdated. However, the DOE technology development efforts have historically been concentrated in the following areas.[5.2]

- Groundwater and Soil Cleanup: Technologies for containment or remediation of hazardous/radioactive contamination in groundwater and soils. Sources of soil and groundwater contamination include previous disposal of wastes in ponds, seepage pits and trenches and shallow land burial sites; spills and leakage from waste transport and storage facilities including underground storage tanks; and discharges to the air and surface waters.
- Waste Retrieval and Waste Processing: Technologies for retrieving and processing hazardous, radioactive and mixed waste from DOE weapons complex operations, treating buried/stored waste, and decontaminating and decommissioning facilities no longer in operation.
- Pollution Prevention: Integration of new technologies and technology systems into processes for waste minimization, methods to reduce the toxicity or the amount of contamination at the source, and methods to reduce the toxicity and volume of waste for disposal through recycling, reuse and treatment.
- Robotics Technology Development: Technologies focusing on DOE site/complex work in hazardous environments and the handling of hazardous and radioactive materials. Site needs intended to be addressed by technologies developed by this program include underground storage tank remediation, buried waste retrieval, decontamination and decommissioning, containment analysis, automation, and other processes.

In order to enable access to information compiled by similar programs various databases have been compiled and referenced in the resource section.[5.3]

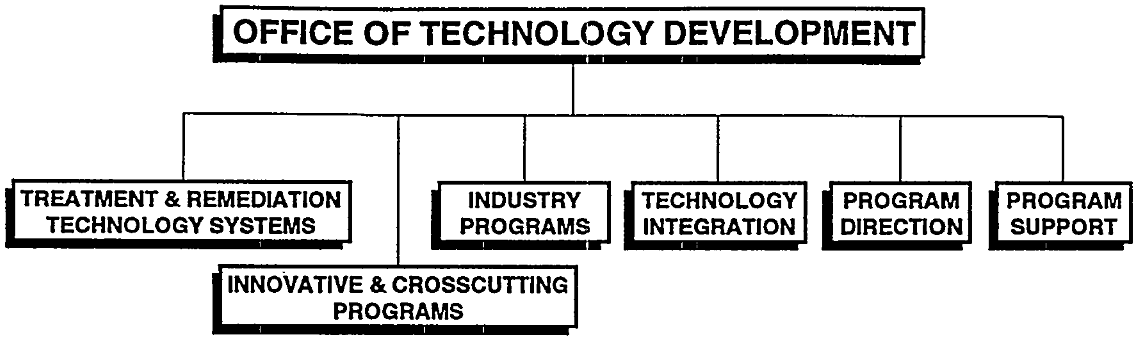


Figure 5.2: DOE/OTD Program Summary

TREATMENT & REMEDIATION TECHNOLOGY SYSTEMS

- MIXED WASTE- CHARACTERIZATION, TREATMENT & DISPOSAL
- RADIOACTIVE TANK WASTE REMEDIATION
- CONTAMINANT PLUME CONTAINMENT & REMEDIATION
- LANDFILL STABILIZATION
- FACILITY TRANSITION DECOMMISSIONING & FINAL DISPOSITION

INNOVATIVE & CROSSCUTTING PROGRAMS

- CHARACTERIZATION MONITORING & SENSORS
- EFFICIENT SEPARATIONS & PROCESSING
- ROBOTICS
- INNOVATIVE TECHNOLOGIES
- POLLUTION PREVENTION

Figure 5.3: DOE/OTD Program Breakdown

B. Remediation Alternatives Based on Innovative Technologies

A description of potential innovative technology alternatives that are applicable to the remediation of ER sites at SNL/NM are given below. Wherever possible, preference was given to innovative technologies that are at the demonstrated or further advanced stage. Also, technologies that can treat multiple contaminants are given preference over those that can only treat a specific contaminant. The innovative technology alternatives in this section are also divided into the previously defined general response action categories.

GRA: Containment

Containment and isolation technologies may consist of multi-layer caps or covers. The multi-layer cap is usually made of different layers of synthetic and/or natural materials and each layer is designed for a specific function. The main advantage of containment technologies over other remediation alternatives is that handling and moving of waste is avoided since the caps are constructed over or around the waste. Conventional RCRA type caps are multi-layer caps and have an unspecified design life. Such a cap may prove to be inappropriate for mixed waste because the radioactive components are usually long lived radionuclides. Due to this characteristic of mixed waste, several alternative cap designs have been proposed. Also, due to the RCRA component of the mixed waste, a cap in all likelihood will have to exceed the minimum requirements for a RCRA Cap. Some examples of containment systems are described below. Additional information concerning containment technologies can be found in the BDAT section.

Alternative 1 - Dry Barrier

The Dry Barrier is a cover system that is being researched and developed by the Environmental Restoration Technologies Department at SNL/NM for application at arid and semi-arid regions. The design utilizes a layer of coarse gravel or similar material beneath a dense, cover layer as shown in Figure 5.4. The design shown in Figure 5.4 will have to be modified to meet RCRA requirements and must be approved by federal, state and local environmental/regulatory agencies. The RCRA requirements may potentially be met by installing additional horizontal subsurface barriers.[5.4]

Application:

Waste Categories 1, 2, 3 & 4 (Table 2.1)

Process Schematic:

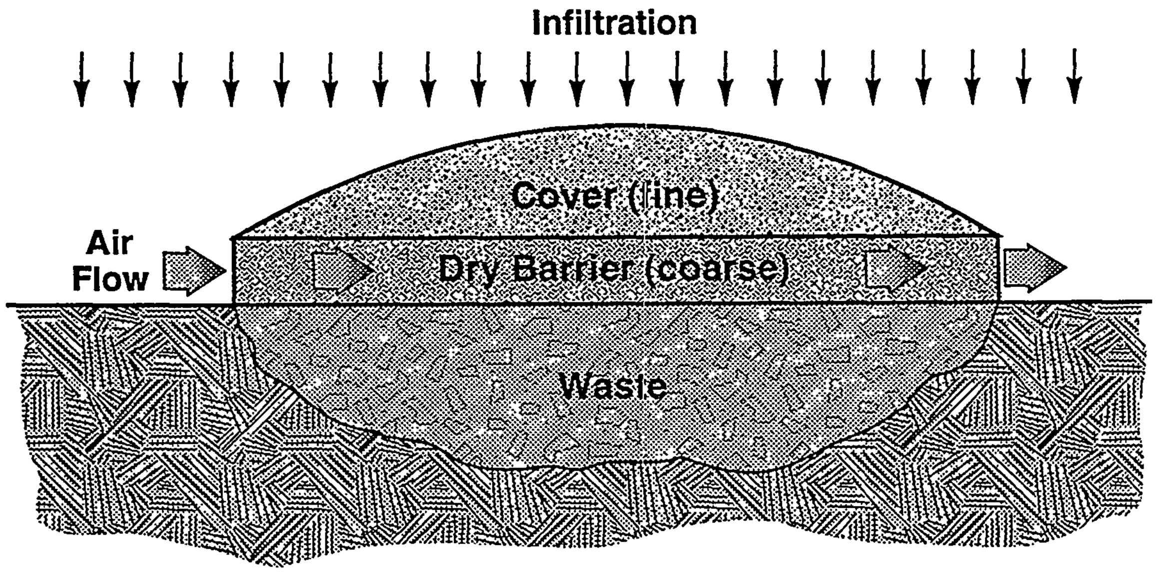


Figure 5.4: SNL/NM Dry Barrier

<u>*Alternative 2 - Permanent Isolation Surface Barrier (PISB)*</u>

This barrier design consists of various layers of naturally occurring materials including fine soil, sand, gravel, riprap, asphalt, and boulders (illustrated in Figure 5.5). Each of these layers, which are placed sequentially over the waste in the form of either an above or below-grade barrier, have a specific function. These concepts are illustrated in Figures 5.6 and 5.7, respectively.[5.5] Naturally occurring materials are used in the PISB to ensure maximum longevity thereby enabling a 1000 year design life. The performance objectives of the PISB are listed below.

- Suitable for a semi-arid to sub-humid climate.
- Limit the recharge of water through the waste to the water table to near zero amounts (0.05 cm/yr).
- Require little to no maintenance.
- Minimize the likelihood of plant, animal and human intrusion.

- Capable of isolating the wastes for a minimum of 1000 years.
- Minimize potential for erosion.
- Meet or exceed RCRA Cover requirements.
- Reduce the potential for unacceptable gas emission or emanation of radiation.
- Be acceptable to the regulatory agencies and the public.

Application:
Waste Categories 1, 2, 3 & 4 (Table 2.1)
Process Schematics:

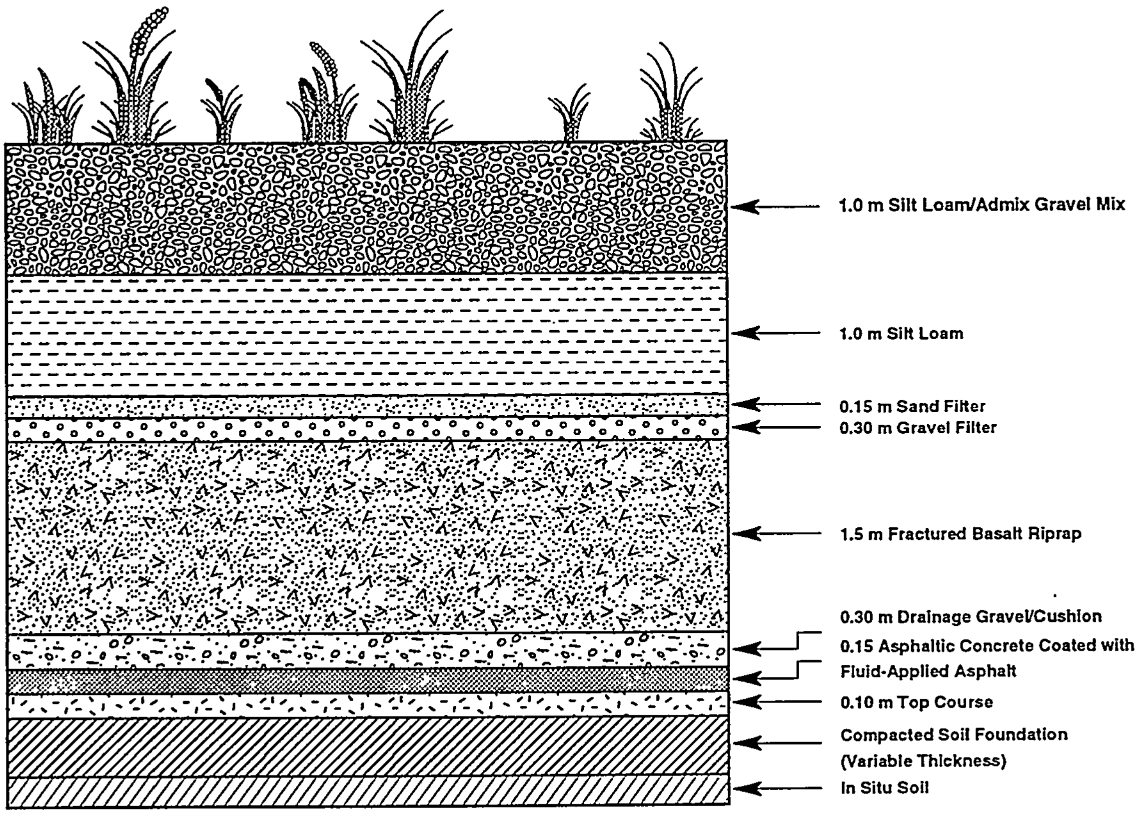


Figure 5.5: Permanent Isolation Surface Barrier (PISB)

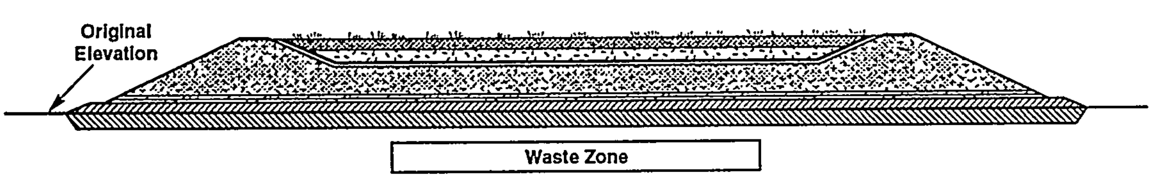


Figure 5.6: Above Grade PISB Design

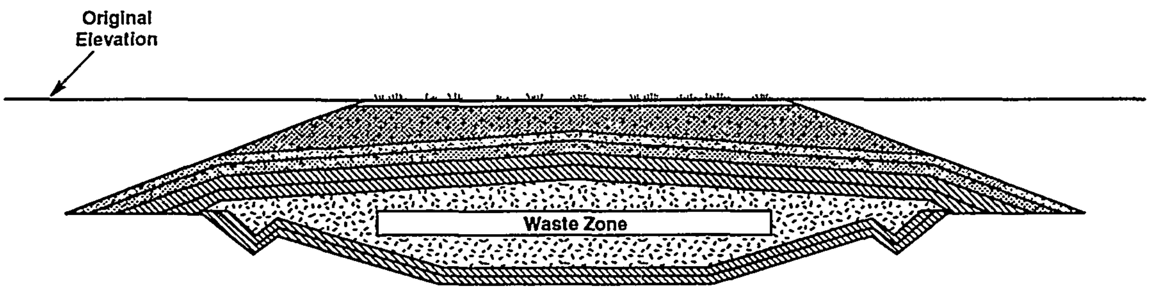


Figure 5.7: Below Grade PISB Design

Alternative 3 - Chemical Barrier

This alternative includes a chemical barrier below the waste in addition to a multi-layer cap above the waste. The multi-layer cap has additional intruder protection provided by a gravel armoring layer. Chemical barriers are installed beneath the waste during the construction of a landfill to form a continuous permeable barrier which allows passage of leachate water but not contaminants. The chemical barrier is designed to control the migration of contaminants by methods such as ion exchange, adsorption or neutralization of the leachate. This alternative is illustrated by Figure 5.8.[5.4]

Application:

Waste Categories 1, 2, 3 & 4 (Table 2.1)

Process Schematic:

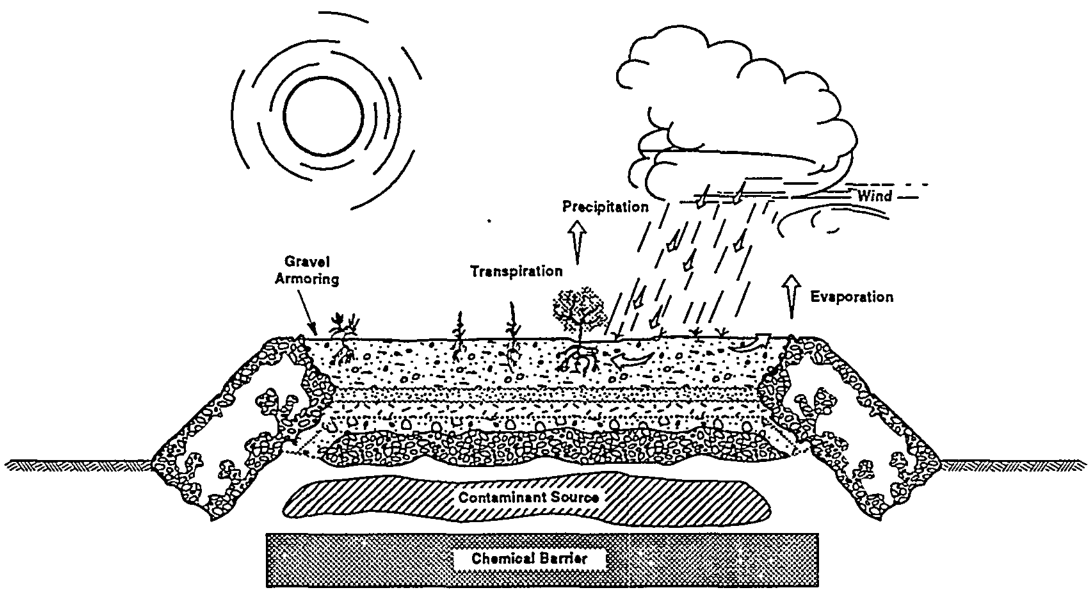


Figure 5.8: Chemical Barrier

GRA: In Situ Treatment

A general description of this GRA is provided in the BDAT section of this document.

Alternative 4 - Thermally Enhanced Vapor Extraction System (TEVES)

In this alternative a vacuum vapor extraction system is used in combination with soil heating to treat contaminated soil. By combining several technologies, this alternative has the potential to reduce the time required to remediate a contaminated site. The system is illustrated in Figure 5.9 and includes the following components:[5.4]

- A vacuum vapor extraction system including vacuum pump and piping system.
- A network of RF excitor and guard electrodes installed in the ground in a predetermined pattern.
- An on-site vapor recovery and treatment system.
- A vapor containment cover.

Application:

Waste Category 1 (Table 2.1)

Process Schematic:

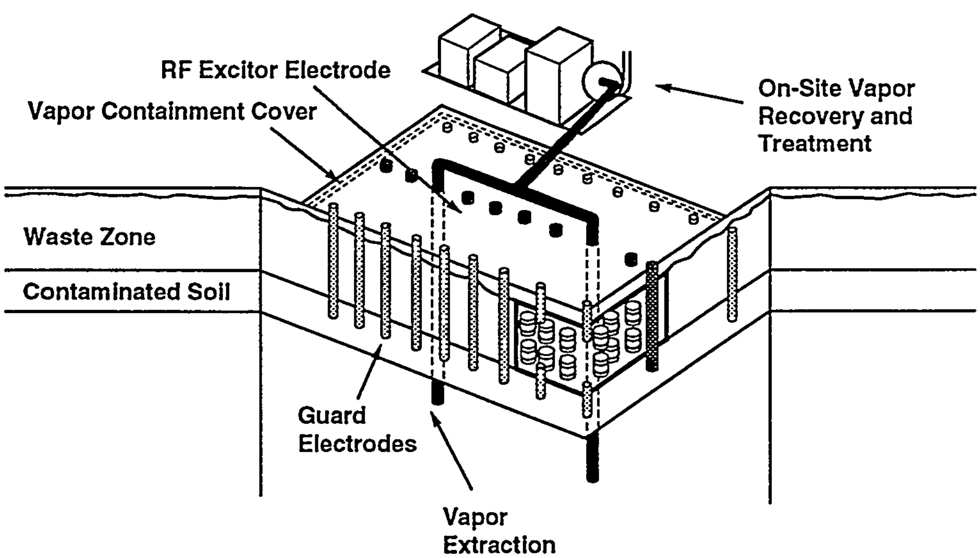


Figure 5.9: Thermally Enhanced Vapor Extraction System

Alternative 5 - Electrokinetics

Alternate Names: Electro-Osmosis, Electroacoustics

This alternative can be used for extracting heavy metals, radionuclides and other inorganic contaminants from soils and groundwater. The technology applies direct current across electrodes and conditioning pore fluids circulating at the electrodes to remove the contaminants. Figure 5.10 illustrates the process. A conditioning pore fluid may be circulated at the electrodes. This pore fluid conditions the reactions at the electrodes based on remediation goals and specific contaminants. The contaminants are either deposited at the electrode or may be removed from the conditioning fluid by a purification process. Acoustic wave energy may also be used in this system to enhance the removal rate and overall performance. This alternative can be used to treat both saturated and partially saturated soils. Further development is needed to reduce the likelihood of residual contamination because 100% removal efficiency is not achievable at the present time. Also, high pH conditions at the cathode could cause the precipitation of salts and inorganics.[5.1]

Application:

Waste Categories 2, 5 (Table 2.1)

Process Schematic:

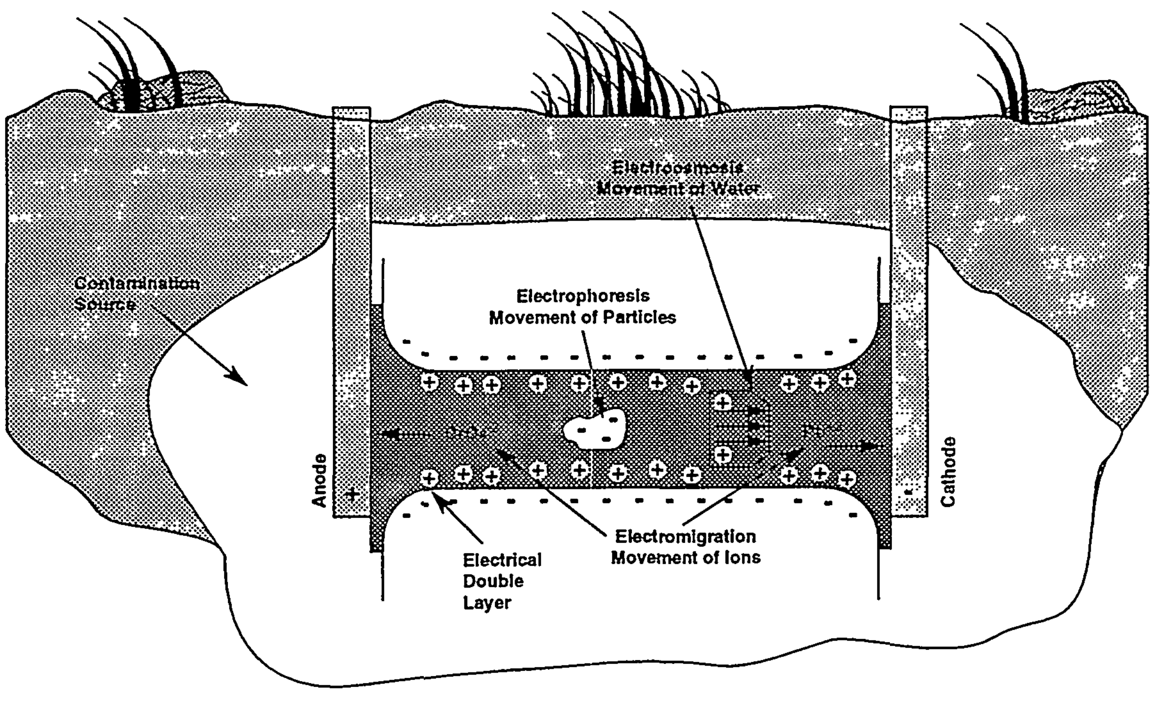


Figure 5.10: Electrokinetics

Alternative 6 - In-Situ Vitrification (ISV)

Alternative Names: Glassification, Molten Glass

In-situ vitrification is intended to convert contaminated soils into a durable glass and crystalline waste form in place. The process involves insertion of electrodes in the contaminated soil. A mixture of graphite and glass frit is placed between the electrodes to form a conductive path. An electrical current is initiated between the electrodes, resulting in resistance heating at temperatures high enough to melt the soil. The graphite is consumed by oxidation as the molten zone grows and becomes conductive, incorporating the soil contaminants and producing a vitreous mass. The off-gases emitted during the process operations are collected by a hood over the area and routed to a gas treatment system. When power to the system is turned off, the molten volume begins to cool which produces a vitrified block. The subsidence that results from the vitrification process must be covered with clean backfill to the original grade level. The principle of ISV operation is based upon joule heating, which occurs when an electrical current passes through the molten mass. As the soil melts and the molten mass grows, the power input must be increased. The process continues until the appropriate depth is reached. Melt depth is limited as the heat loss from the melt approaches the energy level that is deliverable to the molten soil by the electrodes. The main advantage of ISV is that it eliminates the need for retrieval of wastes and the glass that is formed is considered non-leachable. ISV is not recommended for explosives or material that is more than 30% combustible and may not be practical for large sites.[5.7]

Application:

Waste Categories 1, 2 (Table 2.1)

Process Schematic:

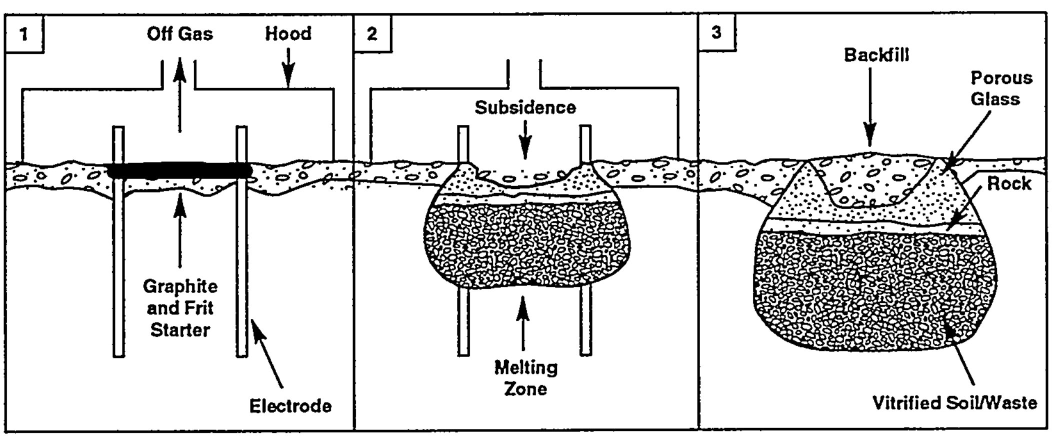


Figure 5.11: Typical In-Situ Vitrification System

Alternative 7 - Biodegradation in an Arid Environment, Solar Enhanced, with Directional/Horizontal Drilling

This alternative is similar to Alternative 3 of the BDAT section. However, the process is enhanced by injecting air heated by solar power into the area below the contaminated zone. Convective heating enhances the microbial activity in this zone thereby accelerating the biodegradation process. The process is further enhanced by treating a larger area by the use of directional/horizontal drilling.

Application:

Waste Categories 1, 5 (Table 2.1)

Process Schematic:

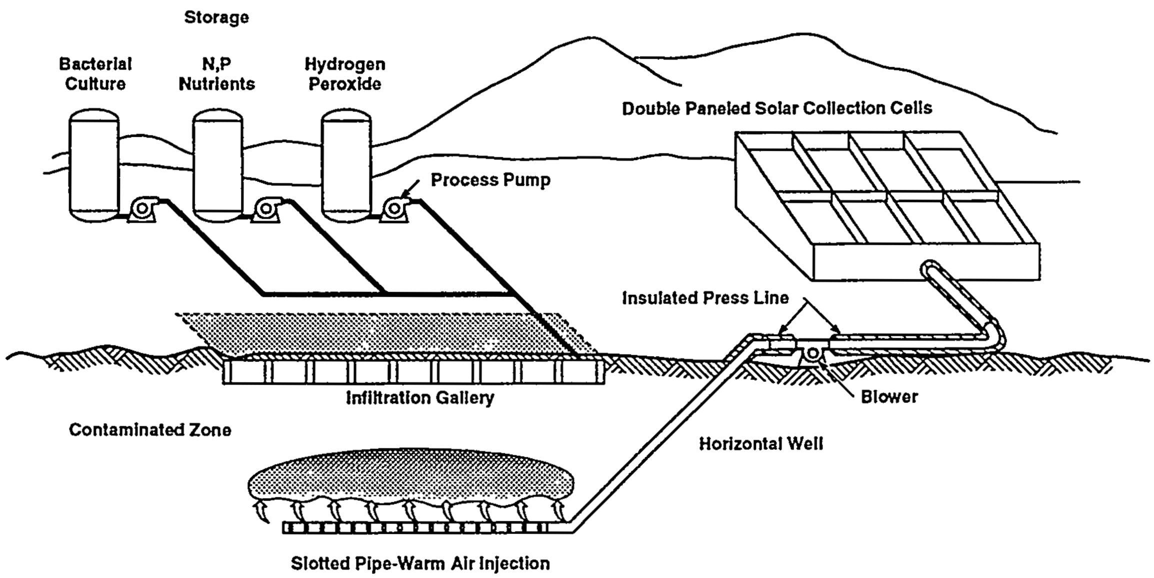


Figure 5.12: Biodegradation in an Arid Environment

GRA: Excavation/Removal, Treatment and Disposal

A general description of this GRA is provided in the BDAT section of this document.

Alternative 8 - Steam Reforming

Alternate Names: Steam Gasification Detoxifier

This is a two stage thermal process in which hydrocarbons are vaporized at 700-1200°F in an autoclave and then injected into a reaction chamber (detoxifier). The reaction chamber contains superheated steam where the organics are decomposed via steam hydrocarbon reforming chemistry. Typical detoxifier operating conditions are 2100-3000°F at a slightly negative pressure. Organics can be vaporized in-drum, minimizing waste handling requirements, or by pumping from large tanks. The off-gas portion of this system may be equipped with halogen absorbers, mercury absorbers, carbon absorbers and catalytic carbon monoxide converters to remove metals, methane, carbon monoxide, hydrogen and HCl, which are normal exhaust gas constituents of the process. The process can achieve a high DRE and the off-gas is free of NO_X, SO_X, PICs, dioxins, and particulates. The process is well suited for organic liquid wastes and its use has also been proven at the pilot stage for organically contaminated solid wastes.[5.1]

Application:
Waste Categories 1, 3 (Table 2.1)
Process Schematic:

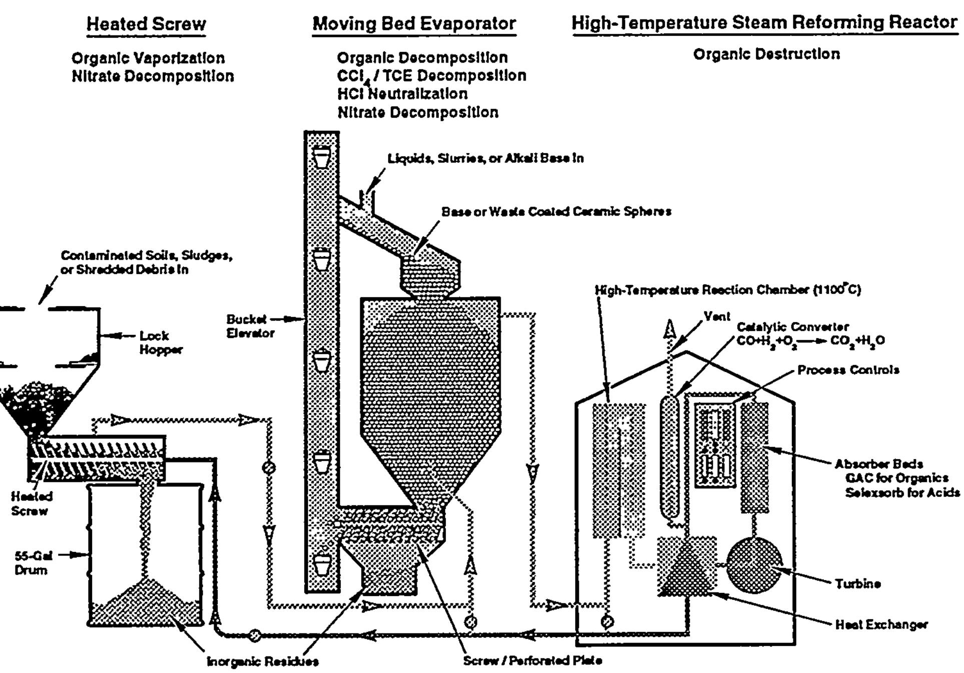


Figure 5.13: Typical Steam Reforming Operation

Alternative 9 - Reverse-Burn Gasification

Alternative Names: ChemChar Process

This alternative involves thermochemical treatment of hazardous and mixed wastes. A key component of this waste treatment process is the granular char matrix on which the waste materials are held immobilized for gasification. The char is prepared by gasification of subbituminous coal in a reactor. The subbituminous coal has to be nonswelling, low in sulfur and have high alkalinity. Figure 5.14 shows a diagram of the batch-mode version of the reactor used for reverse-burn gasification. A continuous-feed version is also under development. For waste gasification, the reactor is charged with the coal char/waste mixture. Water aids the gasification and provides a source of hydrogen for waste destroying free radical induced reactions such as dehydrohalogenation. Water may be present on the solid or introduced as steam into the oxidant stream. Oxygen is used as the oxidant. Reverse-burn gasification occurs with movement of the flame front counter to the oxidant flow and evolution of a combustible synthesis gas from the gasifier. This gas consists of combustible components, CO_2, H_2O vapor, and trace volatile organic constituents. The combustible fraction is approximately 45% CO, 45% H_2 and 10% CH_4. The carbonaceous solid residue retains heavy metals and, when alkaline, acid gases such as HCl. Figure 5.15 illustrates the thermochemical reactions occurring in the region just above the flame front, within the flame front, and in the reducing zone immediately downstream from the flame front.[5.8][5.9]

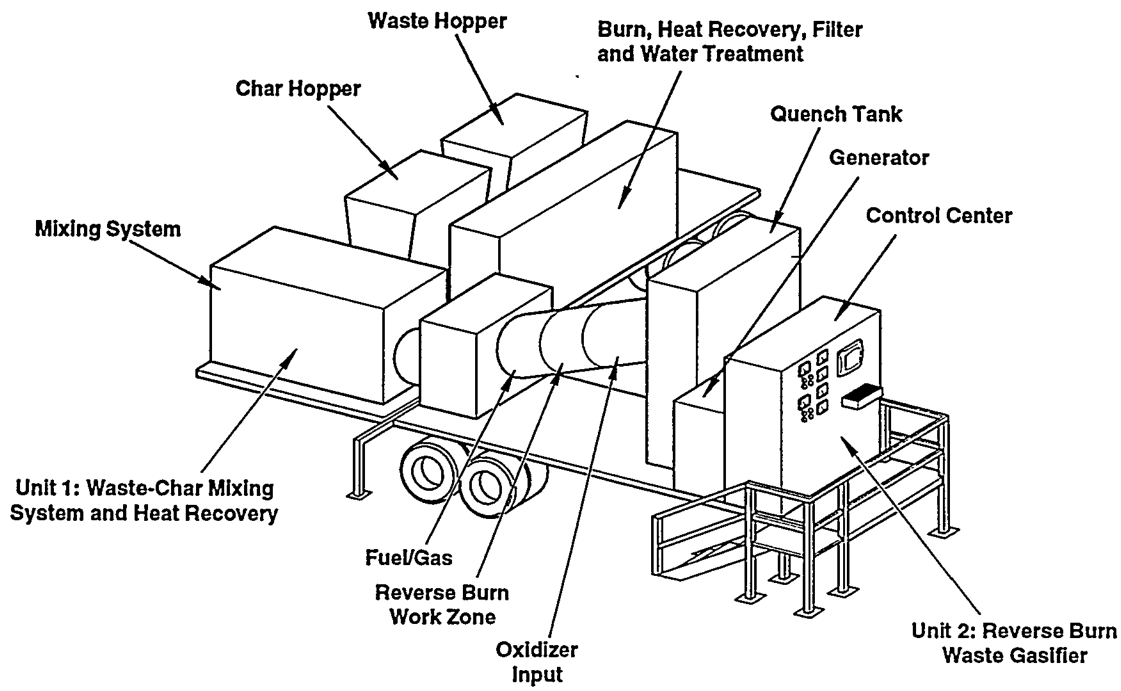
Destruction of wastes by reverse-burn gasification is accomplished with the gasification reaction shown in Figure 5.16. A generalized waste treatment system involves the following steps:

1. Macerated solid wastes mixed directly with char (char can be used to sorb and dry aqueous liquid and solid wastes to produce a dry, granular, readily handled material).
2. Gasification of the char/waste mixture.
3. Removal from the gas stream of aqueous condensate containing impurities and gasification by-products.
4. Filtration of the gas stream through a bed of TRB char.
5. Combustion of the gas product.
6. Recycle to the gasifier of aqueous condensate and char from the filter.

Application:

Waste Categories 1, 3 (Table 2.1)

Process Schematic:



Conceptual Design: Dual-Trailer Waste Gasification System

Figure 5.14: Reverse Burn Gasification

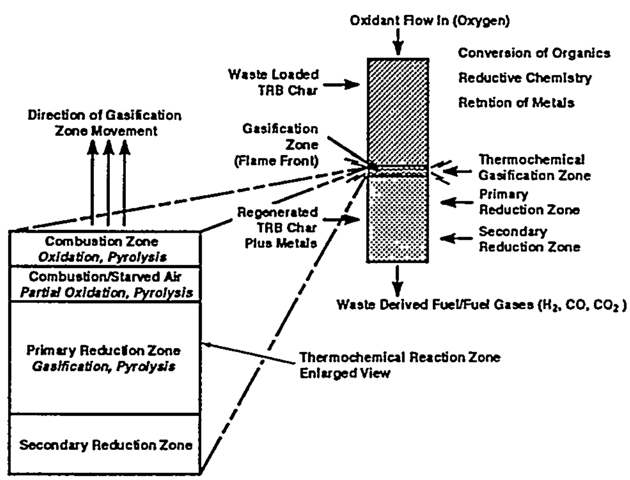


Figure 5.15: Reverse Burn Gasification Details

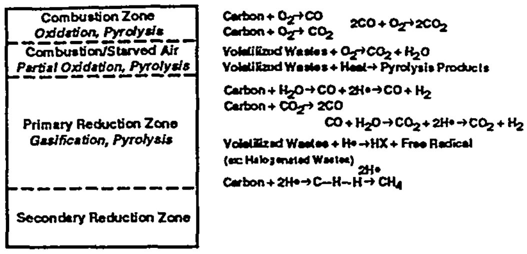


Figure 5.16: Typical Chemical Reactions for Reverse Burn Gasification

Alternative 10 - Joule Heated Melter

Alternate Names: Molten Glass, Molten Glass Incineration, Joule Heated Glass Furnace Processing.

A pool of glass is initially melted by auxiliary heating (fuel fired) in a refractory lined reactor. The material is then maintained in a molten state by joule heating (alternating current passing through the glass between submerged electrodes dissipates energy due to bulk glass resistivity). The nominal operating temperature of 1200°C (maximum) distinguishes this alternative from the High-Temperature Joule Melter. Wastes are typically fed to the process in a slurry form. Glass formers and additives are mixed with the waste to provide the silica and fluxes needed to melt at 1200°C. For non-slurried waste applications, waste is introduced into the molten glass pool along with combustion air. Combustion is achieved by exposure to the radiant heat above the pool or by contact with the molten glass. Exhaust gases flow out of the opposite end of the furnace to an off-gas treatment system. Solid products of combustion and noncombustible materials are encapsulated in the glass, which can be continuously removed or batch discharged to solidify into a glass-like monolith. A feeding variation by one developer introduces the waste and air under the surface of the molten glass via a drop tube to confine most of the combustion below the surface of the pool. This variation enhances intermixing of the waste and combustion gases with the glass and attains higher particulate retention within the melt. Typical mean residence time ranges from 24 to 48 hours. This assures homogeneity of the glass-like material being discharged even with variations in the waste stream.[5.10]

Application:

Waste Categories 1, 2, 3 & 4 (Table 2.1)

Process Schematic:

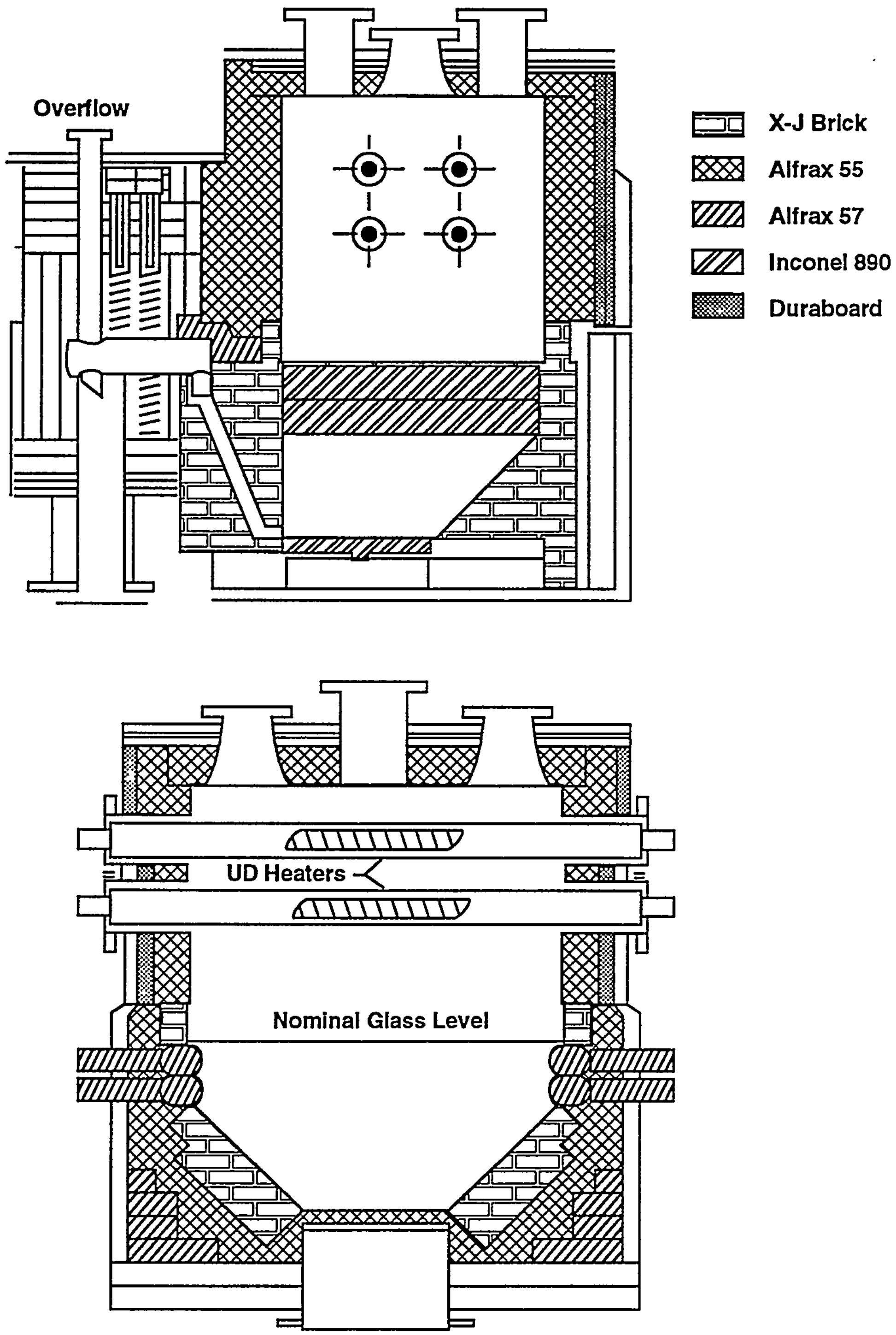


Figure 5.17: Typical Joule Heated Melter

Alternative 11 - Plasma-Arc Furnace

Alternative Names: Plasma-Torch Furnace, Plasma-Arc Vitrification

A plasma arc furnace uses the energy from a thermal plasma arc, generated by joule heating of a gaseous electrical conductor between two high voltage electrodes, to combust organics and melt inert waste components. The plasma arc is generated within the furnace primary chamber by a removable plasma torch. Two types of plasma torches are available: transferred and non-transferred arc. The transferred arc uses a conductive hearth for maintaining the voltage differential for arc generation. In the non-transferred plasma torch, the arc is generated and maintained within the torch body. Waste is introduced into the furnace into a molten bath of material, which could be inert waste or other material. The high temperature plasma zone and the molten bath (in excess of 3000°F) combust (or pyrolyze) the organics and melt all other inert materials into the bath. Volatile organics may be further treated in a secondary combustion chamber. A small input of inert torch gas is required for the plasma arc, resulting in low off-gas volume. Molten solid material can be removed continuously by overflow or poured by batch to form a leach resistant, vitrified glassy waste form. Furnace operation is similar to a dual chamber controlled air incinerator with the substitution of a plasma arc torch for a burner in the primary chamber. The plasma arc furnace can also reprocess all of its by-products such as fly ash, filter and scrubber residues.[5.10]

Applicability:

Waste Categories 1, 2, 3 & 4 (Table 2.1)

Process Schematic:

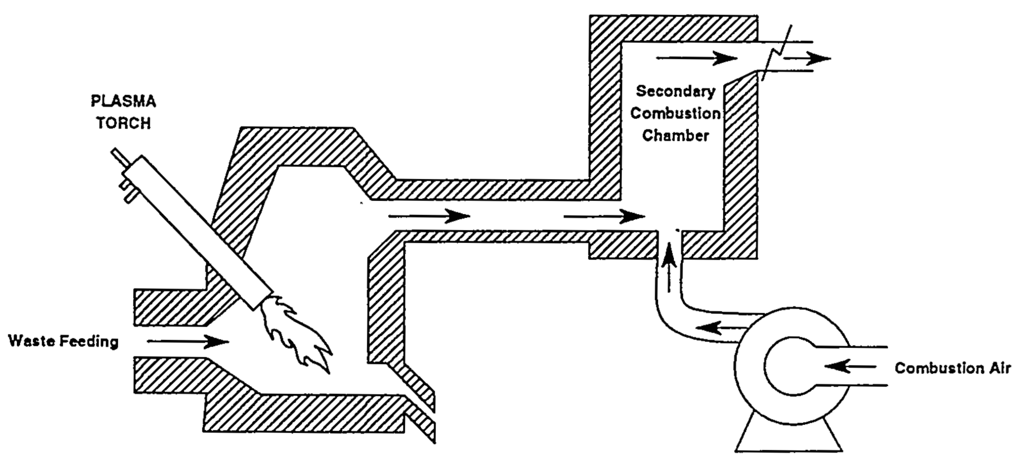


Figure 5.18: Plasma Arc

Alternative 12 - Mercury Removal by Thermal Volatilization and the Boliden-Norzinc Process for Mercury Vapor Treatment

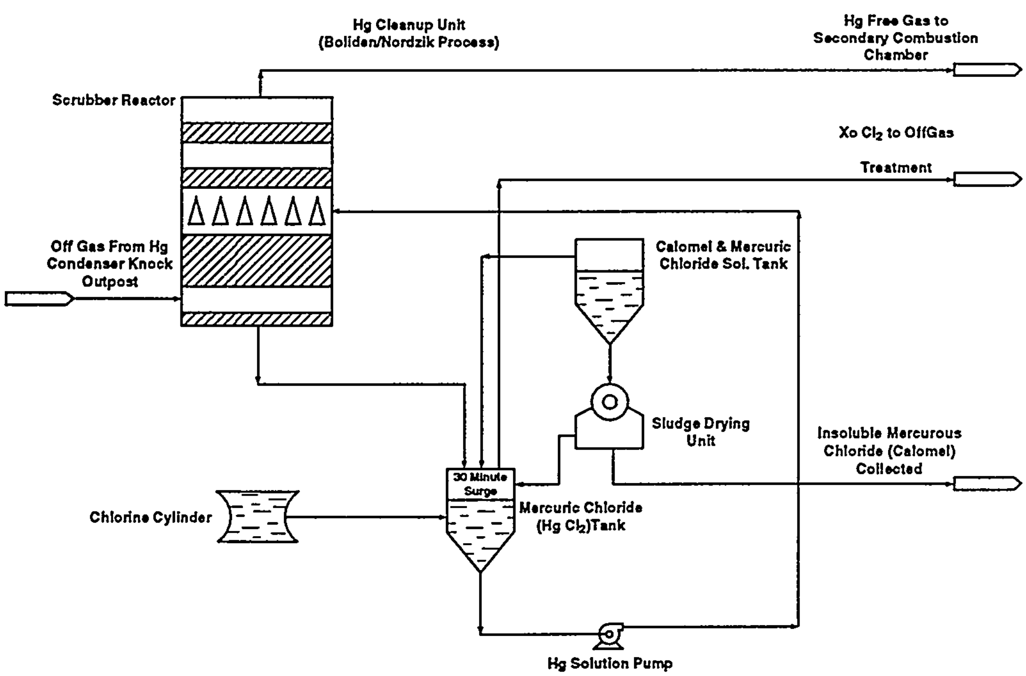
Alternate Names: Mercury Cleanup System

This alternative is an interim step in the removal of mercury by thermal volatilization. The alternative begins by heating the mercury contaminated material to 400°C in a furnace. The vapor from the furnace is run through a chiller and a mercury knockout pot. The off-gas from the knockout pot is routed to the mercury cleanup unit which uses the Boliden-Norzinc Process. This process consists of a scrubber reactor that eliminates mercury vapor completely from the gas stream. The off-gas, which contains metallic mercury vapor, is scrubbed in a counter-current flow with a mercuric chloride solution to produce a mercurous chloride precipitate.[5.11]

Application:

Waste Category 4 (Table 2.1)

Process Schematic:



(Reproduced/Adapted from Mixed Waste Treatment Project for U.S. Department of Energy by BECHTEL, September 1992)

Figure 5.19: Boliden-Norzinc Process

Alternative 13 - Mercury Control/Separation Processes

This alternative describes two additional types of Mercury Control/Separation Processes that could be applied at SNL/NM ER sites. These include solid-phase processes and liquid-phase processes. These two types of processes are described below. A gas-phase process is described in Alternative 12.

1. Solid-Phase Processes: A potential alternative is a process developed by General Electric, Inc. (patent pending).[5.11] The process uses a KI/I_2 solution to oxidize and form soluble mercury iodide complexes. Tests on a synthetic soil matrix dosed with metallic mercury and several mercury compounds including oxides, chlorides, sulfide, phosphate, nitrate, and methyl mercury chloride gave excellent separation.

2. Liquid-Phase Processes: An alternative with potential for liquid streams is the 3M membrane combined with IBC (IBC Advanced Technologies, Inc.) sequestering agents. This technology is currently under investigation by Battelle PNL for cesium and strontium removal. IBC has developed a system of chemically bonding highly selective, non-ion exchange, organic ligands to solid supports such as silica particles.[5.11] 3M has developed methods for incorporating these particles into matrices resulting in Teflon membranes that are highly porous which allows very high flow rates. This is a promising technology for highly selective removal of mercury from an aqueous stream.

Application:
Waste Category 4 (Table 2.1)

Alternative 14 - Sorting/Separation, Selective Chemical Extraction, Leaching, Precipitation followed by Solidification

An important step in processing or treatment of excavated soil is an efficient sorting and separation of soil, debris and other non-soil materials. Furthermore, as a part of this approach, it is recommended that the excavated material be divided into clean and contaminated material categories. Each category will be handled by dedicated equipment in separate areas thereby minimizing waste generation, preventing cross contamination or spreading the contamination to clean areas. The extraction process can be divided into the following unit operations:[5.6]

- Soil screening, washing and size reduction
- Desliming
- Leaching and precipitation
- Wastewater treatment and recycle

The soil screening, size reduction and soil washing operations also condition the soils for the remaining extraction/leaching components of this alternative. Desliming removes slime formed by the washing operation thereby allowing for a more efficient leaching operation. Slime is sent directly to the solidification process for treatment. The leaching operation utilizes acid washing to dissolve the contaminants to form liquor. The liquor is then neutralized to enable the contaminants to precipitate out for removal and disposal. The water utilized by the unit processes is treated and reused by the system.

Application:
Waste Categories 1, 2 & 4 (Table 2.1)
Process Schematic:

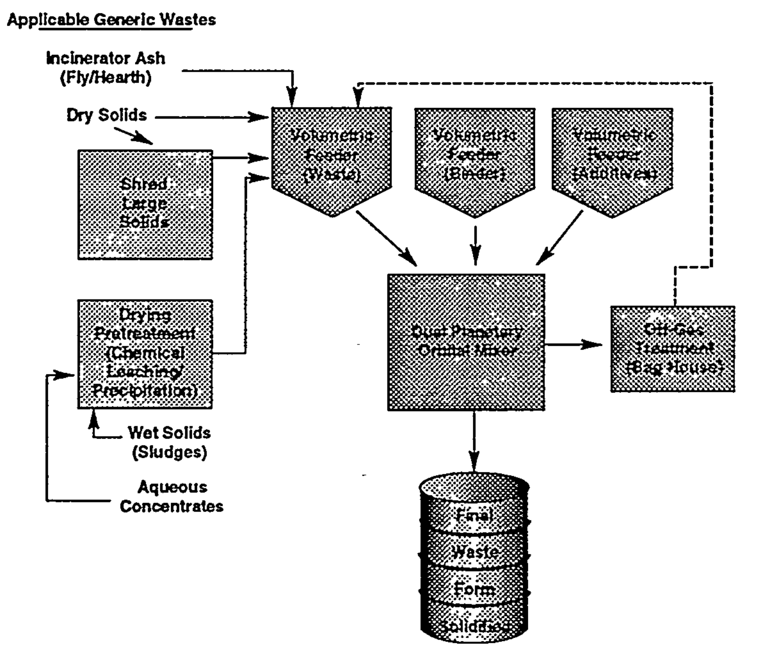


Figure 5.20: Sorting/Separation - Selective Chemical Leaching, Precipitation and Solidification

Alternative 15 - Catalytic Extraction Processing (CEP)

This treatment alternative involves injecting the waste material of any physical form (gas, liquid, slurry, sludge or solid) into a bath of molten iron. The iron acts as both a catalyst and a solvent and the waste feed is broken down into elemental form. CEP operating parameters and reactant additions can be tailored to convert nearly any hazardous material into useful products, including recyclable metals, ceramics and gases that can be used in chemical manufacturing processes. CEP is currently being commercialized by Molten Metal Technology, Inc. (MMT - Waltham Massachusetts), which owns full patent rights to the technology.[5.12]

Application:
Waste Categories 1, 2 & 4 (Table 2.1)
Process Schematic:

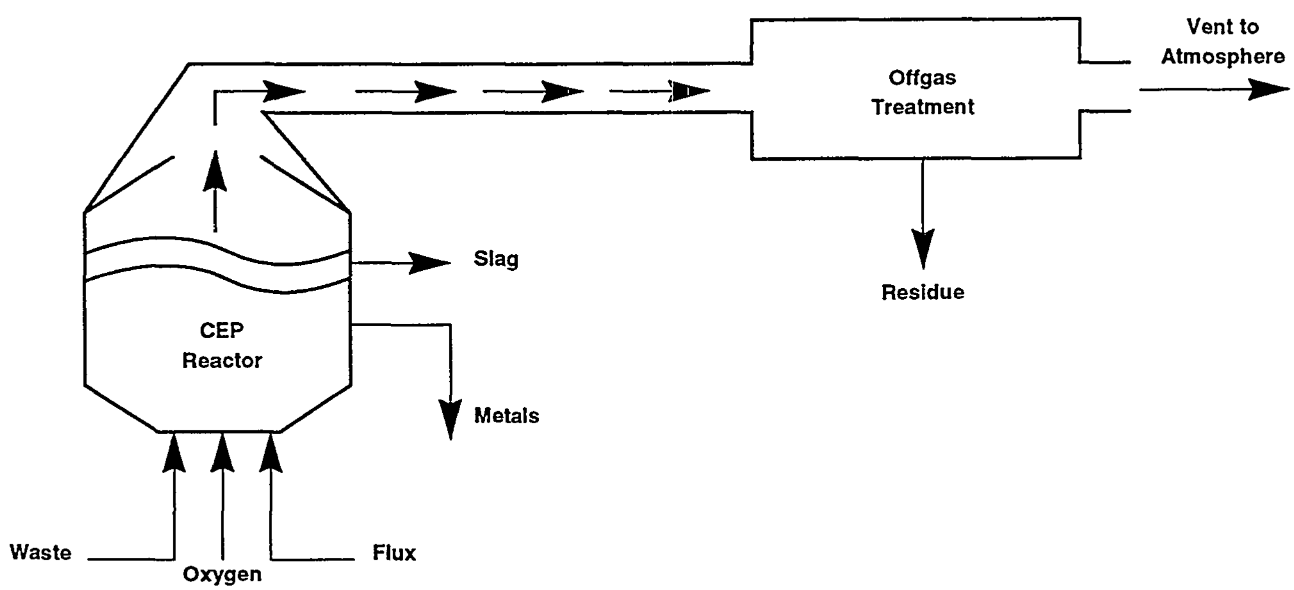


Figure 5.21: Catalytic Extraction Processing

Alternative 16 - Membrane-Media Extraction

This alternative, which has been developed by Harrison Western Environmental Services Inc. of Lakewood, Colorado, involves using peat moss "capsules" to remove metals from wastewater. This system is reported to be effective in reducing concentrations of arsenic, cadmium, lead, nickel, selenium and other metals. In addition, testing at the DOE's Rocky Flats facility in Colorado has shown this process to be effective in reducing radionuclide concentrations in wastewater. Harrison Western's patented system utilizes three process stages in series to remove metals from wastewater. These stages are explained below:

- Membrane separation stage: A nano-filtration membrane removes a high percentage of dissolved metals and organics with molecular weight greater than 150. The concentrate of the contaminants removed (estimated to be approximately 15% of the original waste stream) is treated by a chemical precipitation system.
- Biomass media extraction stage: Residual metals are removed from the membrane-treated water with biomass beads which sorb metals. The beads, described as peat moss capsules, typically reduce metal concentrations to less than 0.1 ppm.
- Mineral media extraction stage: The biomass beads do not remove anions. Therefore, Harrison Western has developed a mineral media to remove arsenic, selenium and other anions from the wastewater.

The biomass beads used in the second stage of the Harrison Western process were originally developed by the U.S. Bureau of Mines and called biofix beads. They are described as "highly porous polymeric beads containing immobilized, non-living biological material to which metals sorb". Essentially, the beads are encapsulated peat moss. An important positive feature of the beads is their ability to be regenerated. Once the surface of the beads is fully covered and soaked with sorbed metals, they can be soaked in a dilute acid solution which strips the metals. The concentrated stream from regeneration is sent to a precipitation system for the recovery of metals. The pH of the beads is then readjusted with a dilute soda ash reagent and the beads are returned to the media extraction system. The developers of the process claim that with the exception of nickel, the wastewater treated with this system results in lower contaminant levels than conventional precipitation systems. The addition of the membrane-media system also significantly reduces the amount of wastewater. The developer also claims that this system reduces the load on the precipitator by 80% and the sludge production is also reduced by 85%.[5.12]

Application:
Waste Category 5 (Table 2.1)
Process Schematic:

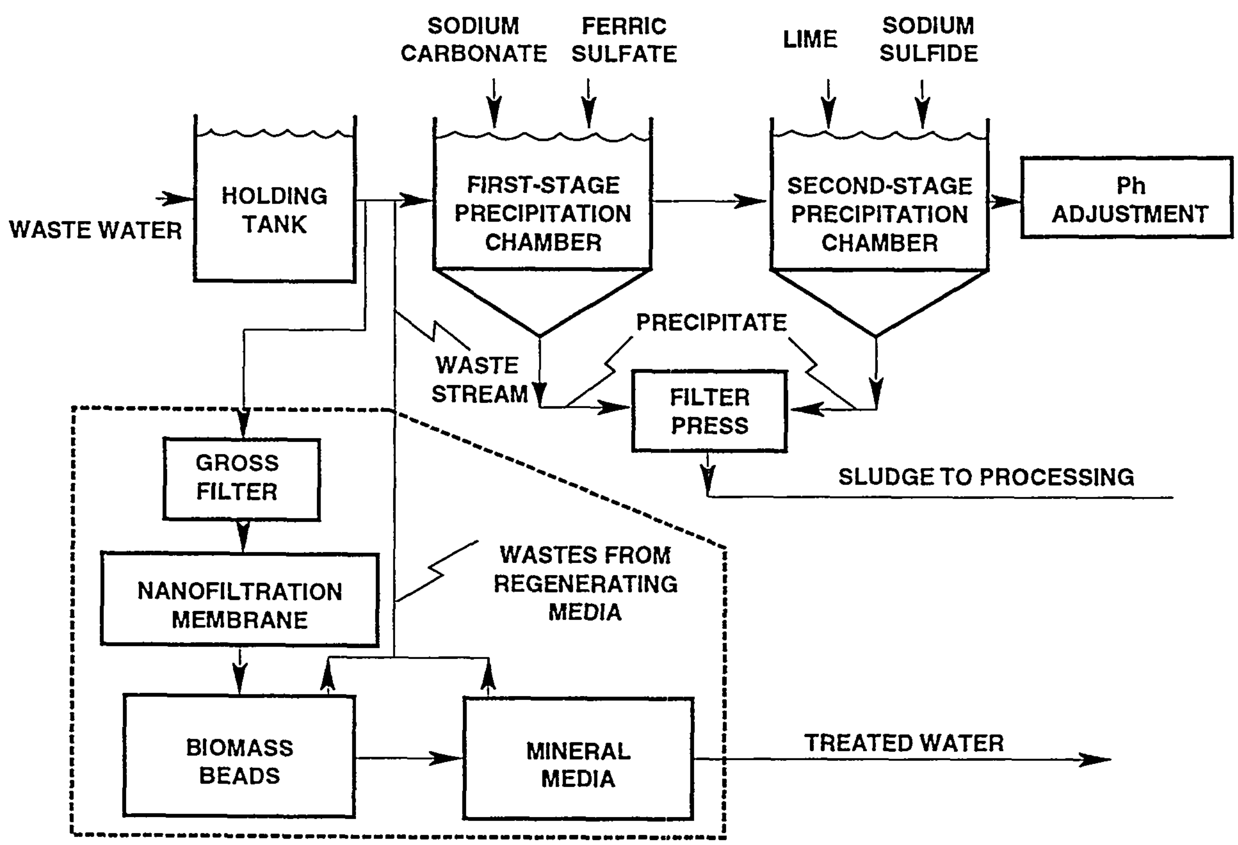


Figure 5.22: Membrane-Media Extraction

Alternative 17 - Photocatalytic Oxidation

This alternative consists of utilizing a UV source (either natural sunlight or UV lamps), a catalyst, in this case titanium dioxide (TiO_2), and a pipe system to contain the contaminated water. The TiO_2, which is either added into the waste water to form a slurry or is fixed to a lattice-type structure, is a non-toxic semiconductor that is an effective catalyst because it does not become depleted during the reactions. The photocatalytic process begins when UV light (below 400 nm in wave length) activates sites on the TiO_2 catalyst surface, producing an electron/hole pair. The electrons are designated by e^-, and the holes are indicated as h^+. The holes react with water to produce hydroxyl radicals (•OH). The electrons react with dissolved oxygen to form additional hydroxyl radicals, or they can react with dissolved metals of the proper reduction potential. Figure 5.23 is a schematic of this process.

The hydroxyl radical is an extremely powerful oxidizing agent that attacks the bonds of a wide variety of organic molecules. The end products of these reactions are carbon dioxide, water and simple mineral acids, such as hydrochloric acid (HCl). Most halogenated organics can be destroyed using this process.

Research at SNL/NM indicates that the photocatalytic process also effectively removes metals. Metals are removed by reduction while the organics are destroyed by oxidation. Both processes are necessary to maintain electroneutrality. During the reduction process metals are attracted to the catalyst and deposited on the TiO_2 surface. Once the catalyst is coated with metals, it can be either discarded or regenerated by dissolving the metals in an acid bath. Mercury and silver have been effectively removed from wastewater by this method. In the case of chromium, the hexavalent form does not directly deposit onto the catalyst. Instead, the trivalent form produced by reduction remains dissolved in the solution until pH conditions cause it to precipitate as Chromium(III) Oxide (Cr_2O_3). Cadmium and some other metals adsorb directly to the TiO_2 surface. This mechanism provides a third route for removing metals from wastewater.[5.12] Photocatalytic oxidation has the following advantages:

- Destruction of organics leaving behind carbon dioxide and water.
- Oxidation of chlorinated compounds creates dilute acids (e.g. HCl) which can be treated relatively easily.
- Onsite destruction of contaminants.
- Non-power intensive. The process, which lends itself to the use of solar power or an artificial UV lamp, is not power intensive (in the presence of the TiO_2 catalyst).

Application:
Waste Category 5 (Table 2.1)

Process Schematic:

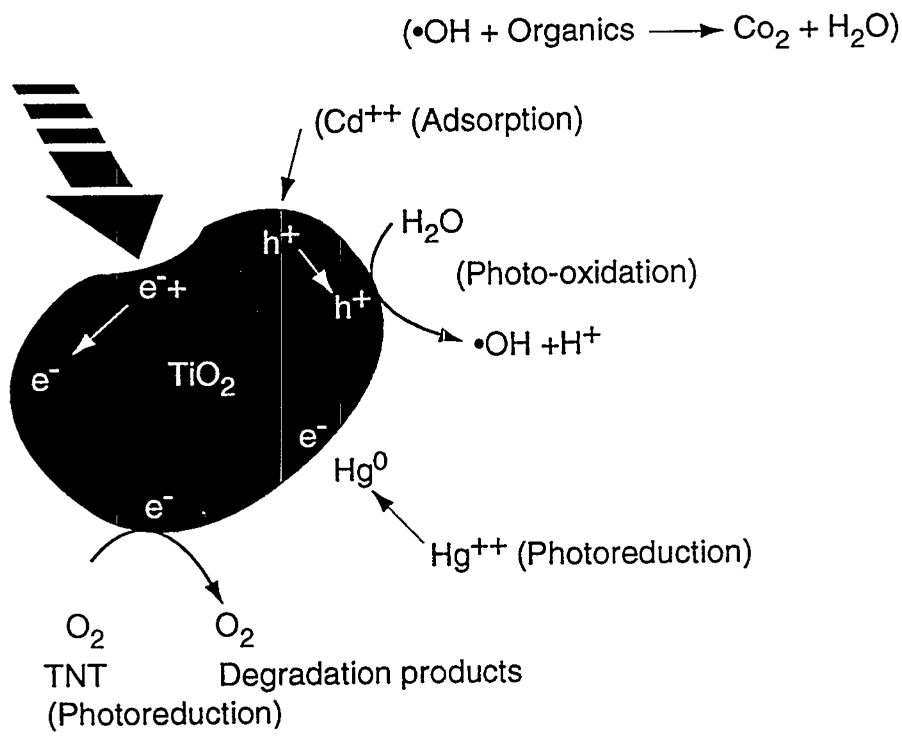


Figure 5.23: Photocatalytic Oxidation

Alternative 18 - Supercritical Water Oxidation

The critical temperature and pressure of water are 705°F (374°C) and 3,208 psia, respectively. Anytime water is maintained above these levels it assumes a supercritical form. As described below, the properties of water in this phase make it an ideal medium for the oxidation of aqueous waste materials.

When water is maintained at supercritical conditions, its liquid and vapor densities converge and the two phases become indistinguishable. Hydrogen bonding that normally occurs is essentially eliminated, making water an excellent solvent for most organic compounds. In addition, gases become completely miscible with supercritical water. Mass transfer limitations typically encountered in two-phase systems are eliminated allowing air or oxygen to be mixed with aqueous wastes above water's critical temperature and pressure. Organic compounds present in the waste are completely oxidized to carbon dioxide (CO_2) and water (H_2O).

Another important property of supercritical water is the fact that inorganic salts become almost insoluble above about 800°F (425°C). Any chlorine, sulfur or phosphorus present in aqueous wastes exposed to supercritical conditions is oxidized into corresponding chlorides, sulfates, and phosphates. If neutralizing agents, such as caustic are added, these compounds are converted into the corresponding salts (such as sodium chloride), which in turn will precipitate out of the supercritical fluid. However, these salts have been reported by some sources to be sticky and difficult to handle.

Figure 5.24 presents a simplified continuous supercritical water oxidation system. To begin the reaction, pressurized aqueous waste and water are preheated and fed into the oxidation reactor. As the waste oxidizes, the exothermic heat content of reaction typically raises the temperature to a self sustaining level above the critical temperature of water. However, if the heat content of the waste is low, an auxiliary fuel feed may be necessary to make the oxidation reaction self sustaining. In some cases, the reactor may have an external heat source in place of the auxiliary fuel feed (and possibly even the preheater). If the aqueous waste contains halogens or other inorganics, neutralizing chemicals may also be fed to the reactor to reduce potential for corrosion and/or facilitate inorganic salt removal. As previously indicated, solids and salts are precipitated from the reactor. Hot oxidation products and excess water are discharged from the reactor through a pressure-reducing valve and then cooled. The mixture then flows through a gas/liquid separator prior to release (or further treatment, recycling, etc.). In some systems, the reactor effluent is routed back through the preheater, supplementing or replacing the cooler.

The relatively low operating temperature of this alternative makes it more energy efficient than incineration and other thermal treatment methods. Waste feed heat content as low as 350 Btu/lb can provide sufficient oxidation energy to make the process energy self-sufficient. The low temperature also means that little or no nitrogen oxides (NO_X) are formed during treatment. In addition, the mass transfer rate of the supercritical water allows near complete organic compound destruction at relatively low residence times as compared to other oxidation methods. This has the potential for reducing the size and the cost of the waste treatment facilities.

Treating certain types of wastes can result in serious corrosion problems. The oxidation of chlorine and other species forms inorganic acid products, which in conjunction with the temperature and pressure of the medium, can lead to general corrosion (dissolution) and/or non-uniform corrosion (e.g. pitting or stress induced corrosion cracking). Methods for dealing with corrosion, such as the use of resistant alloys or replaceable (sacrificial) liners, increase the cost of supercritical water oxidation systems. As mentioned earlier neutralizing agents, such as caustic, can be added to reduce the corrosive effect of inorganic acid products. The presence of metals in waste streams can contribute to corrosion problems. Also, high levels of hazardous metals (e.g. chromium, lead, etc.) can result in the residue's failure of the EPA's toxicity characteristic leaching procedure (TCLP). Such residues would require additional treatment prior to disposal. Finally, some metal species may tend to deposit on the walls of oxidation vessels. This problem can be more significant in the case of mixed waste streams where the fate of the metallic compounds is of particular concern.[5.12]

Application:

Waste Categories 1, 5 (Table 2.1)

Process Schematic:

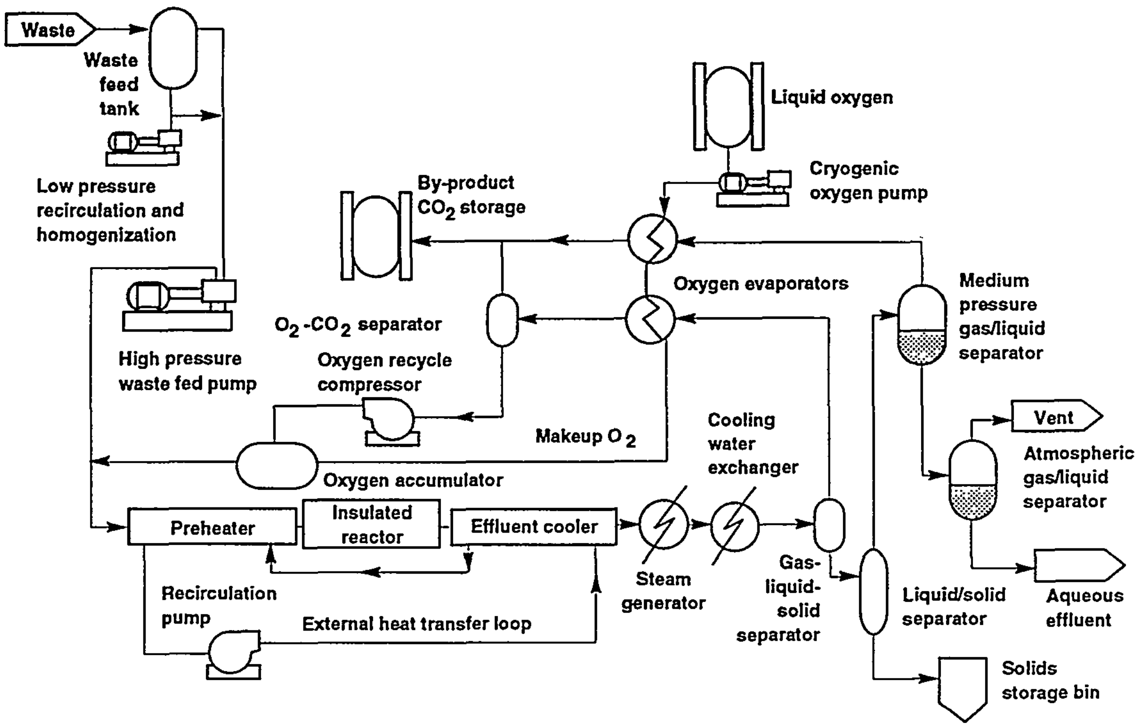


Figure 5.24: Supercritical Water Oxidation

C. Resources

5.1. EPA, 1993; *Superfund Innovative Technology Evaluation Program Technology Profiles*, Sixth Edition, EPA/540/R-93/526, November, 1993.

5.2. DOE, 1994a; *Office of Environmental Restoration and Waste Management, Office of Technology Development, FY 1993 Program Summary*, Office of Research and Development, Office of Demonstration, Testing and Evaluation, February 1994.

5.3. DOE, 1994b; *Waste Management and Technologies Analytical Database System (WMTADS)*, Office of Environmental Restoration and Office of Technology Development.

5.4. SNL, 1992; *The Mixed Waste Landfill Demonstration*, Sandia National Laboratories, Mixed Waste Landfill Integrated Demonstration, Department 6621.

5.5. Wing, N.R., 1993; *Permanent Isolation Surface Barrier: Functional Performance*, Westinghouse Hanford Company, WHC-EP-0650, October, 1993.

5.6. DOE, 1990; *Department of Energy, Feed Materials Production Center, Fernald, Ohio, Feasibility Study Report, Operable Unit 1*, Task 15 Report, December 1990.

5.7. DOE, 1993a; *Technical Area Status Report for Waste Destruction and Stabilization (DRAFT)*, February 1993. Prepared for: Mixed Waste Integrated Program, Office of Technology Development, U.S. Department of Energy under contract DE-AC01-93EW30030.

5.8. Reach, Jr., C., 1991; *The Chem Char Process, Gasification Technology Applied to Mixed Wastes*, Allied Signal Inc., Kansas City Division.

5.9. Kinner, L. L., A. McGowan, S. E. Manahan, D. W. Larsen, 1993; *Reverse-Burn Gasification for Treatment of Hazardous Wastes: Contaminated Soil, Mixed Wastes, and Spent Activated Carbon Generation*, Environ. Sci. Technol., Vol 27, No. 3.

5.10. DOE, 1993b; *Technical Area Status Report for Chemical/Physical Treatment Volumes I & II*, DOE/MWIP-8, May 1993, Prepared for the U.S. Department of Energy under contract number DE-AC05-840R21400, Oak Ridge National Laboratory, Oak Ridge, TN 83731-6285.

5.11. DOE, 1993c; *Mixed Waste Integrated Program: A Technology Assessment for Mercury-Containing Mixed Wastes*, DE-AC05-840R21400, DOE/MWIP-9.

5.12. Elsevier Science Publishing Co., 1994; The Hazardous Waste Consultant, Volume 12, Issue 2, March/April.

Section 6
Recommendations for Future Development

A. Introduction

The purpose of this report is to define the remediation needs of the ER Project and to identify areas where the current baseline/innovative technology base is inadequate to meet those needs. This technology gap represents areas where future technology development efforts should be focused by TAP and other organizations interested in providing remediation technologies for the SNL/NM ER Project. In this section, those technology development focus areas are presented based on the information contained in the previous sections of this report. However, efficient and economical remediation of SNL/NM ER sites will involve more than just the application of baseline and innovative remediation technologies. A unified remediation strategy must also be developed so that ER sites can be remediated in a consistent manner that is acceptable to regulatory agencies and to the public. Programmatic issues that must be addressed in order to develop a unified remediation strategy for the ER Project are also presented in this section.

B. Development of Unified Remediation Strategy

The current situation encompasses widely differing points of view with regard to selection of remediation approaches for SNL/NM ER sites. Some recent project efforts seem to indicate that only a very limited number of remediation technologies will be required for restoration of SNL/NM ER sites. Specifically, in the recent proposal to DOE for SNL retaining control of the ER Project, cost for remediation efforts were developed using conservative residual risk levels (i.e., 1×10^{-6}). An important assumption in this document was that site cleanup to reach this risk level will be achieved by using only BDAT alternatives.[6.1] Also, a remedial options study completed in 1994 by a team charged with developing a plan for treatment of mixed waste under the jurisdiction of the DOE Albuquerque Operations Office (DOE/AL), resulted in a recommendation of thirty technologies being applicable for SNL problems.[6.2] However, for the most part, ER waste was not included in the treatment plan due to lack of comprehensive characterization data for ER waste at most sites. The total volume of waste addressed by the AL Mixed Waste Treatment Plan (AL MWTP) is 9000 drum equivalents (for all sites). This is a relatively small volume compared to the much larger reported estimates for ER Projects. Therefore, the potential for using technologies specified by the AL MWTP for ER wastes is limited since the technologies are based on small scale waste streams. However, scale-up of the technologies discussed in the AL MWTP may be a feasible option for treatability studies.

Other drivers indicate that remediation technology innovation work must be continued for applications such as RCRA CAMUs, execution of TAP's mission (i.e., to develop, transfer, and apply innovative technologies in the areas of characterization, risk assessment, remediation, and long-term monitoring), and headquarters directives concerning better, faster, cheaper and safer alternatives. Any proposal for future work or continuation of on-going work should be clearly tied to these objectives.

Clearly, a critical need at this point is a unified strategy for the approach to be taken for remediation. The following information needs are considered most important from the strategic sense:

1. Future land use: This parameter drives decisions for selection of remedial approach such as: institutional controls versus containment or containment versus removal, treatment, and off-site disposal.

2. Residual risk level: The level of risk to human health or the environment remaining after the remedial action is completed. This parameter is commonly expressed in the form of a probability such as $1x10^{-6}$, which indicates that the probability of someone getting cancer as a result of exposure to a site and residual contamination is one chance in a million, or approximately the same probability as being struck by lightening. If risk-based decision making is employed and is accepted by regulatory entities, other less conservative residual risk levels may be applied. This decision is also crucial to the remediation engineer in selecting a restoration strategy. Basically, the lower the residual risk level required, the more drastic the remediation measure that must be applied for any given type of site.

3. Application of RCRA CAMUs: This parameter implicitly involves the use of innovative technologies to reduce toxicity, mobility, or volume of waste.[6.3] The use of CAMUs could potentially result in significant reductions in cost and schedule for restoration efforts.

C. Technology Development Focus Areas

The sum total of this document to this point has been to identify technology needs for remediation of SNL/NM ER sites and to develop an understanding of both BDAT and innovative technology alternatives potentially available to address the remediation needs. The purpose of this portion of the report is to qualitatively identify development focus areas needed to address remediation issues that cannot be solved with currently available and developing technologies. Due to the magnitude of costs associated with development of remediation technologies, it is not conceivable at this point in time to conclude that TAP can conduct all of these efforts. A proactive approach, however, is needed to influence other development efforts in such a way that SNL/NM ER needs will be addressed.

The following information is a presentation of technology development focus areas relative to the needs identified in Section 3.0. A qualitative assessment is made concerning the applicability of baseline and innovative alternatives presented in Sections 4.0 and 5.0.

Remediation technology need: Separation of DU from soil. A technology development effort for remediation of widely dispersed DU primarily on the surface of the soil is needed for use at SNL/NM ER sites. Some parameters to consider include development of technologies that accomplish the removal of DU from soil with little disturbance to vegetation. This is important because scraping would result in large areas prone to erosion by both wind and precipitation. Reestablishing vegetation after removing a layer of topsoil would be difficult and costly. Techniques for removing DU by exploiting technologies relying on physical properties such as density or magnetic potential may be useful for this program. In addition to development of the separation technology, a parallel effort is needed for the transport vehicle used to convey the separation technology into the field. Wheeled or tracked vehicles from the construction industry are logical choices for the transport platform.

Remediation technology need: Robotics for excavation and remediation. Numerous programs including the development of RETREVR at SNL/NM, and robotics development programs at other DOE facilities have been established to meet this need. Further demonstration on a full-scale basis and verification of improved safety and productivity performance are needed in order to use robotic systems at SNL/NM ER sites.

Remediation technology need: Tritium containment. A development program is needed for developing containment and in-situ stabilization technologies for sites containing soils contaminated with elevated concentrations of tritium. There are no technologies available to reduce the volume of waste matrices contaminated with tritium due to the fact that the chemical and physical properties of tritiated water (i.e., HTO) are very similar to water that does not contain the tritium isotope (technologies used to concentrate weapons grade tritium are impractical for remediation from the cost and schedule perspective). Methods and materials that are designed to either contain or stabilize waste matrices contaminated with tritium should be developed. The containment or stabilization technologies need only retain properties of interest for the period of time needed to allow radioactive decay to hydrogen.

Remediation technology need: Extraction of VOC and SVOC contamination. Sites containing soil and groundwater contaminated with organics such as solvents, polychlorinated biphenyls (PCBs), and fuels are the most prevalent and recurring problem for remediation engineer. The current state of the technology is limited in performance as technologies such as soil vapor extraction require years in many cases to significantly reduce contaminant concentration. Several programs are currently under development to address the limitations of soil vapor extraction (SVE). It is envisioned that decision support tools addressing critical physical, chemical, and hydrologic properties should also be developed. Models are needed for extraction well network placement. Similarly, SVE remediation technologies that are more efficient and effective are needed to reduce cost and schedule while accomplishing better cleanup.

Technology development need: Organics destruction. Contrary to the current opinions concerning incineration, this family of technologies is still the most logical choice for remediation of sites contaminated with organics. This is not meant to imply that incineration should be used for remediation of all sites contaminated with organics, but recognizes that the EPA has specified incineration as BDAT for most waste streams of this type. Limitations for application of incineration focus more on difficulties to permit, public distrust (i.e., NIMBY), and some technological limitations such as the need for a homogeneous waste stream to avoid process upsets. Development programs for replacement technologies designed to meet the performance capabilities of incineration while avoiding some of the issues discussed above are needed not only at SNL/NM but also in industry and at other government facilities.

Technology development need: Remediation strategies for classified waste. It is assumed that many items disposed of in classified landfills (or potentially items that have been in long-term storage) still must be managed in a manner that ensures security. Development is needed for technologies capable of altering the properties that make an item classified. It is anticipated that properties such as shape and chemistry must be physically or chemically changed to render classified materials to a form that can be reclassified for disposition.

Technology development need: Capping technologies. This need appears to be addressed by programs such as the dry barrier development and Alternative Landfill Cover Demonstration (ALCD) at SNL/NM and by a program to develop the Permanent Isolation Surface Barrier for use at the Hanford Site. The ALCD program is studying the capability of alternative landfill cover components and systems to provide long-term containment of waste buried in mixed waste landfills that are located in arid/semi-arid climate regions. The objectives of the demonstration are to collect data from field-scale covers or cover components and to identify critical cover construction defects and the impact of extreme weather events on both the cover components and construction defects. However, further long-term demonstration programs need to be implemented in order to verify the integrity of these innovative capping technologies for the expected lifetime of mixed waste landfills.

Technology development need: Decision support tools. Development of decision support tools to assist decision makers in the selection of remedial process alternatives is needed. A significant body of information is available for understanding remedial technologies at a basic level. However, the decision for selecting a remedial approach is both difficult and complex. Many factors influence the selection process. A decision support tool designed to provide information on parameters such as risk, cost, and technical aspects of remediation alternative performance is one critical need. Other decision support tools are anticipated for application of specific technologies with a high probability of being specified for use at SNL/NM ER sites (e.g., soil washing and thermal treatment).

Technology development need: Specification of technologies applied within a CAMU. There is potential for managing ER wastes within one or two RCRA CAMUs. The impetus from EPA is to use innovative technologies providing enhanced performance within the CAMU. The benefits of this approach are numerous: the waste management process is streamlined, treatment initiatives are put into place, and the long-term disposal of wastes into a controlled facility is accomplished. An initiative is needed to begin to identify data needs for various innovative technologies, to begin to select the various combinations of technologies (alternatives) for application, and to begin engineering design for site-specific considerations. A decision support tool may also be useful in this process.

Technology development need: Biodegradation in arid site applications. There appear to be opportunities at some of the sites containing organic contamination to develop enhanced biodegradation approaches. These development efforts are intended to take advantage of the climate of most arid regions in using solar power to boost performance of microbial degradation of organics such as solvents or fuels. This particular effort is one potential approach to replacing thermal technologies for the particular application of low contaminant concentration widely dispersed in the vadose zone.

Technology development need: Stabilization of heavy metals in soils. Many ER sites contain soil contaminated with heavy metals such as chromium. Options for soil remediation are usually directed towards excavation and disposal in a secure landfill, excavation and soil washing to remove the heavy metals, or in-situ soil washing/downgradient collection. However, less expensive in-situ methods need to be developed. One option is to stabilize heavy metals in the soil matrix by manipulating their geochemical state. Many heavy metals exist in multiple oxidation states in the natural environment and, in most cases, the oxidized state is many times more soluble than the reduced state. Chromium, for example, exists as soluble Cr(VI) or as the much less soluble Cr(III). As a result, Cr(VI) is mobile in the environment while Cr(III) is relatively immobile. In addition, Cr(III) is also much less toxic than Cr(VI). By inducing the reduction of heavy metals by the addition of a reducing agent to the soil or by encouraging microbial activity to reduce the redox potential of the soil, the metals can be tied up in the soil matrix as trace elements and the risks to human health and the environment can be reduced. One system that is currently under development by the Environmental Restoration Technologies Department at

SNL/NM is the introduction of H_2S gas into contaminated subsurface soil. H_2S is a mobile reducing agent which has the capability of reducing chromium and other heavy metals. However, for any proposed technology, laboratory studies and field demonstrations need to be conducted in order to verify the long-term stability of the heavy metals in the soil matrix.

Technology development need: Subsurface barrier emplacement. Underground, horizontal barriers are currently needed to provide short-term confinement of contaminants while other options for a site are evaluated or for long-term confinement to permanently isolate hazardous wastes. A grouted barrier could provide a rapid method for isolating hazardous constituents from the underlying saturated zone. The current state of the art for emplacement of subsurface barriers in near surface soils lies primarily with vertically emplaced barriers. This need is currently being addressed by the Subsurface Barrier Emplacement Program conducted by the Environmental Restoration Technologies Department at SNL/NM. This program is focused on applying this technology to the placement of horizontal barriers by the use of horizontal/directional drilling. Systems to monitor the integrity of the barriers are also needed

At this point in time, it is believed that development of the technologies listed above in conjunction with the existing baseline/innovative technology base will meet the future needs of the remediation portion of the ER project.

D. Resources

6.1. SNL, 1994; *Project Plan Summary: Environmental Restoration Project, Sandia National Laboratories, New Mexico*, Presented to the U.S. Department of Energy.

6.2. Bounini, L., et al., 1994; *AL Mixed Waste Treatment Plan*, DOE Grand Junction Field Office, Final Report, March 1994.

6.3. Calland, D.A., 1993; *Treatment of Remediation Wastes in RCRA Corrective Action Management Units*, Remediation, Volume 3, Number 4, Autumn 1993.

(this page left blank)

Section 7
Conclusions

The intent of this report is to develop a logical framework for selecting focus areas of remediation needs that require technology development. This strategy is in keeping with one objective of the TAP mission, namely the development, transfer, and application of innovative technologies in the area of remediation. Several critical points were made concerning not only the direction in which development efforts must be made but also certain key programmatic and regulatory guidance decisions that will affect remediation technology development strategies. Three critical programmatic and regulatory guidance issues that must be addressed in order to approach the remediation of ER sites with a unified strategy were defined. These include:

- Decisions concerning the future land use of the ER sites
- Definition of the residual risk level for ER sites
- Application of RCRA CAMUs to ER sites

Baseline and innovative remediation alternatives were also presented in this report. These baseline and innovative remediation alternatives will play a large role in the remediation of SNL/NM ER sites. However, these alternatives alone will not completely meet the remediation needs of the ER Project. Therefore, additional technologies will be required to be developed and have been designated as technology development focus areas. Based on interviews with the ER Task Leaders and the knowledge and experience of the TAP remediation engineers, the following technology development focus areas were defined:

<u>Separation of depleted uranium from soil</u>: Technologies for remediation of widely dispersed DU primarily on the surface of the soil.

<u>Robotics for excavation and remediation</u>: Technologies for the use of robotics at hazardous waste sites to enhance the productivity and safety of workers.

<u>Tritium containment</u>: Technologies for containment and in-situ stabilization of sites with soils contaminated with elevated concentrations of tritium.

Extraction of VOC and SVOC contamination: Programs to address the limitations of soil vapor extraction (SVE) for the in-situ treatment of soils contaminated with VOCs and SVOCs.

Technologies for the destruction of organics: Development of technologies to replace or enhance current incineration technologies.

Remediation strategies for classified waste: Development of technologies capable of altering the properties that make an item classified so that it can be reclassified for disposition.

Capping technologies: Development of landfill caps capable of containing hazardous and mixed wastes in an arid environment.

Decision support tools: Development of automated tools to assist decision makers in the selection of remedial process alternatives.

Specification of technologies applied within a CAMU: Initiatives to identify data needs for various innovative technologies, to begin to select the various combinations of technologies for application, and to begin engineering design for site-specific considerations.

Biodegradation in arid site applications: Development efforts to take advantage of the climate of most arid regions in using solar power to boost performance of microbial degradation of organics such as solvents or fuels.

Stabilization of heavy metals in soils: Inexpensive in-situ methods to stabilize heavy metals in the soil matrix by manipulating their geochemical state or by causing the formation of insoluble precipitates.

Subsurface barrier emplacement: Underground, horizontal barriers to provide short-term confinement of contaminants while other options for a site are evaluated or for long-term confinement to permanently isolate hazardous wastes.

Development of these critical remediation technologies along with the key regulatory guidance and management decisions which are summarized above are essential in order to successfully implement the remediation phase of the SNL/NM ER Project.

(this page left blank)

Distribution:

External:

Mushtaq A. Khan (5)
IT Corporation
5301 Central Avenue NE, Suite 700
Albuquerque, NM 87108-1513

John M. Valdez (5)
IT Corporation
5301 Central Avenue NE, Suite 700
Albuquerque, NM 87108-1513

Sandia National Laboratories/NM:

MS0726 J.K. Rice, 6600
MS0715 R.E. Luna, 6652
MS0719 J. E. Nelson, 6621
MS0719 J.D. Betsill, 6621
MS0719 T.D. Burford, 6621
MS0719 J.M. Phelan, 6621
MS0720 C.D. Massey, 6626
MS0720 W.C. Cheng, 6626
MS0720 R.G. Knowlton, 6626
MS0734 L.D. Bustard, 6624
MS0734 M.D. Tucker, 6624 (15)
MS1315 T.E. Blejwas, 7500
MS1306 J.A. Fernandez, 7574
MS1347 W. Cox, 7581
MS1347 F.B. Nimick, 7582
MS1348 R.E. Fate, 7585
MS1350 D.L. Stermer, 7584
MS0899 Technical Library, 13414 (5)
MS0619 Print Media, 12615
MS0100 Document Processing, 7613-2
For DOE/OSTI (2)

Sandia National Laboratories/CA:

MS9018 Central Technical Files, 8523-2