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INFORMAL REPORT

IN SITU TECHNOLOGY EVALUATION AND FUNCTIONAL AND OPERATIONAL GUIDELINES FOR TREATABILITY STUDIES AT THE RADIOACTIVE WASTE MANAGEMENT COMPLEX AT THE IDAHO NATIONAL ENGINEERING LABORATORY

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ABSTRACT

At the Idaho National Engineering Laboratory (INEL) Site, the In Situ Treatment Evaluation (ISTE) project supports the Buried Waste Program (BWP) with a primary objective of remediating all buried waste located there. The published results of the ISTE project will also provide remedial assistance to other Department of Energy (DOE) sites (that possess contaminated buried waste) in support of the Buried Waste Integrated Demonstration (BWID) Program and provide information for Feasibility Studies performed under the Comprehensive Environmental Response, Compensation, and Liability Act.

SUMMARY

The purpose of this report is to: (1) provide the EG&G Waste Technology Development Department with a basis for selection of in situ, buried waste treatment technologies for subsequent demonstration at the Radioactive Waste Management Complex (RWMC), (2) provide an overview of in situ treatments for buried waste, (3) provide an overview of functional and operational guidelines for treatability studies, (4) provide an overview of the ISTE project, and (5) provide information for future Feasibility Studies to be performed by Environmental Restoration (ER). The demonstrations recommended herein will aid in meeting Environmental Restoration/Waste Management (ER/WM) schedules for remediation at Waste Area Group (WAG) 7.

The purpose of performing treatability tests is to reduce cost and to ascertain performance uncertainties for treatment alternatives. The treatability study is required to produce sufficient data to permit the treatment alternative to be fully developed and evaluated under the CERCLA process. The results of treatability tests allow a treatment alternative to be considered for support of a remedial design for a selected alternative.

Guidelines for design of remediation systems for the RWMC are discussed in this report. These guidelines are based on project objectives, regulatory requirements, the availability of facilities and services at the RWMC, process requirements, safeguards and security considerations, environmental considerations, allowable exposure limits, necessary project plans, and community involvement.

Based on waste characterization studies and the measurements of soil gas, groundwater, and well vapor performed at the Subsurface Disposal Area (SDA), the volatile organic compounds (VOCs) of primary concern have been determined to be carbon tetrachloride, trichloroethylene, 1,1,1-trichloroethane, chloroform, and tetrachloroethylene. The radionuclides of concern include isotopes detected in previous studies of surface and subsurface soil as well as isotopes on the Environmental Restoration Program (ERP) Target List of radionuclides, which is based on past operations and

disposal records at the INEL. Inorganic compounds that have been detected in the interbed soils are arsenic, barium, beryllium, cadmium, chromium, cobalt, lead, nickel selenium, silver, thallium, zinc, cyanide, and tin. Mercury has also been detected in borehole vapors.

The environment is a major factor to be considered in any remediation effort. The upper Snake River Plain, where the INEL is located, is characterized as a cold, high desert. It is a region of relatively hot summers and cold winters. The surface of the Snake River Plain is covered by waterborne and windborne topsoil. The soils are derived from silicic volcanics and eroded Paleozoic rocks of the surrounding mountains. Surface water at the INEL comes from streams draining through intermountain valleys to the west and north, localized snow melt, and rain. The INEL is a sagebrush ecosystem, comprised of shrubs and an understory of perennial grasses and forbs. At some areas of the INEL, the sagebrush was removed by disc and the area reseeded with crested wheatgrass.

There are no threatened or endangered plant or animal species on the INEL site. The sagebrush ecosystem supports a diverse wildlife population including a variety of invertebrates, amphibians, reptiles, birds, and mammals.

This report contains a list of all in situ treatment technologies considered for the treatability studies at the RWMC. It addresses the criteria used to screen these technologies and any site specific effectiveness considerations. Much of the information on in situ treatment technologies in this report was obtained from vendors and universities. Solicitations for remedial technologies were placed in the January 25 and April 5, 1991 issues of *Commerce Business Daily* (CBD), and this information was screened for applicability to the ISTE buried waste project. Responding companies or universities who did not have an in situ treatment technology applicable to buried waste were eliminated from consideration. In addition, several EPA documents, the Remedial Technology Information System (RTIS), and various research materials listed in the references section were used to compile this document.

This report also contains an evaluation of the in situ treatment technologies and their applicability at the three waste sites under consideration. A standard set of criteria based on the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) criteria of implementability, effectiveness, and cost was used to evaluate each alternative. As a result of this technology evaluation, the following in situ technologies (listed alphabetically, not in order of anticipated performance) are recommended for further consideration in planning the demonstrations of remedial technologies at the acid pit, the soil vaults, and the low-level pits and trenches:

Acid Pit

- DETOXIFIER™
- Radio Frequency Heating followed by Solidification/Stabilization
- Simultaneous Injection, Extraction, and Recharge with Solidification/Stabilization
- Solidification/Stabilization
- Solidification/Stabilization with a Cap
- Steam/Air Stripping followed by Solidification/Stabilization
- Vacuum Extraction followed by Solidification/Stabilization.

Soil Vaults and Low-Level Pits and Trenches

- Slurry Wall and Bottom Sealing
- Slurry Wall and a Cap
- Slurry Wall and Bottom Sealing and a Cap
- Slurry Wall followed by Steam/Air Stripping or Vacuum Extraction and a Cap
- Soil/Cement Wall and Bottom Sealing
- Soil/Cement Wall and a Cap
- Soil/Cement Wall, Bottom Sealing, and a Cap

- Soil/Cement Wall followed by Steam/Air Stripping or Vacuum Extraction and a Cap

- Steam/Air Stripping or Vacuum Extraction followed by the Fluidized-Bed Zeolite System

- Steam/Air Stripping or Vacuum Extraction followed by the Fluidized-Bed Zeolite System and a Cap.

Much of the technology information contained in this report was supplied by vendors and/or universities. EG&G documented their claims in this report without any comment as to effectiveness. In general, conditions at each waste site must be known and considered prior to selection of a technology and, even then, a specific treatability study is required to verify performance at each specific waste site.

A revision to this report is scheduled to be published in March 1992 depending on FY-92 funding constraints.

ACKNOWLEDGMENTS

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CONTENTS

TABLES

FIGURES

ACRONYMS

ADG	Administrative Dose Guidelines
AEC	Atomic Energy Commission
ALARA	As low as reasonably achievable
ARARs	Applicable or Relevant and Appropriate Requirements
ASID	Arid Site Integrated Demonstration
BWID	Buried Waste Integrated Demonstration
BWP	Buried Waste Program
CBD	Commerce Business Daily
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
DOE	Department of Energy
DOE-ID	Department of Energy - Idaho Operations
DQOs	Data Quality Objectives
DT&E	Demonstration, Test, & Evaluation
EM	Electromagnetic
EPA	Environmental Protection Agency
ER	Environmental Restoration
ERP	Environmental Restoration Program
ER/WM	Environmental Restoration/Waste Management
FSP	Field Sampling Plan
HSP	Health and Safety Plan
HSWA	Hazardous and Solid Waste Amendments
INEL	Idaho National Engineering Laboratory
ISTE	In Situ Treatment Evaluation project

ISV	In Situ Vitrification
LLW	Low-level Waste
MFP	Mixed Fission Product
NEPA	National Environmental Policy Act
NRC	Nuclear Regulatory Commission
O&M	Operating and Maintenance
OSHA	Occupational Safety and Health Administration
OTD	Office of Technology Development
PCBs	Polychlorinated biphenyls
QAPjP	Quality Assurance Project Plan
R&D	Research and Development
RCRA	Resource Conservation and Recovery Act
RD&D	Research Development and Demonstration
RF	Radio Frequency
RFP	Rocky Flats Plant
RFQ	Request for Quote
ROD	Record of Decision
RTIp	Remedial Technology Information project
RTIS	Remedial Technology Information System
RWMC	Radioactive Waste Management Complex
SAP	Sampling and Analysis Plan
SARA	Superfund Amendments and Reauthorization Act
SDA	Subsurface Disposal Area
SDS	System Design Study
SOP	Standard Operating Procedure
SVOCs	Semivolatile Organic Compounds

TCLP	Toxicity Characteristic Leaching Procedure
TSCA	Toxic Substances Control Act
TRU	Transuranic
VOCs	Volatile Organic Compounds
VVE	Vapor Vacuum Extraction
WAG	Waste Area Group
WIPP	Waste Isolation Pilot Plant
WM	Waste Management

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1. INTRODUCTION

1.1 Purpose and Organization of Report

The purpose of this document is to provide EG&G Idaho's Waste Technology Development Department with a basis for selection of in situ technologies for demonstration at the Radioactive Waste Management Complex (RWMC) of the Idaho National Engineering Laboratory (INEL) and to provide information for Feasibility Studies to be performed according to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The demonstrations will aid in meeting Environmental Restoration/Waste Management (ER/WM) schedules for remediation of waste at Waste Area Group (WAG) 7.

This report is organized in six sections. The Introduction, contained in Section 1, summarizes background information on the sites to be remediated at WAG-7, specifically, the acid pit, soil vaults, and low-level pits and trenches. Section 2 discusses the identification and screening of in situ buried waste remediation technologies for these sites. Section 3 outlines the design requirements. Section 4 discusses the schedule [in accordance with Buried Waste Integrated Demonstration (BWID) scoping]. Section 5 includes recommendations for the acid pit, soil vaults, and low-level pits and trenches. A listing of references used to compile the report is given in Section 6. Detailed technology information is included in the Appendix section of this report.

1.2 Background Information

1.2.1 Site Description(s)

Following is a brief description of the RWMC as a whole, and the SDA portion of the RWMC. A site description for each specific area of WAG-7 pertinent to the In Situ Treatment Evaluation (ISTE) project follows.

The RWMC occupies 144 acres (582,750 m^2), with buried waste contained in the 88-acre (356,125 m^2) section referred to as the Subsurface Disposal Area (SDA). In addition to wastes generated at the INEL, wastes from the DOE's Rocky Flats Plant (RFP) and other DOE facilities are stored and disposed of at the RWMC.[1]

The SDA is a fenced area in the western part of the RWMC and contains numbered pits, trenches, soil vault rows, and Pad A (a storage area located on a ground-level asphalt pad). The pits generally have surface areas of several acres and range in depth from 5 to 15 ft (1.5 to 4.6 m). The pits were usually excavated to bedrock and covered with 2 ft (.6 m) of soil. After the waste was emplaced, the pits were backfilled with a minimum of 3 ft (.9 m) of soil. However, time has shown that this procedure might have left some waste directly on the basalt layer. During weekly or daily operations, soil cover was applied over the waste (depending on the procedures in place at the time). Closure of a filled pit included applying a final soil cover a few yards deep and planting stabilizing vegetation.[1]

The SDA is underlain by soils, thin sedimentary layers, and thick basalt deposits. The surficial deposits at the SDA range in thickness from 1 to more than 23 ft (.3 to more than 7.01 m). The irregularities in the soil thickness reflect the surface of the underlying basalts. Generally, the soils are shallow and consist of gravelly sand and fine-grained eolian deposits. The SDA soil has a high clay (approximately 36%) and a high silt content (approximately 56%). The SDA soil has a very low vertical hydraulic conductivity of approximately 1.54×10^{-7} ft/s (4.7×10^{-6} cm/s). If the soil is disturbed, perhaps by backfill over trenches, the vertical hydraulic conductivity could be higher. A few common features of the soils in the area displayed by a stratigraphic section of the surficial sediments include pebble layers, freeze-thaw textures, glacial loess deposits, and platy caliche horizons.[1]

1.2.1.1 Acid Pit. The acid pit is centrally located in the RWMC and covers approximately 20,500 ft^2 (1900 m^2), which is roughly 200 x 100 ft (60 x 30 m). A seismic refraction geophysical survey indicates an average depth to basalt of about 18 ft (5.5 m).[1]

Geophysics studies conducted in 1989 by UNC Geotech indicated that the acid pit was smaller than all previous research suggested. The studies suggested that acid may have migrated beneath the original base of the pit.[1]

1.2.1.2 Soil Vaults. The soil vaults were constructed by auguring cylindrical holes into the ground. When the auger reached the basalt level, 2 ft (.6 m) of backfill was placed in the bottom of the hole. Containers of waste were then placed in the cylindrical holes and covered with a minimum of 3 ft (.9 m) of soil. The waste stored in the soil vaults has a high radiation level--usually greater than 500 millirem per hour (mR/hr). The containers used to hold the waste vary in size, shape, and material. Typically, the containers were steel canisters 4 ft (1.22 m) in diameter and 8 ft (2.44 m) in height.[a]

The diameter of the soil vaults ranges from 1.3 to 6.5 ft (0.4 to 2.0 m) and averages 12 ft (3.7 m) in depth, with a minimum depth of 6.6 ft (2.0 m). When a soil vault bottoms in basalt, 2 ft (0.6 m) of soil is placed on the bottom of the vault. The vaults are separated by an edge distance of 2 ft (0.6 m) and are drilled along predetermined center lines. A filled vault is

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a. Unpublished research results of M. J. Case et al., *Radioactive Waste Management Complex Performance Assessment (Draft)*, November 1989.

covered with a minimum of 3 ft (0.9 m) of soil. Presently, approximately 20 soil vault rows exist within the SDA.[a]

1.2.1.3 Low-level Pits and Trenches. The pits are 16.4 ft deep x 99 ft wide (5 m x 30.2 m) on average and vary in length. Pits were excavated into the basalt, and the exposed basalt was then covered with 2 ft (0.6 m) of soil to maximize use of the SDA. Earth berms serve as radiation shielding, firebreaks, and dikes.[2]

> The edges of trenches were dug along predetermined centerlines and were separated from adjacent centerlines by no more than 16.1 ft (4.9 m). This allowed maximum use of available space without disturbing previously buried waste. The average width of the trenches was 10.2 ft (3.1 m) (those with collapsing walls were wider). Waste with high gamma radiation levels was handled remotely using special shielded containers and boom cranes. When the trenches were full, they were covered with a minimum of 3 ft (0.9 m) of soil. Locations of all trenches were identified by concrete monuments. A brass plate on each monument was stamped with the opening and closing dates. All non-TRU waste packages exceeding 500 Mr/hr at 3 ft (0.9 m) were deposited in trenches, except for those placed in soil vaults. In July 1981, trench disposals were discontinued, and the unfilled trench area was redesignated for soil vault disposals.[b]

1.2.2 Site History

The RWMC, located near the southwestern corner of the INEL, was selected as a waste disposal area in 1952 by the Atomic Energy Commission (AEC), predecessor to the U.S. Department of Energy (DOE). Initially it was established as a disposal site for solid low-level waste generated by INEL operations.[1]

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a. Private communication between Dale Wells, EG&G Idaho, and Robert B. Piper, EG&G Idaho, July 1991.

b. Unpublished research results of M. J. Case et al., *Radioactive Waste Management Complex Performance Assessment (Draft)*, November 1989.

Currently, the RWMC mission is to provide waste management for the present and future needs of the INEL and assigned DOE offsite generators of low-level and transuranic (TRU) wastes and to retrieve, examine, and certify stored TRU waste for ultimate shipment to the DOE Waste Isolation Pilot Plant (WIPP).[1]

1.2.2.1 Acid Pit. The acid pit was excavated to the top of the basalt layer, then backfilled with 1 to 2 ft (.3 to .6 m) of soil. A soil cover was applied periodically over the waste. Records indicate this area was an open pit from 1954 to 1961, but the pit is believed to have been used for disposal by RWMC operations as late as the early 1970s. Closure of the pit included a final soil cover a few meters deep with an overlying vegetated layer.[1]

1.2.2.2 Soil Vaults. Beginning in 1977, areas not suited for pits were set aside for drilling soil vaults. This practice not only helped to conserve SDA space, but also reduced personnel exposure to radiation. High-radiation (greater than 500 mR/hr) beta-gamma waste is deposited in soil vaults. Rows of these vaults are drilled along predetermined centerlines, with each vault separated from previously buried waste by approximately 2 ft (0.6 m). Soil vault diameters vary from 1.3 ft to 6.6 ft (0.4 to 2 m); with a minimum depth of 6.6 ft (2 m). If the drilling has penetrated basalt, 2 ft (0.6 m) of soil was placed on the vault floor. Open soil vaults are surrounded by barriers denoting the hazard.[2]

1.2.2.3 Low-level Pits and Trenches. This excerpt from reference 2 describes the first use of pits and trenches at the SDA for waste storage.

> Excavation of pits began in 1957 to accommodate large, bulky items being shipped from Rocky Flats. Trenches were used for disposal of the Mixed Fission Product (MFP) waste; but MFP waste too bulky to fit into the trenches was also placed in pits.

Pits and trenches in the SDA were constructed by scraping the surficial sediments off until basalt was exposed. It is unclear whether a shallow soil layer was left in the bottom of the pits and trenches. Some reports state that at least 1 ft (.3 m) of soil was left. The surface of the basalt is very irregular, and the depth of the surficial sediments beneath the waste is estimated to be from 9 to 15 ft (2.7 to 4.6 m). In general, the pits were excavated to bedrock, which was then usually covered with 2 ft (.6 m) of dirt, although some waste is believed to lay directly on basalt. After the waste was emplaced, the pits were backfilled with at least 3 ft (.9 m) of soil. During operations, soil cover was applied over the waste during weekly or daily operations, depending on the procedures for that particular year. Closure of a filled pit included applying final soil cover a few yards deep and planting stabilizing vegetation.[2]

> Routine, low-radiation-level, solid waste, emitting less than 500 mR/hr, was to be boxed in cardboard cartons, placed in Dempster Dumpsters [6 x 6 x 7-ft (1.83 x 1.83 x 2.13 m) carbon steel containers for waste transfer and dumping], transferred to the Burial Ground, and dumped into trenches. Routine disposal was limited to a 9.4 x 9.4 x 19.0 ft (3 x 3 x 6.1 m) bulk of < 20,000 lbm (9 metric tons). Trenches were to be excavated 4.7 ft (1.5 m) wide, at least 2.8 ft (0.9 m) deep on 15.3 ft (4.9 m) centers. Trenches were to be backfilled such that radiation 2.8 ft (0.9 m) from the surface was less than 1 mR/hr. Partly filled trenches were barricaded at the 60 mR/hr point to limit access and control radiation exposure. After each trench or pit was filled and backfilled with a least 2.8 ft (0.9 m) of dirt, the location was permanently marked with a concrete monument.[2]

1.2.3 Nature and Extent of Contamination

The SDA also contains numerous forms of waste. The waste stored in the SDA includes (but is not limited to) construction equipment and materials (such as lumber, fuse boxes, insulation, etc.); laboratory equipment and materials (such as hoods, glassware, solutions stabilized in concrete or plaster, etc.); process equipment (such as tanks, organic wastes, HEPA filters, etc.); maintenance equipment (such as hand tools, cranes, welders, etc.); decontamination materials (such as rags, floor sweepings, steel wool, etc.); and miscellaneous materials (such as sewer sludge, animal remains, jet engines, vehicles, Test Reactor Area fuel, etc.).[3]

Based on waste characterization studies, soil gas, ground water, and well vapor measurements performed at the SDA, carbon tetrachloride, trichloroethylene, 1,1,1-trichloroethane, chloroform, and tetrachloroethylene were determined to be the VOCs of primary concern. VOCs of concern appearing at lower concentrations at the SDA are 1,1,2-trichlorotrifluoroethane, 1,1-dichloroethane, 1,1-dichloroethylene, dichlorodifluoromethane, and toluene. All of these compounds except toluene are chlorinated hydrocarbons that are relatively resistent to microbial degradation.[1]

The radionuclides of concern include isotopes detected in previous studies of surface and subsurface soil as well as isotopes on the ERP Target List of radionuclides, which is based on past operations and disposal records at the INEL. The radionuclides detected in various transport media at the SDA are strontium-90, americium-241, europium-254, cesium-137, plutonium-238, plutonium-239, cobalt-60, and tritium. Most of these radionuclides were detected in the surficial sediments and interbed soils.[4]

Inorganic compounds that have been detected in the interbed soils are arsenic, barium, beryllium, cadmium, chromium, cobalt, lead, nickel, selenium, silver, thallium, zinc, cyanide, and tin. Mercury has also been detected in borehole vapors.[4]

1.2.3.1 Acid Pit. The acid pit contains an estimated 6000 gal (22,500 L) of organic-, inorganic-, and radioactively-contaminated wastes. Accurate disposal records that identify the source and composition of the waste are limited. However, INEL-generated waste is believed to have been the major source. Personal interviews and record searches indicate that the disposed liquids included carbon tetrachloride, organic solvents (trichloroethylene, trichloroethane, and tetrachloroethylene), radiologically-contaminated acids, and cleaning solutions, some of which were disposed directly into the pit. An RWMC employee during the 1965 period of disposal recalled the practice of releasing 500-gal (1893 L) tanks of contaminated solvents directly into the pit, as well as bimonthly releases of 500-gal (1893 L) carbon tetrachloride tanks over a 5-year period.[1]

Radiologically-contaminated wastes disposed of in the acid pit are believed to contain typical low-level radioactive waste nuclides (e.g., ^{90}Sr, ^{137}Cs, ^{60}Co). Uranium and TRU radionuclides are considered to be present in small quantities.[1]

The estimated composition of waste buried in the acid pit compiled from waste disposal records is as follows: HNO_3, U-Al alloy in HCl, concentrated H_2SO_4, diatomaceous earth, $Al_2(SO_4)_3$, washwater with fission products, normal U solution, sodium hypochlorite, "chemical waste," normal U in acid, normal U in basic aqueous solution, U in chloroform, ethyl alcohol, tributyl phosphate in amsco, dithizone in chloroform, acetone-tributyl phosphate in amsco, dithizone in chloroform, acetone-thiocynate mixture, U in mix of acetone-thiocynate, tributyl phosphate-kerosene with HNO_3 and U, caustic waste, $Cu(NO_3)_2$, $Al(NO_3)_3$, Na, NO_3, $Hg(NO_3)$, anhydrous hydrazine, calcium sulfate, Zr, F^-, H^+, Al, Cr^{3+}, Hg^{2+}, Al^{3+}, HF, NH_4, NaOH, UO_3 slurry, organic waste, tin nitrates, chlorides, RaLa waste, Ba, Sr, penta-ether, hexane, Cr, acid, miscellaneous laboratory samples and waste (may contain H^+, CN^-, SCN^-, iron cyanide complex, Ba^{2+}, K^+, Cs^+, NO_3^-, Cl^-, ClO_4^-), UNH_7NaBr, $NaCr_2O_7$, $NaAlO_2$, UAl_5, mixed acid and base salts, depleted U, $Fe(OH)_3$, organic salvage, Be, CCl_4, oxine, U-Zr alloy in HF-HNO_3 mix, $Zr_3(Al_6)_4$, H_3AlF_6, CO, and NaCN.[4]

Quantities and disposal dates differ for each individual contaminant. The disposal dates for these contaminants range from April 2, 1954 to January 19, 1970. Quantities of contaminants disposed of in the acid pit range from 1 to 22,162 gallons (3.8 to 83,892 L) and from .15 to 196 lbm (70 g to 89 kg).[4]

1.2.3.2 Soil Vaults. The waste deposited of in the soil vaults is classified as high radiation (greater than 500 mR/hr) beta-gamma waste.[2] Typically the waste was placed in steel containers 4 ft in diameter and 8 ft in height.[a] The waste deposited of in the soil vaults includes, but is not limited to, the following: hot cell and decon cell waste, metal assemblies,

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a. Private communication between Dale Wells, EG&G Idaho, and Robert Piper, EG&G Idaho, July 1991.

combustible waste, water pit scrap, core subassembly parts, and unknown waste.[a]

1.2.3.3 Low-level Pits and Trenches. The pits classified as low-level were used for routine, solid, low-level, beta-gamma contaminated waste with dose rates below 500 mR/hr at approximately 3 ft (0.9 m).[2]

1.2.4 Environmental Description

The environment is a major factor to be considered in any remediation effort. This section gives an overview on the environment at the RWMC. Section 1.2.4.1 discusses the climate and meteorology; Section 1.2.4.2 addresses the geology; Section 1.2.4.3 examines the hydrology; and Section 1.2.4.4 reviews the ecology.

1.2.4.1 Climate and Meteorology. The upper Snake River Plain is characterized as a cold, high desert. It is a region of relatively hot summers and cold winters. The mean annual temperature is 44°F (7°C). Temperature extremes range from -40°F (-40°C) in January to 100°F (38°C) in July. Average annual precipitation for the area is 9.8 in. (24.8 cm), with 2 in. (5 cm) of that total falling as snow between November and the end of March. The surrounding mountains cause a prevailing southwest to northeast wind pattern for the area. In the summer, relative humidity, increased by irrigation, reaches a maximum just before sunrise and minimum late in the afternoon. This humidity is contingent upon ambient temperature lows and highs.[5]

1.2.4.2 Geology. The surface of the Snake River Plain is covered by waterborne and windborne topsoil. The soils are derived from silicic volcanics and eroded Paleozoic rocks of the surrounding mountains.[5]

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a. Debbie L. Litter letter to Robert B. Piper, DLL-86-91, *Transmittal of Soil Vault Special Data Request Results*, July 18, 1991.

Underlying the plain are composite layers of interbedded volcanic and sedimentary rocks, principally basaltic lava with interflow beds of sedimentary materials. Those layers partly fill a basin of older sedimentary and volcanic rocks. The older rocks underlie all of the plain at a minimum depth of 5000 ft (1.5 km).[5]

The Snake River Plain is surrounded by the Intermountain Seismic Belt, which is a zone of intensive earthquake activity. However, both microseismic evidence and the absence of known faults indicate the plain is presently aseismic. Southeast Idaho (including INEL) was classified as Seismic Zone No. 2 by the International Conference of Building Officials on October 8, 1981.[5]

1.2.4.3 Hydrology. Surface water at the INEL comes from streams draining through intermountain valleys to the west and north, localized snow melt, and rain. Water from the Big Lost River, Little Lost River, and Birch Creek all enter the INEL. Flows from these sources are diverted for irrigation purposes upstream of the INEL, especially during very dry years, thereby eliminating any water from reaching the INEL. Most surface outflows are a result of localized runoff.[5]

Throughout the year (typically during winter and spring), the Big Lost River may flow onto the INEL. Except for evaporation losses, all water from the Big Lost River on the INEL is recharged to the perched groundwater beneath the river and into the Snake River Plain aquifer.[5]

The Snake River Plain aquifer is estimated to be a continuous body of groundwater that underlies nearly all of the Eastern Snake River Plain. Approximately 200 miles (320 km) long and 20 to 60 miles (32 to 97 km) wide, it comprises an area of about 9700 square miles (25,000 km^2). The depth to the aquifer at the INEL varies from 200 ft (61 m) in the northeast corner to 900 ft (270 m) in the southeast corner. The aquifer may contain 2.5×10^9 acre-ft (3.1×10^{12} m^3) of water. It discharges about 6.5×10^6 acre-ft (8×10^9 m^3) annually through springs in the Hagerman area, through springs upstream from the American Falls Reservoir, and through irrigation-well withdrawals. Discharges from the spring make a significant contribution to the flow of the Snake River downstream from Twin Falls, Idaho.[5]

1.2.4.4 Ecology. The INEL has been designated as a sagebrush ecosystem, comprised of shrubs, primarily belonging to the genus *Artemisia*, and an understory of perennial grasses and forbs. The dominant species (covering approximately 80% of the area) is big sagebrush (*Artemisia tridentata*). Other shrubs, including green rabbit-brush (*Chrysothamnus viscidiflorus*), also are common in some areas. Understory grasses include bluebunch wheatgrass (*Agropyron spicatum*), thickspike wheatgrass (*Agropyron dasystachyum*), squirreltail (*Sitanion hystrix*), needle-and-thread grass (*Stipa comata*), and Indian ricegrass (*Oryzopsis hymenoides*). At some areas on the INEL, the sagebrush was removed by disc and the area reseeded with crested wheatgrass (*Agropyron cristatum*).[5]

The sagebrush ecosystem supports a diverse wildlife population including a variety of invertebrates, amphibians, reptiles, birds, and mammals. Lists of commonly occurring animal species have been compiled by the Radiological and Environmental Sciences Laboratory of DOE-ID and are summarized in the INEL Characterization Report.[5]

While no endangered animal species reside at the INEL, bald eagles may winter on or migrate over the area, but are not known to nest or breed in the vicinity of INEL. A sighting of a peregrine falcon was reported at the INEL in 1975, and other sightings have been reported in areas near the INEL.[5] Game animals that reside on the INEL include the pronghorn, mule deer, elk, mountain lions, sage grouse, and ring-necked pheasant. Other animals that reside on the INEL include bobcats and coyotes.

2. IDENTIFICATION AND SCREENING OF TECHNOLOGIES

2.1 Introduction

The purpose of this section is to summarize various in situ technologies and to describe the process used to determine the applicability of the technologies for remediating buried waste at the RWMC. Section 2.2 discusses the technology identification procedure. Section 2.3 addresses the screening procedures, the criteria and rating system used, and the evaluation of the technologies. Section 2.4 gives an overview of some in situ technology delivery and recovery systems. Finally, Section 2.5 gives an overview of other projects ISTE personnel have reviewed for information pertaining to in situ treatments.

2.2 Candidate Technology Identification Procedure

Much of the information on in situ treatment technologies in this report was obtained from vendors and universities. Solicitations for remedial technologies were placed in the January 25 and April 5, 1991 issues of *Commerce Business Daily* (see Appendix A), and this information was screened for applicability to the ISTE buried waste project. EG&G documented their claims in this report without any comment as to effectiveness. Responding companies or universities who did not have an in situ treatment technology applicable to buried waste were eliminated from consideration. Summaries of the pertinent vendor information can be found in Appendix B (for those companies that responded to the CBD solicitation). The complete information supplied by these vendors and universities is contained in the ISTE project file.

Other sources of technologies and vendors include the Remedial Technology Information System (RTIS) and various EPA documents. A copy of information obtained from RTIS is on file and a list of referenced EPA documents are included in Section 6.

The following sections contain brief descriptions of the technologies identified, their applications, and lists of vendors for each technology.

2.2.1 Biological Treatments

2.2.1.1 Description. Biological treatments utilize the natural activity of microorganisms (primarily bacteria, actinomycetes, or fungi) to remediate polluted soils and groundwater.[6] While biological treatments require a longer period for remediation than other treatment alternatives, they have the potential to completely destroy organic contaminants.

2.2.1.2 Bioremediation.

Description--The bioremediation process utilizes the natural activity of microorganisms to decontaminate soils and groundwater polluted with organics.[6] Effective microorganisms are often found in small quantities at the contaminated site and, through nutrient enrichment, can be multiplied and encouraged to accelerate the natural degradation process. If the proper organisms are not already present, they may be introduced.[a,b,c,d,e,f,g,h]

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a. Private communication between Carol Wilson, H_2O Chemists, Inc., Gilbert, Arizona, and Stephanie Walker, EG&G Idaho, Inc., May 1991.

b. Private communication between Scott C. Manatt, Allied-Signal Aerospace Corporation, AiResearch Division, and David E. Shropshire, EG&G Idaho, Inc. (response to EG&G's January 25, 1991 CBD solicitations), April 1991.

c. Private communication between A. W. (Bill) Ferris, Allied-Signal Aerospace Corporation, AiResearch Division, and Reva A. Hyde, EG&G Idaho, Inc. (response to EG&G's April 5, 1991 CBD solicitations), April 1991.

d. Private communication between Dr. Susan Fuhs, Allied-Signal Aerospace Corporation, AiResearch Division, Torrence, California and Stephanie Walker, EG&G Idaho, Inc., April 1991.

e. Private communication between Kurt M. Shewfelt, Allied-Signal Aerospace Corporation, AiResearch Division, Torrence, California, and Stephanie Walker, EG&G Idaho, Inc., April 1991.

Applications--Bioremediation can be applied to chlorinated solvents and non-chlorinated organic contaminated water, soil, sludge, sediment, and other types of materials.[7]

Vendor(s)--The following vendors have been identified as suppliers of bioremedial services:

- A & V Incorporated
- Allied-Signal Aerospace
- Bioscience Management, Inc.
- C-E Environmental, Inc.
- C-EE Bioremediation Systems
- Celgene
- Certified Environmental Consulting, Inc.
- Detox, Inc.
- Ebasco
- ECOVA Corp.
- Ensotech, Inc.
- ENSR
- Environmental Remediation, Inc.
- Environmental Science and Engineering, Inc.
- Environmental Technology Southeast
- Envirotech Mid-Atlantic
- General Physics Corp.
- Groundwater & Environmental Service

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f. Private communication between Dr. George Pierce, Celgene Corporation, and David E. Shropshire, EG&G Idaho, Inc. (response to EG&G's January 25, 1991 CBD solicitation), February 1991.

g. Private communications between Dr. George Pierce, Celgene Corporation, Warren, New Jersey, and Stephanie Walker, EG&G Idaho, Inc., April 1991.

h. Private communication between Joseph S. Staska, Certified Environmental Consulting, Inc., Benicia, California, and Stephanie Walker, EG&G Idaho, Inc., April 1991.

- Harding Lawson Associates
- Hayward Baker
- Hunter Biosciences, Inc.
- H20 Chemists, Inc.
- International Process Research Corp.
- In-Situ Fixation Co.
- Keystone Environmental Resources
- O'Brien and Gere Engineers, Inc.
- OHM Corp.
- Polybac Corp.
- Remediation Technologies
- RMT, Inc.
- Roy F. Weston, Inc.
- Southern Research Institute
- Spelman College, Department of Biology
- Sybron Chemicals, Inc.
- Thorne Environmental, Inc.
- Waste Stream Technology, Inc.
- Western Research Institute
- Woodward Clyde Consultants.

2.2.1.3 Bioaccumulation.

Description--Biological techniques can also result in the precipitation and immobilization of metals. Metals such as Fe, Cu, Zn, and Pb can react with hydrogen sulfide produced by anaerobic microbial activity and form insoluble metal sulfides. Although the toxicity and volume of the metals will not be changed, insoluble metal sulfides will not dissolve and therefore the possibility of their migration will be significantly reduced.[a,b]

Applications--Bioaccumulation has been applied to metal-contaminated soils, groundwater, and surface water.

Vendor(s)--The following vendor has been identified as supplying bioaccumulation services:

- Allied-Signal Aerospace Co.

2.2.1.4 Dual Auger System.

Description--The technology utilizes a dual auger system to drill into contaminated soils and inject microorganism mixtures, water, and nutrients.

Applications--This process is applicable to soils contaminated with organics. Soils at depths greater than 100 ft (30.48 m) can be treated.[c]

Vendor(s)--The following vendor has been identified as supplying dual auger services:

- In-Situ Fixation Co.

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a. Private communication between Dr. Susan Fuhs, Allied-Signal Aerospace Corporation, AiResearch Los Angeles Division, Torrence, California, and Stephanie Walker, EG&G Idaho, Inc., April 1991.

b. Private communication between Kurt M. Shewfelt, Allied-Signal Aerospace Corporation, AiResearch Los Angeles Division, Torrence, California, and Stephanie Walker, EG&G Idaho, Inc., April 1991.

c. Permanent In-Situ Treatment of Toxic Wastes, In-Situ Fixation Company, Chandler, Arizona, date unknown.

2.2.2 Containment

2.2.2.1 Description. Containment is a technology that is used to reduce the mobility of contaminants. Containment can be used in conjunction with other in situ technologies to assist in the remediation of the site, or it can be used to control the migration of the contaminants until an appropriate remediation technology is selected. However, it is does not treat or reduce the toxicity of contaminants.

Applications--Containment can be used to completely enclose a hazardous waste site to prevent the migration of the contaminants. It can be used in conjunction with other remediation technologies to help increase the efficiency of the remediation process. Also, containment can be used as a temporary solution until a permanent method of remediation is developed or selected. Containment barriers usually are in the form of walls, floors, and caps composed of various types of materials. Possible configurations for a containment can be seen in Figure 1.

Vendor(s)--The following vendors have been identified as supplying containment services:

- AWD Technologies
- Chapman, Inc.
- Environmental Science and Engineering, Inc.
- Groundwater Control Environmental Services
- Harding Lawson Associates
- Hart Crowser
- International Technology Corp.
- Kuss Environmental Liners
- Weston Services.

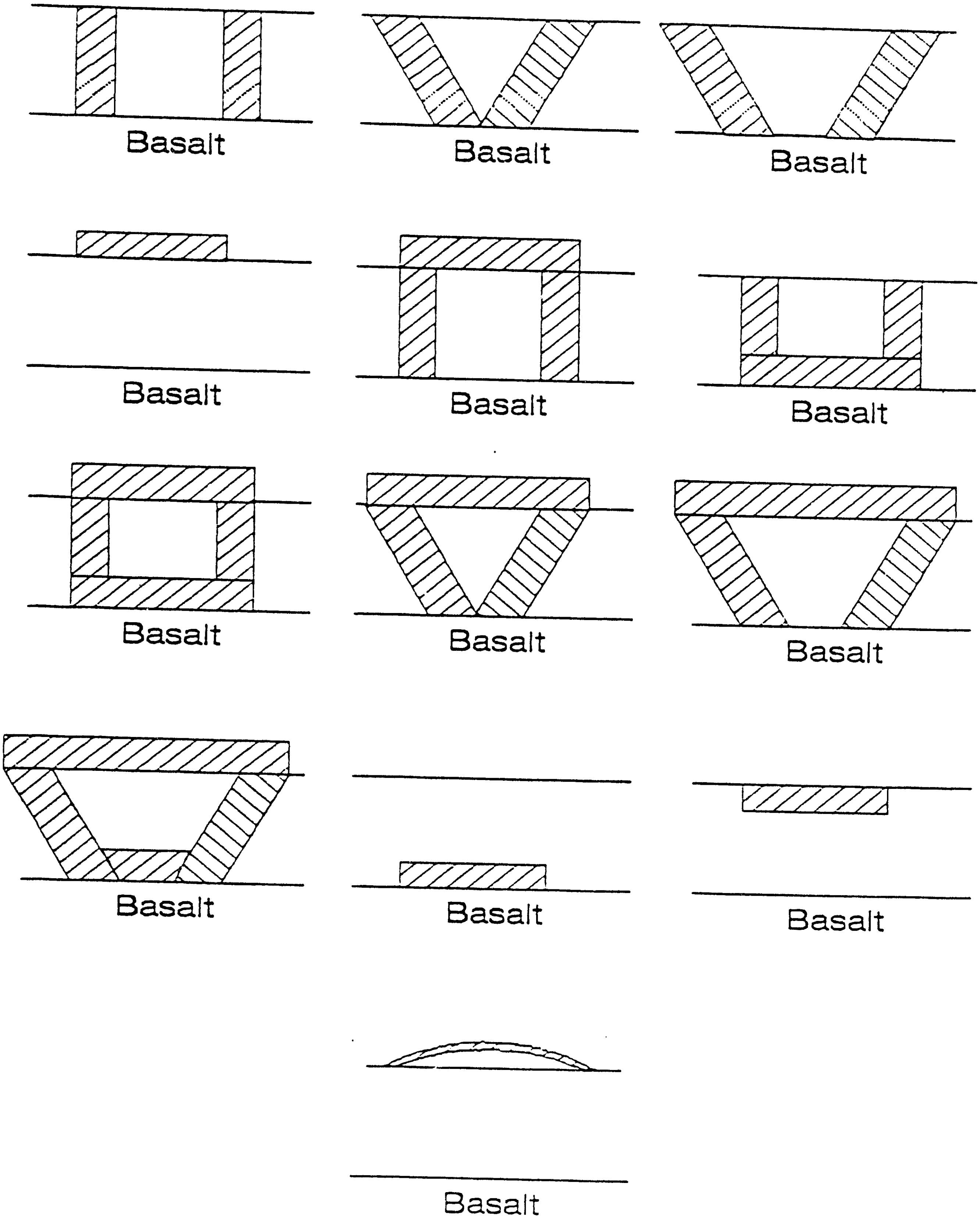

Figure 1. Possible Site Containment Configuration.

2.2.2.2 Bottom Sealing.

Description--Using a horizontal or directional drilling method, bottom sealing involves the use of grout injection techniques to place horizontal or curved barriers beneath a hazardous waste site to prevent downward migration of contaminants. Once in place, the barrier acts as a floor and seals the bottom of the waste site. One technique, jet grouting, consists of drilling a pattern of holes across the site to the desired barrier depth. A special jet nozzle is lowered into the holes, and a high-pressure stream of air and water from the jet erodes the soil. By turning the nozzle through a complete rotation, a flat, circular cavity is formed. The cavity is then grouted, and the barrier is formed by intersecting grout masses.[8]

Applications--This technology has possible applications in all soils, including silts, clays, and weak rocks. It can be used with most contaminants including inorganics, organics, metals, mixed, high-level, low-level, and TRU waste. This technology only serves as a containment application. It does not treat or destroy the contaminants. It can be used with other containment methods and in situ technologies to provide complete migration control. It is used in soils that are contaminated with liquid waste that have the potential of migrating downward.[8]

Vendor(s)--The following vendors have been identified as supplying bottom sealing services:

- Geo-Con, Inc.
- Hayward Baker Environmental
- Halliburton Environmental Technologies, Inc.
- Nuclear Remediation Technologies Corp. (NRT)
- Pressure Grout Co.
- Rockwell Hanford Operations
- W. G. Jaques Co.
- Westinghouse Hanford Co.

2.2.2.3 Capping.

Description--The capping process is used to cover buried waste materials to prevent their contact with the land surface and groundwater. Usually, the cap design conforms to the performance standard in 40 CFR 264.310, which addresses Resource Conservation and Recovery Act (RCRA) landfill closure requirements. In instances where the cap is intended to be temporary, where there is very low precipitation, and when the capped waste is not leached by infiltrating rainwater, the above performance standards may not always be appropriate.[9]

Cap designs and capping materials available vary. Most cap designs are multi-layered to conform with design standards. However, single-layered designs are also used for special purposes. Selecting capping materials and a cap design is influenced by materials, desired functions of cover materials, the nature of the wastes being covered, local climate, hydrogeology, and projected future use of the site in question.[9]

Applications--Capping is required whenever contaminated materials are to be buried or left in place at a site. Generally, capping is performed when extensive subsurface contamination at a site prevents excavation and removal of the wastes due to potential hazards and/or unrealistic costs.[9] Capping may be used for water, liquids other than water, gas, and/or soil contaminated with organics, inorganics, metals, and/or radionuclides.[8]

Vendor(s)--The following vendors have been identified as supplying capping services:

- American Colloid
- AWD Technologies
- Geo-Con, Inc.
- Gundle Lining Systems, Inc.
- Hayward Baker, Inc.
- National Seal Co.
- Poly-Flex, Inc.

- SAIC
- Seaman Corp.
- STAFF Industries, Inc.
- Stevens JPS Elastomerics Corp.

2.2.2.4 Polymer Concrete Barrier.

Description--This containment technology uses high strength, impervious polymer concrete to create an in situ barrier. Contaminants are not destroyed or treated; but simply contained. Sealant materials are used that consolidate an earth/sand/gravel matrix into a high strength, impervious polymer concrete useful for the formation of barriers in the earth. These materials have very good chemical resistance and are typically two or three times stronger than structural concrete. Permanently installed monitors such as pH sensors and radiation detectors installed around the exterior of the perimeter of the site can be used to ensure that there is no movement of the waste beyond the barrier.[a]

Applications--This technology is effective for the containment of most contaminated waste. Residual risk from the untreated waste is greatly reduced once contained within a perimeter barrier with a sealant cap over the top (may also be composed of polymer concrete). This containment barrier could be used in conjunction with other in situ technologies.[a]

Vendor(s)--The following vendor has been identified as supplying concrete barrier services:

- 3M Corp.

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a. Private communication between Jack F. Evert, 3M Corporation, and Mathew W. Roy, EG&G Idaho, Inc. April 1991.

2.2.2.5 Cryogenic Barrier.

Description--Cryogenic barriers are a containment technology. The technology involves installing freezing pipes around the circumference of a contaminated site. Refrigerant is pumped down the outside pipe and returned through the inner pipe. The double wall design allows the entire volume between walls [40 to 50 ft (12.2 to 15.2 m) thick] to freeze, thus containing the site. If necessary, another in situ treatment could then be applied with little risk of contaminant migration. This technology is reversible.[a]

Applications--This technology can be used to isolate or contain all contaminant types and can be used on all media states in which freeze pipes can be installed. It appears to be more cost effective to use this technology for temporary rather than permanent containment because of the high operational costs. Under certain circumstances, containment for a relatively short period of time is sufficient in itself. For example, containment may be used when awaiting the development of an appropriate technology, while still preventing the contaminant volume from growing into a catastrophic cleanup problem. Often, containment may be used to assist another technology while it is being applied. Cryogenic barriers are compatible with most other in situ technologies.[b,c]

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a. Private communication between Roland K. Krieg, Concept RKK, Ltd., and Mathew W. Roy, EG&G Idaho, Inc., (response to EG&G's January 25, 1991 CBD notice), February 1, 1991.

b. Private communication between Roland K. Krieg, Concept RKK, Ltd., and Mathew W. Roy, EG&G, Idaho, Inc., April 1991.

c. Private communication between Roland K. Krieg, Concept RKK, Ltd., and David E. Shropshire, EG&G Idaho, Inc., (response to EG&G's January 25, 1991 CBD notice), February 1, 1991.

Vendor(s)--The following vendors have been identified as supplying cryogenic barrier services:

- Concept RKK, Ltd.
- Freezwall, Inc.
- Nuclear Remediation Technologies Corp. (NRT).

2.2.2.6 Fluidized-Bed Zeolite System.

Description--The system, under development by a Department of Energy Laboratory Contractor, utilizes zeolite and particulate/solution polymer based grouts for in situ stabilization and isolation of radioactive and hazardous chemical waste materials that have been disposed of in, and proximal to, underground waste disposal and containment structures. The fluidized-bed will provide chemical fixation by mechanically homogenizing and incorporating waste tank residuals (tank bottoms and sludges) with granular zeolite (or equivalent) materials. Particulate and solution polymer based materials are then incorporated into the interstitial void volume of the granular zeolite and surrounding geologic media to provide chemical isolation and physical stabilization.[a]

Applications--This system could be used for remediation of subsurface waste storage/disposal structures such as underground storage tanks, cribs, caissons, piping, and buried sites. This technology will produce a physically stable structure, wherein contaminated materials contained within and proximal to disposal structures are anticipated to be isolated from the environment over hundreds to thousands of years. This technology will significantly reduce cost of in-place treatment and accelerate schedules for closure of waste storage/disposal structures.[a]

NOTE: The design of the prototype for the fluidized-bed zeolite system is completed. Westinghouse has the following actions in progress: specification

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a. Private communication between Steve Phillips, Westinghouse Hanford Company, and Thomas W. Garrison, EG&G Idaho, Inc., February 20, 1991.

and procurement of system modules, fabrication of fluidized-bed zeolite system, and formulation testing of zeolite wasteform. In FY-92 and FY-93, field demonstration, testing and evaluation, and technology transfer will be completed.

Vendor(s)--No commercial vendors of this technology are known. Fluidized-Bed Zeolite systems are part of a Department of Energy technology development activity at:

- Westinghouse Hanford Co.

2.2.2.7 Plasma Arc Glass Cap.

Description--This technology uses a plasma torch to generate a high heat flux in the vicinity of the disposal site surface. This vitrifies the surface soil which will create an impermeable glass cap. Depending on how the torch is operated, the cap may be anywhere from 1-6 in. (2.54 to 15.24 cm) deep.[a,b]

Applications--This is a containment technology. The mobility of the toxic contaminants will be greatly reduced by placing an impermeable glass cap over the site. Moisture from rain and snow melt will be shielded from the waste, eliminating leaching and resulting downward migration of the contaminants. Contaminants will be constrained from migrating upward. This technology can be used with all contaminants and soils that can be vitrified.[a,b]

Vendor(s)--The following vendor has been identified as supplying plasma arc glass cap services:

- Science Applications International Corp. (SAIC).

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a. Private communication between Ray Geimer, SAIC, and David E. Shropshire, EG&G Idaho, Inc. (response to EG&G's January 25, 1991 CBD solicitation), February 4, 1991.

b. Private communication between Ray Geimer, SAIC, and Mathew W. Roy, EG&G Idaho, Inc., April 8, 1991.

2.2.2.8 Slurry Wall.

Description--Slurry walls are subsurface barriers that are used to reduce groundwater flow in unconsolidated earth materials. Slurry wall construction involves excavating a narrow vertical trench through pervious soils, and then backfilling the trench with an engineered material. The backfill material is usually a mixture of soil and bentonite or cement and bentonite. The cement-bentonite slurry initially provides trench support (also prevents high fluid losses to the surrounding soil) and then sets to form an impervious barrier. Some slurry walls also use geomembrane liners to help prevent the migration of contaminants.[8,10]

Applications--This is a containment technology. Slurry walls can be used to contain most contaminants with a few exceptions. Soil-bentonite slurry walls are not suitable for leachate or contaminated groundwater containing strong acids/bases and alcohols. Also, cement-bentonite slurry walls are not applicable for wastes or leachates containing chlorinated hydrocarbons, organic acids, or acid chlorides. Barrier walls are not totally impermeable to water and can only inhibit the spread of contaminants. Soil-bentonite walls have the lowest installation cost, the widest range of chemical compatibilities, and the lowest permeabilities, however, they are the most prone to failure of all slurry containment options. Cement-bentonite slurry walls provide better trench support because of the inherent cohesive quality of the cement.[8]

Vendor(s)--The following vendors have been identified as supplying slurry wall services:

- Nuclear Remediation Technologies Corp. (NRT)
- Hayward Baker Environmental
- Geo-Con, Inc.
- American Colloid Co.
- Bencor Corporation of America
- Case International Co.
- International Minerals and Chemical Corp.
- Moretrench American Corp.

- Mueser, Rutledge, Johnson, and Desimone
- Raymond International Builders, Inc.
- Thatcher Engineering Corp.

2.2.2.9 Soil/Cement Wall.

Description--The soil/cement wall technology involves fixation, stabilization, and solidification of contaminated soils. Solidification/stabilization agents are blended in situ with the contaminated soils by a multi-axis overlapping hollow stem auger. The product is a monolithic block that extends down to the treatment depth. The system capacity for treating soils up to 100 ft (30.48 m) depth is 11 to 17 yd^3/hr (8.4 to 13 m^3/hr).[7]

Applications--This technology is effective on soils that are contaminated with metals and semi-volatile organic compounds. This technology has been used on various construction applications, including soil stabilization and cutoff walls.[7]

Vendor(s)--The following vendors have been identified as supplying soil/cement wall services:

- S.M.W. Seiko, Inc.
- Halliburton Environmental Technologies, Inc.

2.2.2.10 Vitrified Barriers.

Description--In situ vitrification is a thermal treatment technology in which a region of soil volume is melted. This process can also be used to produce vitrified barriers. Upon cooling, the resulting product is a glass and crystalline monolith resembling natural obsidian. The process involves creating a barrier by inserting electrodes in the ground and placing a conductive starter path between them. Soil is melted when an electric potential is applied to the electrodes causing the starter path to heat up above the melting point of the soil. Vitrified walls and floors can be joined as needed to isolate waste sites from transport mechanisms or to totally contain them, if necessary (e.g., for additional in situ treatment). The vitrified soil barrier is extremely leach resistant and possesses about ten times the strength of unreinforced concrete. It is predicted stable over geologic periods of time.[a] It also results in significant volume reduction because no additives are required and the soil is densified in the melting process.

Applications--This technology can be used to isolate or contain all contaminant types and can be used on all media states. It can be used to permanently contain a waste site or to temporarily contain a waste site while another method of in situ remediation is applied.[a]

In the presence of acids and salts, there is one concern that must be addressed with ISV technologies. Acids and salts can cause the soil to have an abnormally high electrical conductivity (hence, a low electrical resistance), which is generally more pronounced as the moisture content of the soil increases. This low resistance will require the application of more electrical energy to the treatment area in order to achieve a vitrified melt. This will also probably result in a much higher melt temperature.

Vendor(s)--The following vendor has been identified as supplying vitrified barrier services:

- Battelle, Pacific Northwest Laboratories.
- Geosafe, Inc.

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a. Private communication between Steven Slate, Battelle Pacific Northwest Laboratories, and Monica Patterson, EG&G Idaho, Inc., March 25, 1991.

2.2.3 Physical/Chemical Treatment

2.2.3.1 Description. Physical/chemical treatment involves physical (heat, freezing, etc.) and/or chemical manipulation of a waste site in order to reduce the toxicity or volume of the waste.

Applications--In situ physical/chemical treatment can be used on soils, sludges, slurries, gases, sediments, and water. Contaminants may include metals, organics, radioactive contaminants, inorganics, acids, or bases.

2.2.3.2 Dechlorination.

Description--Dechlorination displaces chlorine from chlorinated organic compounds. This process is based on the affinity of alkali metals for chlorine. Polyethylene glycol and some hazardous chemicals can be used as catalysts for the reaction. The reagent reacts with the chlorinated organic by displacing a chlorine molecule. This chlorine displacement produces a lower toxicity, water soluble material. The reagent can be recovered and recycled after the reaction is complete. For in situ dechlorination, the mixture is typically heated by radio frequency heating or microwave heating to reduce the viscosity of the reagent.[8]

Applications--In situ dechlorination should be used for uniform, shallow, soil-contaminated areas. Conventional agricultural equipment is used to mix the soil and the reagent. If the contaminated soil is deeper than 1 to 2 ft (.3 to .61 m), or if high concentrations are apparent, the soil should be excavated and dechlorinated after it is made into a slurry.

Alkali metal dechlorination is used on contaminated oils and liquid wastes to displace chlorine from chlorinated organic compounds such as polychlorinated biphenyls (PCBs) and dioxins.[8]

Vendor(s)--The following vendors have been identified as supplying dechlorination services:

- Accurex
- Chemical Waste Management
- Galson Research Corp.
- PPM.

2.2.3.3 DETOXIFIER™.

Description--The DETOXIFIER™ is a mobile, thermal-mechanical process that detoxifies organic and inorganic contaminated waste sites to a depth of 30 ft (9.14 m) In Situ. Organic compounds are volatilized and inorganic compounds are chemically stabilized and rendered insoluble. The proposed remediation techniques involve: the treatment and removal of volatile organic compounds (VOCs); precipitation of nonvolatile compounds and certain radionuclides; and the pozzolonic cementing encapsulation of the remaining radionuclides into a non-permeable matrix.[a]

Applications--This technology is applicable for radioactive and mixed waste sites, whereby hazardous chemicals are removed or stabilized In Situ and radioactive contaminants are solidified. Based upon previous field remediation actions on hazardous waste sites, hazardous compounds (VOCs) removal rates exceed 96%. Inorganic insoluble levels after precipitation and treatment exceeded the current Toxicity Characteristic Leaching Procedure (TCLP) requirements.[a]

Vendor(s)--The following vendors have been identified as supplying DETOXIFIER™ services:

- KLM Technologies.

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a. KLM Technologies, Inc., *An Introduction to the DETOXIFIER™ In Situ Remediation Technology*, as submitted to EG&G Idaho, Inc., Attn: Mr. Robert Piper, May 1991.

2.2.3.4 Electroacoustics.

Description--Electroacoustic decontamination is used to remediate soils by applying electrical and acoustical fields. The electrical field is used to transport liquids through soils. The acoustic field can enhance the dewatering or leaching of waste such as sludges.[8]

Applications--Electroacoustic decontamination is effective on soils contaminated by inorganic, organic, and/or heavy metal liquids. The process may be effective in alleviating recovery well clogging if it succeeds in clearing the contaminated particles that plug the pores and interstitial spaces around the recovery well.[8] Because this technology depends on surface charge to be effective, fine-grained clay soils are an ideal medium for application.[7]

Vendor(s)--The following vendor has been identified as supplying electroacoustic services:

- Battelle Memorial Institute (EPA SITE program).

2.2.3.5 Electrokinetics.

Description--Electrokinetic soil processing uses electricity to remove/separate organic and inorganic contaminants and radionuclides from the soil. A low direct current is run between an anode and a cathode inserted in a soil mass saturated with deionized water. This results in an acid front at the anode and a base front at the cathode. The acid front advances toward the cathode and eventually flushes across the specimen and neutralizes the base. The movement of the front results in desorption of contaminants from the soil. The concurrent mobility of the ions and the advection of pore fluid under the electrical gradients supplies the method to flush contaminants from the soil.[a,b,c,d,e,f] (See also references 11-16.)

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a. Private communication between John F. Gibbons, Applied Research Associates, Inc. and David E. Shropshire, EG&G Idaho, Inc. (response to EG&G's CBD January 25, 1991 solicitation), February 1991.

Applications--This process is an in situ separation/removal technique for extracting heavy metals and/or organic contaminants from soils and sediments.

Vendor(s)--The following vendors have been identified as supplying electrokinetic services:

- Applied Research Associates, Inc.
- Electrokinetics, Inc., Louisiana State University (LSU)
- Electro-Petroleum, Inc.

2.2.3.6 Neutralization.

Description--The in situ neutralization process is performed by injecting dilute acids or bases into the ground in order to optimize pH for further treatment, or to neutralize plumes that do not require further treatment.

Applications--Neutralization is used on liquids, sludges, slurries, and gases contaminated by acidic or alkaline wastes.[8]

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b. Private communication between Frank A. Maestas, Applied Research Associates, Inc., Albuquerque, New Mexico, and Mathew W. Roy, EG&G Idaho, Inc., April 1991.

c. Private communication between Yalcin B. Acar, Electrokinetics, Inc., and Reva A. Hyde, EG&G Idaho, Inc. (response to EG&G's April 5, 1991 CBD solicitation), May 1991.

d. Private communications between Dr. Robert Gale, Electrokinetics, Inc., and Stephanie Walker, EG&G Idaho, Inc., March-May 1991.

e. Private communication between Yalcin B. Acar, Electrokinetics, Inc., and Stephanie Walker, EG&G Idaho, Inc. (response to EG&G's April 5, 1991 CBD solicitation), May 1991.

f. Private communication between J. Kenneth Wittle, Electro-Petroleum, Inc., and Reva A. Hyde, EG&G Idaho, Inc. (response to EG&G's April 5, 1991 CBD solicitation), April 1991.

Vendor(s)--The following vendors have been identified as supplying neutralization services:

- AAA CSI
- Bioscience Management, Inc.
- C-EE Bioremediation Systems
- Chemenco, Inc.
- Diversified Engineering, Inc.
- Earth Technology Corp.
- EM&C Engineering Associates Earth Technology Corp.
- Ensotech, Inc.
- Environmental Resource Associates
- Environmental Technology Southeast
- Enwright Environmental, Inc.
- Francis A. McLoughlin
- General Physics Corp.
- Harmon Environmental Services, Inc.
- Hayward Baker
- Hunter Services, Inc.
- International Process Research Corp.
- International Technology Corp.
- Maecorp, Inc.
- Marine Pollution Control
- McNamee Advanced Technology, Inc.
- O'Brien and Gere Engineers, Inc.
- OHM Corp.
- River Oak Associates
- RMT, Inc.
- RNK Environmental, Inc.
- Roy F. Weston, Inc.
- Versar, Inc.
- Western Research Institute
- Woodward Clyde Consultants
- YEC, Inc.

2.2.3.7 Oxidation/Reduction.

Description--This process takes advantage of the reactant's oxidation state and chemically transforms it by reduction-oxidation (REDOX). By raising one reactant's oxidation state while lowering the other, the toxicity of many organics and heavy metals can be reduced or destroyed using REDOX reactions. Decreased permeability of soils (due to hydroxide precipitation) or loss of adsorption (due to oxidation/reduction of soil organics) may affect in situ soil treatment. Violent reactions may occur with in situ methods because subsurface injection of reagents and water is required.[8]

Applications--This process can be used In Situ on soils that are contaminated with cyanide, aldehyde, mercaptans, phenols, benzidine, unsaturated acids, pesticides, benzene, organics, arsenic, iron, manganese, chromium VI, mercury, lead, silver, chlorinated organics, or unsaturated hydrocarbons. Oxidation/reduction may also be used ex situ on water, slurries, and sludges.[8]

Vendor(s)--The following vendors have been identified as supplying oxidation/reduction services:

- Andco Environmental Processes
- ATW-Caalweld, Inc.
- Chemical Waste Management
- DETOX, Inc.
- Ensotech, Inc.
- Envirochem Waste Management Services
- Rexnord
- USPCI.

2.2.3.8 Precipitation/Flocculation.

Description--Precipitation is a treatment technique that transforms a substance in solution to a solid phase by physiochemical mechanisms. It involves alteration of the ionic equilibrium to produce insoluble precipitates that can be easily removed by sedimentation or filtration. Typically, flocculating agents are added to cause the precipitate to become agglomerated. The solubility of metal hydroxides and sulfides is greatly affected by pH.[8]

<u>Applications</u>--Precipitation may be used as an in situ process to treat aqueous wastes in surface impoundments. In this type of application, lime and flocculants are added directly to the lagoon and mixing, flocculation, and sedimentation occur within the lagoon. Wind and pumping action can provide the energy for mixing in some cases.[9]

Contaminants that may be affected by this treatment include zinc, cadmium, chromium, copper, lead, manganese, mercury, phosphate, sulfate, fluoride, arsenic, iron, nickel, and organic fatty acids.[8]

<u>Vendor(s)</u>--The following vendors have been identified as supplying precipitation/flocculation services:

- Chemical Waste Management, Inc.
- DETOX, Inc.
- Ecolochem, Inc.
- Engineering-Science, Inc.
- Ensotech, Inc.
- Enviro-Chem Waste Management Services, Inc.
- Rexnord
- Tetra Recovery Systems.

2.2.3.9 <u>Soil Flushing</u>.

<u>Description</u>--Soil flushing is the washing of contaminants from the soil with a suitable solvent such as water or other aqueous or nonaqueous solutions. Soil flushing enables permanent removal of contaminants from the soil and is most effective in permeable soils. The technology can introduce potential toxins into the soil system. An effective collection system is required to prevent contaminant migration.[6]

The use of soil flushing to remove soil contaminants involves the elutriation of inorganic constituents from soil for recovery and treatment. The site is flooded with the appropriate washing solution, and the elutriate is collected in a series of shallow wellpoints or subsurface drains. The elutriate is then treated and/or recycled back into the site. During the elutriation process, contaminants are mobilized into the flushing solution by way of solubilization, formation of emulsions, or a chemical reaction with the flushing solution. Collection of elutriate is required to prevent uncontrolled contaminant migration through uncontaminated soil and into receiver systems, including ground and surface waters.[6]

Flushing solutions may include water, acidic solutions, basic solutions, chelating agents, and surfactants. Water can be used to extract water-soluble or water-mobile constituents. Acidic solutions are used for recovery and for basic organic constituents. Basic solutions are used for recovery of metals, some phenols, complexing and chelating agents, and surfactants. Chelating agents are compounds that bind to metal ions. Chelating agents are used on liquids and soils contaminated by metals. Surfactants alter soil/organic adsorption so organics can be flushed from the soil.[6,9]

Applications--Soil flushing and elutriate recovery may be appropriate in situations where chemical oxidizing or reducing agents are used to degrade waste constituents and results in the production of large amounts of oxygenated, mobile, degradated products. The most conservative and safest approach may be to flush the soil after treatment to recover and possibly to reapply the elutriate in a controlled manner to the soil surface.[6] In situ soil flushing is effective on sludges, soils, sediments, and other solids contaminated with inorganic corrosives, organic corrosives, oxidizers, halogenated nonvolatiles, halogenated volatiles, nonvolatile metals, volatile metals, organic cyanides, inorganic cyanides, nonhalogenated volatiles, nonhalogenated nonvolatiles, PCBs, pesticides, dioxins/furans, oxidizers, and reducers.[17] Chelation is used on liquids and soils contaminated by metals.[8]

Vendor(s)--The following vendors have been identified as supplying soil flushing services:

- Applied Surface Technology
- C-EE Bioremediation Systems
- Cyto Culture Envir. Biotech.
- Detox, Inc.
- Earth Technology Corp.
- E M & C Engineering Associates
- Ensotech, Inc.
- Environmental Technology Southeast
- Envirotech Mid-Atlantic
- Groundwater & Environmental Service
- Hunter Biosciences, Inc.
- International Technology Corp.
- Nuclear Remediation Technologies Corp. (NRT)
- O'Brien and Gere Engineers, Inc.
- OHM Corp.
- Remediation Technologies
- RMT, Inc.
- Roy F. Weston, Inc.
- Sybron Chemicals, Inc.
- Thorne Environmental, Inc.
- Western Research Institute.

2.2.3.10 In Situ Steam/Air Stripping.

Description--Steam/air stripping involves injecting steam or air into the soil beneath a contaminated zone to volatilize and strip organic contaminants. A transportable treatment unit for detoxification is used with this technology and consists of two main components--the process tower and process train. The process tower contains two counter-rotating hollow-stem drills with each drill containing two concentric pipes. The inner pipe is used to convey steam at 450°F (232°C) and 450 psig (3.1×10^6 Pa) to the rotating cutting blades, and the outer pipe conveys air at approximately 300°F (149°C) and 250 psig (1.7×10^6 Pa) to the rotating cutting blades. The air and steam carry the contaminants to the surface where a metal shroud collects the vapors for off-gas treatment and ducts them to the process train for treatment.[6,7,8]

Applications--The in situ steam/air stripping system is effective in reducing the toxicity of soil by removing contaminated organics, such as hydrocarbons and solvents. This system is also commonly used to remove VOCs from ground or surface waters for the purpose of reinjection (for ground water) or discharge. Soil particle size, initial porosity, chemical concentration, and viscosity do not limit the technology. The compound's vapor pressure and polarity are important in determining how effectively this technology will remove the contaminants.[a] (See also references 6-8.)

Vendors--The following vendors supplied information regarding in situ steam/air stripping:

- Toxic Treatments (USA), Inc.
- Nuclear Remediation Technologies Corp. (NRT).

2.2.3.11 Simultaneous Injection, Extraction, and Recharge.

Description--This process involves the remediation of unsaturated soils by injection of a medium to strip and transport contaminants to an extraction well(s). Water and steam are commonly used media. In unsaturated soil, steam will condense at some distance from the injection point and form a diffuse front consisting of a transient saturated zone with soil permeated by condensing steam on one side and relatively cool, unsaturated soil on the other side. This front is a region of radical contrasts in electromagnetic properties. The placement of injection points and extraction wells are designed to allow injection fronts to coalesce and move the contaminant to

a. Private Communication between James R. Allen, Nuclear Remediation Technologies Corporation, and David E. Shropshire, EG&G Idaho, Inc. (response to EG&G's January 25, 1991 CBD Solicitation), February 13, 1991.

strategically located extraction wells. After being transported to the extraction wells, the contaminants would have to be removed and treated.[a]

Applications--This technology removes contaminants that can be mobilized by steam or water from unsaturated soil. Highly soluble or volatile contaminants in transmissive soils will be the best application for this technique, and these contaminants are expected to be removed very rapidly.[b]

Vendor(s)--The following vendor has been identified as supplying simultaneous injection, extraction, and recharge services:

- Applied Research Associates, Inc. (ARA).

2.2.3.12 Vacuum Extraction.

Description--Vacuum extraction systems involve the extraction of contaminants from unsaturated soils through air injection. Clean air is injected into the contaminated soil, and a vacuum apparatus is used to extract the vapor-filled air from recovery or extraction wells. Volatile contaminants are extracted, and the soil is decontaminated to levels required by regulatory agencies. The established air flows are a function of the equipment used and soil characteristics. Spent carbon and contaminated water are residuals of this treatment and further treatment of these residuals is necessary.[6,7,17]

Applications--Vacuum extraction is used for the treatment of soils, sediments, sludges, and ground water contaminated with volatile or semivolatile organic compounds (VOCs or SVOCs) at ambient temperatures. This technology is effective on VOC and SVOC total concentrations ranging from 10 ppb to 100,000 ppm by weight. For effective removal, contaminants should have a Henry's

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a. Private communication between Frank A. Maestas, Applied Research Associates, Inc., and Mathew W. Roy, April 1991.

b. Private communication between Frank A. Maestas, Applied Research Associates, Inc., and Matthew W. Roy, April 1991.

constant of 0.001 or higher. The use of vapor extraction systems is typically limited to permeable unsaturated soils such as sands, gravels, and coarse silts; diffusion rates through dense soils, such as compacted clays, are much lower than through sandy soils. Clayey soils usually lack the conductivity necessary for effective vapor extraction, unless they are first fractured.[6,7,17]

Vendor(s)--The following vendors have been identified as suppliers of vacuum extraction services:

- AAA CSI
- AWD Technologies
- C-E Environmental, Inc.
- C-EE Bioremediation Services
- Chemenco, Inc.
- Detox, Inc.
- Earth Technology Corp.
- Ensotech, Inc.
- Environmental Technology Southeast
- Envirosafe Technologies, Inc.
- Envirotech Mid-Atlantic
- Hunter Biosciences, Inc.
- Maecorp, Inc.
- Nuclear Remediation Technologies Corp. (NRT)
- O'Brien and Gere Engineers, Inc.
- OHM Corp.
- Petroleum Testing Service, Inc.
- Remediation Technologies
- RMC Env. & Analytical Laboratories
- RMT, Inc.
- Roy F. Weston, Inc.
- Solvent Services, Inc.
- Sybron Chemicals, Inc.
- Terra Vac, Inc.
- Vapex
- Woodward Clyde Consultants.

2.2.4 Solidification and Stabilization

2.2.4.1 Description. Solidification and stabilization are treatment processes designed to accomplish one or more of the following: (a) improve handling and physical characteristics of the waste by producing a solid from a liquid or semiliquid waste, (b) reduce contaminant solubility in the treated waste, and (c) decrease the exposed surface area across which transfer or loss of contaminants may occur.[6]

Solidification techniques eliminate free liquid, increase the bearing strength, decrease the surface area of the waste material, and produce a monolithic solid product of high structural integrity. Solidification may involve encapsulation of fine waste particles (microencapsulation) or large blocks of wastes (macroencapsulation). Chemical interactions do not necessarily occur between the wastes and the solidifying agents, but the waste material is mechanically bound within the solidified matrix in such a way that the release rate of hazardous substances is significantly decreased upon exposure to air, water, soil, or mild acidic conditions.[6]

Stabilization refers to the process of reducing the hazardous potential of waste material by converting the contaminants into their least soluble, mobile, or toxic form. This technique does not necessarily change the physical characteristics of the waste.[6]

Solidification and stabilization reduces the mobility of a contaminant, increases the volume, and has only an incidental effect on toxicity. Waste solidification/stabilization systems that are potentially useful in remediation activities are as follows: DETOXIFIER™, in situ vitrification, lime-fly ash pozzolan systems, organic binding, pozzolan-portland cement systems, sorption, and thermoplastic microencapsulation. These solidification/stabilization processes are discussed in sections 2.2.4.2 - 2.2.4.7.[6]

Applications--With proper recipe and additives, solidification and stabilization can be applied to virtually all contaminants including organics, inorganics, heavy metals, mixed wastes, and all classes of radioactive wastes. Solidification and stabilization can be applied to refuse, sediment, sludge/slurry, soil, structures, and water.[8]

Possible problems with solidification and stabilization by chemical fixation and encapsulation are an increase in volume of the treated waste over the original waste and the effectiveness of the various binders in incorporating organics and acid salts. Because the same binders are generally available to all the vendors, the selection of a vendor for this process would be based on the proposed technique and the vendor's experience with solidification/stabilization techniques. The vendor would be responsible for selecting the most effective binder.

Vendor(s)--The following vendors have been identified as supplying solidification and stabilization services:

- AAA CSI
- AEA Technology
- American Colloid
- Andco Environmental Processes, Inc.
- AWD Technologies
- Chemenco, Inc.
- Chemical Waste Management, Inc.
- Chemfix Technologies, Inc.
- Earth Technology Corp.
- Enreco Technologies Group
- Ensotech, Inc.
- Environmental Science and Engineering, Inc.
- Enwright Environmental, Inc.
- General Physics Corp.
- Harmon Environmental
- Hayward Baker
- Hazco
- Hunter Services
- IIT Research Inst.

- International Technology Corp.
- International Waste Technologies/Geo-Con, Inc.
- Jacobs Engr. Group, Inc.
- Kiber Associates, Inc.
- Maecorp, Inc.
- Marine Pollution Control
- McNamee Advanced Technology, Inc.
- NUS Laboratory Services Group
- OHM Corp.
- Osco, Inc.
- Peoria Disposal Co.
- Radian Corp.
- RNK Environmental, Inc.
- Roy F. Weston Services
- UPSCI, Inc.
- Weston Services
- Woodward Clyde Consultants
- Zenon Environmental.

2.2.4.2 DETOXIFIER™. See Section 2.2.3.3.

2.2.4.3 In Situ Vitrification. See Section 2.2.5.4.

2.2.4.4 Lime-fly Ash Pozzolan Systems.

Description--Lime-fly ash pozzolanic processes use a finely divided, noncrystalline silica in fly ash and the calcium in lime to produce low-strength cement. The waste solidification/stabilization is produced by microencapsulation in the pozzolan concrete matrix.[6]

Applications--With proper recipe and additives, the lime-fly ash pozzolan process can be applied to inorganics, metals, mixed, low-level, and TRU radioactive wastes; specifically, refuse, sediment, sludge/slurry, soil, structures, and water mediums.[8]

Vendor(s)--The following vendors have been identified as supplying lime-fly ash pozzolan systems:

- Halliburton Environmental Technologies, Inc.
- KLM Technologies
- Laidlaw Environmental Services.

2.2.4.5 Organic Binding.

Description--Modified clays can be used to immobilize organic contaminants. Clay particles are platy-shaped minerals that have negative charges on their surfaces as a result of isomorphous substitution. To achieve neutrality in their structure, clay particles attract cationic metals such as Li, Na, Ca, and Mg on their surfaces. Introduction of these organic cations into clays increases the interplanar distance between the clay particles and provides more suitable conditions for bonding of organic contaminants. Other organic binder types are epoxy, polyesters, asphalt, polyolefins, and urea-formaldehyde.[a] (See also reference 6.)

Applications--Soils or sludges with organic contamination.

Vendor(s)--The following vendors have been identified as supplying organic binding services:

- Halliburton Environmental Technologies, Inc.
- In Situ Fixation Co.
- KLM Technologies
- Laidlaw Environmental Services.

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a. Personal Communication between E. C. Garcia, EG&G Idaho, and Reva A. Hyde, EG&G, Idaho, in a letter, ECG-09-91, Chemical Evaluation of Treatments Considered for the In Situ Treatment Evaluation (ISTE) Project, June 21, 1991.

2.2.4.6 Pozzolan-Portland Cement Systems.

Description--In this process, portland cement and pozzolan materials (i.e., fly ash) are combined to create a high-strength waste and concrete matrix, where solidification/stabilization is achieved through the physical entrapment of waste particles. Fly ash or another pozzolan is often added to the cement to react with free calcium hydroxide and thus improve the strength and chemical resistance of the solidified product. The types of cement used for the solidification can be selected specifically to emphasize a particular cementing reaction, or to enhance cementation (such as sulfate resistance).[6,8]

Applications--Hazardous/toxic waste sites effectively treated by the pozzolan-portland cement process include: (1) heavy metals in metallic or cationic forms, (2) inorganics in anionic form, (3) water-soluble organics, and (4) water-insoluble organics. The wastes that can be treated include aqueous solutions, sludges, and contaminated soils.[18]

With proper recipe and additives, the pozzolan-portland cement process can be applied to virtually all contaminants including organics, inorganics, heavy metals, mixed, and all classes of radioactive wastes. The pozzolan-portland cement process can be applied to refuse, sediment, sludge/slurry, soil, structures, and water.[8]

Vendor(s)--The following vendors have been identified as supplying pozzolan-portland cement systems:

- HAZCON, Inc.
- Halliburton Environmental Technologies, Inc.
- In-Situ Fixation Co.
- Laidlaw Environmental Services.

2.2.4.7 Sorption.

Description--Sorption is the addition of solid adsorbents (to a waste) to soak up and prevent the loss of drainable liquids through the mechanisms of capillary action, surface wetting, and chemical reaction. To prevent undesirable reactions, the absorbent material must be matched to the waste.

Zeolite, kaolite, vermiculite, calcite, amorphous entonites silicates, acidic and basic fly ash, and kiln dust are all typical adsorbents. There are also synthetic adsorbents available. Adsorbents can be spiked with scavengers to bind trade metals, flocculating agents, and agents to improve subsequent solidification (cementing) processes.[6,8]

Applications--Sorption can be used to solidify any contaminants in water, liquids other than water, or sludges/slurries. For in situ treatment, the waste can be in the groundwater, surface water, saturated soil, or source term.[8]

Vendor(s)--The following vendors have been identified as supplying sorption services:

- Diamond Shamrock Corp.
- DOW Chemical Co.
- Radecca Corp.

2.2.4.8 Thermoplastic Microencapsulation.

Description--Thermoplastic microencapsulation involves blending fine particulate waste with melted asphalt or other matrix. Liquid and volatile phases associated with the wastes are driven off, and the wastes are isolated in a mass of cool hardened asphalt.[6]

Applications--No information as of June 1991.

Vendor(s)--No information as of June 1991.

2.2.5 Thermal Treatments

2.2.5.1 Description. Thermal technologies elevate the temperature of the soil to volatilize contaminants. These contaminants are captured at the surface, thereby reducing the toxicity of the soil.

Applications--Thermal treatment can be used to treat most contaminants and can be used in most media states.

Vendor(s)--The following vendors have been identified as supplying thermal treatment services:

- Detox, Inc.
- Geosafe Corporation
- ITT Research Institute
- RMC Env. & Analytical Laboratories.
- Roy F. Weston, Inc.

2.2.5.2 High Energy Corona.

Description--High energy corona is an innovative thermal treatment process that does not require high temperatures or additives. Electrodes/vents are placed in the contaminated soil. Peripheral electrodes/vents are used as air inlets, while a center electrode/vent is used as an off-gas vent. A form of corona develops at higher voltages to generate energetic electrons and robust oxidants from soil gases.[8]

Applications--High energy corona is used to treat organic contaminated soils, sludges, slurries, and sediments.[8]

Vendor(s)--No information as of June 1991.

2.2.5.3 Radio Frequency and Electromagnetic Heating.

Description--In situ radio frequency (RF) heating is a rapid process that uniformly heats soil without excavation or digging. This process uses electromagnetic wave energy in the range of 45 Hz to well over 10 GHz to heat soil. Exciter and guard electrodes are placed in the ground, and the temperature rise occurs due to ohmic or dielectric heating mechanisms. The RF technology is capable of heating soils to temperatures in excess of 212°F (100°C) (boiling point of water). The gases and vapors formed in the soil are recovered at the surface or through vented electrodes used for the heating process. A vapor containment cover collects volatilized organics for incineration or carbon absorption. This process is also referred to as electromagnetic (EM) heating. The only major difference between RF and EM is in the choice of frequency of the applied power. The EM technology is suitable for heating soils only to the boiling point of water.[a] (See also reference 8.)

Applications--RF and EM Heating works on sludges, other solids, soils, and sediments contaminated with volatile and semivolitile dioxins/furans, pesticides, halogenated volatiles, halogenated nonvolatiles, radioactive materials, PCBs, nonvolatile metals, volatile metals, nonhalogenated nonvolatiles, and nonhalogenated volatiles. This technology can be used in saturated or unsaturated soil. Both of these technologies have the potential for economic and efficient remediation of soils at hazardous waste sites contaminated with organic compounds. Both volatile and semivolatile contaminants can be removed.[b] (See also references 8 and 17.)

Vendor(s)--The following vendors have been identified as supplying radio frequency and electromagnetic heating services:

- IIT Research Institute
- Roy F. Weston, Inc.

2.2.5.4 In Situ Vitrification.

Description--In situ vitrification (ISV) involves the electric melting of contaminated soils in place. ISV uses an electrical network consisting of four electrodes, placed in a square pattern and at the desired depth, to

a. Private communication between Guggilam C. Sresty, IIT Research Institute, and David E. Shropshire, EG&G Idaho, Inc. (response to EG&G's January 25, 1991 CBD solicitation), February 5, 1991.

b. Private communication between Guggilam C. Sresty, IIT Research Institute, and David E. Shropshire, EG&G Idaho, Inc., (response to EG&G's 1/25/91 CBD), February 5, 1991.

electrically heat and melt contaminated soils and solids at temperatures of 2912 to 3632°F (1600 to 2000°C). ISV destroys organic pollutants by pyrolysis. Inorganic pollutants are immobilized within the vitrified mass, which has properties of glass. Both the organic and inorganic airborne pyrolysis by-products are captured in a hood, which draws the contaminants into an off-gas treatment system that removes particulates and other pollutants of concern.[6,7,8]

Applications--ISV is effective on aqueous media, organic liquid, sediments, soils, and sludges contaminated with halogenated volatiles, halogenated nonvolatiles, nonhalogenated volatiles, nonhalogenated nonvolatiles, pesticides, dioxins/furans, organic cyanides, organic corrosives, volatile metals, nonvolatile metals, and PCBs.[17]

The ISV process can be used to destroy or remove organics and/or immobilize inorganics in contaminated soils or sludges. On saturated soils or sludges, the initial application of the electric current must reduce the moisture content before the vitrification process can begin. This increases energy consumption and associated costs. Also, sludges must contain a sufficient amount of glass-forming material (nonvolatile, nondestructible solids) to produce a molten mass that will destroy or remove organic and immobilize inorganic pollutants. The ISV process, however, has the following limitations: (a) individual void volumes in excess of 150 ft^3 (4.25 m^3); (b) buried metals in excess of 5% of the melt weight or continuous metal occupying 90% of the distance between two electrodes; (c) rubble in excess of 10% by weight; and (d) the amount and concentration of combustible organics in the soil or sludge. These limitations must be addressed for each site.[7]

In the presence of acids and salts, there is one concern that must be addressed with ISV technologies. Acids and salts can cause the soil to have an abnormally high electrical conductivity (hence, a low electrical resistance), which is generally more pronounced as the moisture content of the soil increases. This low resistance will require the application of more electrical energy to the treatment area in order to achieve a vitrified melt. This will also probably result in a much higher melt temperature.

Vendor(s)--The following vendors have been identified as supplying in situ vitrification services:

- Detox, Inc.
- Geosafe Corp.
- RMC Env. & Analytical Laboratories.

2.3 Technology Screening

After an initial screening of the technologies, each technology was rated from 1 to 5 for effectiveness, implementability, and cost according to CERCLA criteria. These criteria and the rating system are briefly discussed below.

2.3.1 Criteria for Rating Technologies

The criteria for rating technologies is as follows:

- The assessment of the *effectiveness* of a technology was based on the effects the treatment is expected to have on the reduction and prevention of hazards to the public, workers, and environment. The components of this criterion include the magnitude of risks after treatment, adequacy and reliability of controls, protection of the community during remedial actions, protection of workers during remedial actions, environmental impacts, treatment process and remedy, amount of hazardous material destroyed or treated, reduction of toxicity, mobility, and/or volume, irreversibility of the treatment, and the type and quantity of treatment residual.

- The assessment of the *implementability* of a technology was based on the lack of difficulties anticipated in performing the technology under the constraints of the project. This rating includes the ability to construct and operate the technology, reliability of the technology, time until remedial response objectives are achieved, ease of undertaking additional remedial action if necessary, monitoring considerations, administrative feasibility, and the availability of services and materials.

- The assessment of *cost* was based on expected capital costs and annual operating and maintenance costs of a technology. Since many important details of the planned demonstrations have not been decided to date, reliable information for this criterion was difficult and often impossible to obtain. However, low cost is not considered a primary objective for these treatability tests, and the uncertainties involved with cost will have little effect on the overall technology ratings. The lower priority of cost in these treatability studies is reflected in the low weight given this criterion in the rating scheme in Section 2.3.2.

2.3.2 Technology Ratings

Using ratings of 1 to 5, the technologies are assigned numbers to represent how well they meet each criterion when treating toxic and radioactive mixed waste. Higher numbers are assigned to technologies which better satisfy the requirements. A more detailed discussion of the process and rating parameters can be found in Appendix C. The weightings for the relative importance of the three criteria are shown below.

Effectiveness	50%
Implementability	40%
Cost	10%

In addition to the three criteria explained above, the experience of the company or university that supplied information on in situ buried waste remedial technologies and its' capital and establishment were also assessed. The weightings shown below were used to rate the vendors/universities. This evaluation can be found in Appendix D.

Experience	40%
Capital/Establishment	60%

The resulting technology ratings are shown in Table 1. The scores are based on the weights given above for effectiveness, implementability, and cost.

Table 1. Technology Ratings

TECHNOLOGY	EFF	IMP	CST	TECH SCORE
Weighting (%)	50	40	10	
Bioremediation/bioaccumulation	2.5 h-b i-a	2.5 g	4	53%
Bioremediation	2 i-a	2.5 g	4	48%

Table 1. (continued)

Bioremediation--Dual Auger System	2 i-a	3	3	50%
Bottom Sealing	3.5 h-a,b,c,d	3.5	3	69%
Capping	3.5 h-a,b,c,d	5	5	85%
Cryogenics	4 h-a,b,c,d f	2.5 l	2	64%
Dechlorination	2 i-a	4	4	60%
DETOXIFIER™	4.7 h-b,c,d i-a,b,c,d k	4	3.5	86%
Electrokinetics	3 i-a,b,c k	3.5 e	4	66%
High Energy Corona	2 i-a	3 e	3	50%
In Situ Stabilization Fluidized Bed Zeolite System	3 h-b,c,d i-b,c,d	2 e	3	52%
ISV	5 h-b,c,d,m i-b,c,d,m j	3 e	2	78%
ISV Barrier	4 h-a,b,c,d	4 e	2	76%
Neutralization	1.5 i-a,b,c,d	4	3	53%
Oxidation	1.5 i-a,b	4	3	53%
Plasma Arc Glass Cap	3.5 h-a,b,c,d	3.5 e	4	71%
Polymer Concrete Barrier	3.3 h-a,b,c,d	4 e	3	71%
Radio Frequency and Electromagnetic Heating	2 i-a k	3.5	3	54%
Simultaneous Injection, Extraction, and Recharge	2 i-a k	4 e	3	58%
Slurry Wall	3.5 h-a,b,c,d	4	4	75%

Table 1. (continued)

Soil/Cement Wall	3.5 h-a,b,c,d	4	3	73%
Soil Flushing	2 i-a k	4	4	60%
Solidification/Stabilization	4.8 h-b,c,d,m i-b,c,d,m	4	3.5	87%
Steam/Air Stripping	2 i-a k	4	3	58%
VVE	2 i-a k	4	3	58%

a Organics
b Metals
c Radioactive
d Inorganics
e Technology gaps
f Not for salts
g Long time to treat
h Reduces mobility
i Reduces toxicity
j Reduces volume
k Separation technology
l Long-term management
m May not be effective on organics

2.3.3 Site Specific Concerns

To this point, the technologies have been evaluated based on their merit, without including site characteristics at the RWMC in their analyses. Factoring known site characteristics into the analyses, identified the concerns discussed below.

2.3.3.1 Bioremediation Technologies. In the dry soil at the RWMC, the proposed bioremediation technologies would not be feasible to implement. Significant amounts of liquid must be added to the soil for the process, and this is likely to cause migration of the contaminants. To overcome this problem, the site may be contained with an impermeable barrier. This containment would also provide protection from inorganic and radioactive elements that would not be treated by this process. However, the overall rating must now be dependent on the barrier as well as the bioremediation process.

At the acid pit, where bioremediation may be used to destroy organic wastes, the major organic waste appears to be carbon tetrachloride. The breakdown of this compound has proven to be difficult. In addition, if the soil has not caused neutralization to occur naturally at the acid pit, the large quantity of disposed acid solutions may require neutralization before treatment.

Confidence in the effectiveness of bioaccumulation for soil contamination was difficult to establish. Only limited information could be found on the process, and no references to its previous successes or failures in soils were found. Also, the nature of the bioaccumulation process (a method of migration control) makes its success difficult to measure.

2.3.3.2 Cryogenic Barrier. The primary obstacle to building a cryogenic barrier at the RWMC is the close proximity of waste sites at the facility to one another. For example, the acid pit, lies only a few yards from other waste sites, and almost directly on the basalt layer. The basalt layer is not of consistent depth throughout the area. This makes positioning the cooling pipes outside of the site's contamination zone extremely difficult.

In addition, it is possible that the barrier could be penetrated by concentrated brine carried by runoff or groundwater from any salt contaminated waste. There is a considerable amount of contaminated salt waste stored at the RWMC. For these reasons, the use of a cryogenic barrier will not be considered for this project.

2.3.3.3 Electrokinetics. As with bioremediation, electrokinetics requires large quantities of water to be added to the soil. An impermeable barrier containing the waste site would prevent migration of contaminants and would also add reliability to the treatment. Because of the dangers of adding liquid to the soil, electrokinetics alone cannot be considered for this project, but will be considered in combination with a containment method.

Electrokinetics is a separation technology. Contamination is dissolved in water and removed from the soil, but it is not treated. A treatment or disposal method for the resulting waste water must also be used.

The presence of other ions in the soil may interfere with the desorption and dissolution of the contaminant species. No information was found which addresses the situation of removal of ppm-range heavy metals and/or VOCs in the presence of percent-range sodium, chloride, or carbonate ion.

Caution should be taken when buried metallic objects (water and gas lines, and metal drums) are adjacent to the field where electrokinetics is being applied. These objects should be removed or isolated. Power requirements may have to be considered.

2.3.3.4 In Situ Vitrification. In the presence of acids and salts, such as those existing in the acid pit, there is a concern that must be addressed with ISV technologies. Acids and salts can cause the soil to have an abnormally high electrical conductivity (hence, a low electrical resistance), which is generally more pronounced as the moisture content of the soil increases. This low resistance will require the application of more electrical energy to the treatment area in order to achieve a vitrified melt. This will also probably result in a much higher melt temperature.

2.3.3.5 Soil Flushing. The use of soil flushing poses the following problems: a) soil flushing introduces potential toxins (the flushing solution) into the soil system; b) a potential exists for solvents to transport contaminants away from the site into uncontaminated areas; and c) a potential exists for incomplete removal of contaminants due to the heterogeneity of soil permeability. Due to these disadvantages, in situ soil flushing technologies were eliminated from consideration for performing a treatability study.

2.3.3.6 Steam/Air/Water Stripping. With steam/air stripping, there is a possibility that the injected medium (if steam or water) could cause the contaminant to migrate downward. A containment technique might need to be used along with this technology.

An additional concern that should be addressed prior to operation is the possibility that unstable or explosive compounds in the form of organic nitrates will be present due to the mixing of organics with nitric acid.

2.3.3.7 Vacuum Extraction. If steam or water is used as the injected medium, there is a possibility that the contaminant could migrate downward. A containment technology might be needed in combination with this technology.

Another concern that should be addressed prior to operation is the possibility that unstable or explosive compounds in the form of organic nitrates will be present due to the mixing of organics with nitric acid.

2.3.3.8 Radio Frequency Heating. As with electrokinetics, caution should be taken when buried metallic objects such as drums and gas lines are adjacent to the area where this technology is being applied. These objects will distort the applied field. The metallic objects should be removed or isolated.

Additionally, power requirements would have to be considered. Radio frequency heating requires approximately 500 - 700 kW of power. Diesel generators have been recommended.

2.3.3.9 Plasma Arc Glass Cap. As with radio frequency heating, power requirements would have to be considered. This technology requires approximately 300-1000 kW of power. Diesel generators have been recommended.

2.3.4 Site-Specific Evaluation

The site-specific restrictions eliminate a number of the original in situ remediation technologies considered for this project. The ratings for effectiveness, implementability, and cost in have been reassessed for the three sites of concern--the acid pit, soil vaults, and the low-level pits and trenches. The acid pit results are recorded in Table 2. The wastes in the low-level pits and trenches are similar to those in the soil vaults, so the results for the two sites are grouped together and recorded in Table 3.

Many of the treatments may be improved by using them in combination with other technologies. Combinations that either improve the effectiveness and/or implementability of both technologies or allow consideration of a technology that otherwise would not be feasible at the RWMC are also included in Tables 2 and 3.

Table 2. Technology Ratings for the Acid Pit

TECHNOLOGY	EFF	IMP	CST	TECH TOTAL
Weighting (%)	50	40	10	
Bottom Sealing and Containment Walls	3.5 h-a,b,c,d	4.8	4.8	83%
Bottom Sealing, Containment Walls, and a Cap	3.7 h-a,b,c,d	4.7	4.6	83.8%
Capping	3.4 h-a,b,c,d	5	5	84%
Capping and Containment Walls	3.5 h-a,b,c,d	4.9	4.9	84%
DETOXIFIER™	5 h-b,c,d i-a,b,c,d k	4.3	4.3	93%
In Situ Vitrification	4.3 h-b,c,d,m i-b,c,d,m j	3 e	3.5	74%
Electrokinetics with ISV Barrier	4.5 h-a,b,c,d i-a,b,c k	4 e	3.9	84.8%
Electrokinetics with ISV Barrier and a Cap	4.7 h-a,b,c,d i-a,b,c k	3.8 e	3.8	85%
Electrokinetics with Slurry Wall and Bottom Sealing	4.5 h-a,b,c,d i-a,b,c k	4 e	4.1	85.2%

Table 2. (continued)

Electrokinetics with Slurry Wall and Bottom Sealing and a Cap	4.8 h-a,b,c,d i-a,b,c k	3.8 e	3.9	85.2%
Electrokinetics with Soil/ Cement Wall and Bottom Sealing	4.5 h-a,b,c,d i-a,b,c k	4 e	4	85%
Electrokinetics with Soil/ Cement Wall and Bottom Sealing and a Cap	4.7 h-a,b,c,d i-a,b,c k	3.8 e	3.9	85.2%
Radio Frequency Heating with Solidification/Stabilization	5 h-b,c,d i-a,b,c,d k	4.3	4.3	93%
Simultaneous Injection, Extraction, and Recharge with Solidification/ Stabilization	5 h-b,c,d i-a,b,c,d k	4.2 e	4.3	92.2%
Solidification/Stabilization	4.7 h-b,c,d,m i-b,c,d,m	4.5	4.5	92%
Solidification/Stabilization with In Situ Vitrification	4.8 h-b,c,d,m i-b,c,d,m	3 e	3.3	78.6%
Solidification/Stabilization with a Cap	4.8 h-b,c,d i-b,c,d,m	4.4 e	4.4	92%
Steam/Air Stripping with Solidification/Stabilization	5 h-b,c,d i-a,b,c,d k	4.3	4.3	93%
Vacuum Extraction with Solidification/Stabilization	5 h-b,c,d i-a,b,c,d k	4.3	4.3	93%

a Organics
b Metals
c Radioactive
d Inorganics
e Technology gaps
f Not for salts
g Long time to treat
h Reduces mobility
i Reduces toxicity
j Reduces volume
k Separation technology
l Long-term management
m May not be effective on organics

Table 3. Technology Ratings for the Soil Vaults and the Low-Level Pits and Trenches

TECHNOLOGY	EFF	IMP	CST	TECH TOTAL
Weighting (%)	50	40	10	
Slurry Wall with Bottom Sealing	3.3 h-a,b,c,d	4.5	4.5	78%
Slurry Wall with Cap	3.3 h-a,b,c,d	5	5	83%
Slurry Wall with Bottom Sealing and Cap	3.5 h-a,b,c,d	4.0	4.3	75.6%
Slurry Wall with Bottom Sealing followed with Steam/Air Stripping (or Vacuum Extraction)	3.8 i-a h-a,b,c,d	3.5	3.5	73%
Slurry Wall with Bottom Sealing followed with Steam/Air Stripping (or Vacuum Extraction) and Cap	4 i-a h-a,b,c,d	3.3	3.3	73%
Slurry Wall followed by Steam/Air Stripping (or Vacuum Extraction) and Cap	3.8 i-a h-a,b,c,d	3.7	3.7	75%
Soil/Cement Wall with Bottom Sealing	3.3 h-a,b,c,d	4.5	4.3	77.6%
Soil/Cement Wall with Cap	3.3 h-a,b,c,d	5	4.8	82.6%
Soil/Cement Wall with Bottom Sealing and Cap	3.5 h-a,b,c,d	4	4.1	75.2%
Soil/Cement Wall with Bottom Sealing followed by Steam/Air Stripping (or Vacuum Extraction)	3.8 i-a h-a,b,c,d	3.5	3.3	72.6%
Soil/Cement Wall with Bottom Sealing followed by Steam/Air Stripping (or Vacuum Extraction) and Cap	4 i-a h-a,b,c,d	3.3	3.1	72.6%
Soil/Cement Wall followed by Steam/Air Stripping (or Vacuum Extraction) and Cap	3.8 i-a h-a,b,c,d	3.7	3.5	74.6%
Steam/Air Stripping (or Vacuum Extraction) with Fluidized-Bed Zeolite System	4.5 i-a,b,c,d h-b,c,d	3 e	3.7	76.4%

Table 3. (continued)

Steam/Air Stripping (or Vacuum Extraction) with Fluidized-Bed Zeolite System	4.5 i-a,b,c,d h-b,c,d	3 e	3.7	76.4%
Steam/Air Stripping (or Vacuum Extraction) with Fluidized-Bed Zeolite System and Cap	5 i-a,b,c,d h-b,c,d	2.8 e	3.5	79.4%

a Organics; b Metals; c Radioactive; d Inorganics; e Technology gaps; f Not for salts; g Long time to treat; h Reduces mobility; i Reduces toxicity; j Reduces volume; k Separation technology; l Long-term management; m May not be effective on organics

These tables identify the most applicable technologies for remediating the acid pit, soil vaults, and low-level pits and trenches. Based on these technologies' weighted scores, recommendations were made on processes that should be demonstrated. Section 5 discusses these recommendations.

2.4 Delivery and Recovery Systems for In Situ Treatments

This section deals with common delivery and recovery systems for in situ treatments, and discusses traditional applications, as well as some new applications for hydraulic fracturing, radial well drilling, ultrasonic methods, kerfing, jet-induced slurry method, carbon dioxide injection, hot brine injection, and cyclic pumping.[6] The purpose of this section is to provide an overview of some delivery and recovery systems that could be used in conjunction with the technologies discussed in Section 2.3.

Hydraulic fracturing is commonly used to stimulate the recovery of hydrocarbons from low-permeability reservoirs and enhance the delivery of fluids used to displace petroleum in sweeping operations. A single fracture, horizontal or vertical, that propagates away from the borehole is generated by this process. Sand is introduced into the formed fracture to hold it open and to create a highly permeable channel suitable for delivery of remediating materials or the recovery of contaminants. Possible applications include increasing the efficiency of pump and treat systems, stimulating the extraction of vapor phases from dense soils, or forming horizontal drain to capture leachate.[6]

Radial well drilling may be used to enhance access to a contaminated soil system or groundwater aquifer. Multiple wells may be placed at the same or various levels within the same borehole. Radial wells applied to hazardous waste sites can be positioned in both the saturated and unsaturated media and can facilitate the remediation of contaminated sites by increasing the available delivery/recovery routes for delivering remediating materials or recovering contaminated groundwater. Although not fully demonstrated at hazardous waste sites, this technology is the focus of current research and is being refined for that purpose.[6]

Ultrasonic methods have been used extensively by soil scientists to disperse clay and silt particles, and has also proved to be effective for removing mineral films and clay aggregates from sand grains. Possible applications of ultrasonic methods in hazardous waste sites would be to increase recovery volumes from wells clogged with clay particles or microorganisms and to separate contaminants from clay particles near well sites. This technology could eliminate the need for anti-bacterial agents in the cleaning of wells used in bioreclamation.[6]

Kerfing, or borehole notching, is currently used to produce a slot either perpendicular or parallel to the axis of a previously drilled borehole. This technology is a possible method for preventing the migration of pollutants from hazardous waste sites, but kerfing may also have applications as a recovery technique.[6]

Jet-induced slurry method is a mining industry technique used to excavate an ore formation by fragmenting the subsurface ores with a high-velocity hydraulic jet and then pumping the slurry to the surface through a borehole. Although no documented applications for this method in the remediation of hazardous waste sites were found, this technique should be applicable to any soil or rock formation that could be fragmented by a hydraulic jet.[6]

Carbon dioxide injection in the petroleum industry involves injecting carbon dioxide into oil-bearing rock formations to maintain pressure and to displace the oil. The two principal mechanisms for mobilizing the oil by carbon dioxide injection are the reduction of the ore viscosity upon solution of the gas into the oil and an increase in the volume of the reservoir. Use of this technology for the recovery of groundwater contaminants probably would be limited to applications where carbon dioxide is either dissolved in water or contained in aphrons. The feasibility of applying this technique to a site where contamination is near the surface is also questionable.[6]

The hot brine injection technology is used to convert solid or liquid natural gas deposits to a vapor state. Hot brine injection uses the reduction in dissociation temperature resulting from an increase in salinity as its principal mechanism. Reducing the dissociation temperature decreases the thermal energy required during recovery. The proposed stimulation of contaminant removal by use of hot brine is based on the results of theoretical analyses. This technique has not yet been tested in the laboratory or the field.[6]

Cyclic pumping is a delivery and recovery technique which varies the rates of either injection or extraction in an effort to minimize pumping costs. Optimizing pumping activities could conceivably reduce remediation costs at contaminated waste sites. This manner of pumping has variable rates where the pumps are turned on during active cycles and turned off during rest cycles. These techniques are designed to increase the efficiency of pump and treat systems by increasing the concentration of contaminants recovered (or reactants delivered) per volume of groundwater. This technology has been proposed for use at contaminated waste sites, and EPA is initiating research on this subject.[6]

2.5 Related Projects

The In Situ Treatment Evaluation (ISTE) project has identified several projects which have performed some related effort. ISTE obtained and incorporated information from these other projects into the technology evaluation, thereby avoiding any duplication of effort. Following is a list of projects which complemented the ISTE project and a brief description of how the efforts tied together.

1) *Remedial Technology Information project (RTIp)*; INEL. RTIp has developed the Remedial Technology Information System (RTIS) which contains information on remedial technologies.

   ISTE accessed RTIS to develop a list of potential in situ, buried waste treatment technologies. This information aided in determining the range of in situ technologies available and obtaining information on implementability, effectiveness, cost, and vendors.

2) *System Design Study (SDS)*; INEL. The SDS is part of a technology development program within the EG&G Waste Technology Development Department. Its mission is to capture the latest and most comprehensive techniques available and apply them to environmental remediation.

   The SDS considered systems that would remediate the waste into a final waste form, including processing and leaving the waste in place. Out of the processes evaluated, those which met the requirement for processing and leaving in place were a barrier system and in situ vitrification. Information and analyses on these processes was included in the ISTE evaluation.

3) *Horizontal Drilling*; Savannah River. Horizontal drilling could be used to complement an in situ treatment. ISTE project members obtained information on horizontal drilling and established contacts to monitor progress and problems with the technology.

4) *In Situ Grouting*; Hanford. At Hanford, a grout wall is being formed around a waste site (primary containment) and then subcontractors are drilling in the waste to solidify it (i.e. double containment). Hanford is also investigating filling in fracture media with some type of grout.

   The ISTE project has been continuing coordination with Westinghouse Hanford Company on in situ stabilization and barrier technologies applicable to buried waste. A joint technical task plan is currently being developed for monolithic confinement of the RWMC acid pit. This technology is being considered because there is a need to develop and demonstrate a long-term technology to treat fractured rock (basalt) and interbed media In Situ. This technology will produce a large monolithic structure entombing the waste disposal site and underlying contaminated fractured and granular materials. Efforts at EG&G will continue in an attempt to receive funding approval under a separate cost account plan.

5) *Arid Site Integrated Demonstration (ASID)*; Hanford. This demonstration focuses on cleanup of VOCs in soils and groundwater at arid sites. Emphasis is being placed on in situ and above-ground biological treatment technologies for the remediation of organic and nitrate contaminated soils and groundwater. The Arid Site Integrated Demonstration (ASID) team has identified three technologies which would apply to both Hanford and INEL, including radio frequency heating.

   ISTE and EG&G personnel involved with ASID exchanged information on radio frequency heating, ideas for testing, suggestions for improvement, and application concerns.

6) *Brain Storming Session*; INEL. In 1988, a brainstorming session was held to develop ideas on how to remediate the INEL. Six hundred ideas were documented. Those ideas were narrowed down to approximately 120, based on feasibility. ISTE obtained two binders full of those concepts and evaluated the ideas. Since the information contained in the binders was mostly proposals, the facts were too vague to include in this investigation.

7) *In Situ Vitrification (ISV)*; INEL. There are ongoing tests being performed at the INEL on ISV. Information was obtained on the results of previous tests and future plans. Contacts were established to monitor progress and problems. ISTE used this information to evaluate ISV.

8) *Vapor-Vacuum Extraction (VVE)*; INEL. VVE is currently being demonstrated at the INEL. After preliminary testing, it was concluded that VVE should be considered a viable remedial technology for removal of VOCs from the vadose zone beneath the RWMC.

   Information was obtained on the project and reviewed. The VVE project staff identified key issues and problems for ISTE project members to consider in this analysis of technologies.

9) *In Situ Bioremediation*; INEL. Various bioremediation techniques are currently being researched and demonstrated at the INEL. Landfarming is being demonstrated for oil contamination at the INEL Central Facilities, and numerous research projects such as biosorption and biorelease of metals from soils and uranium mill tailings are also underway.

   Contacts were established with personnel working on this effort. These personnel were in attendance at a meeting between ISTE personnel and a bioremediation vendor. Their questions and comments during this meeting helped in the evaluation of the vendor and the technology.

10) *Previous INEL Grouting Study*. Information on the in situ grouting experiment performed to improve confinement of buried TRU waste at

the INEL was obtained by ISTE and closely reviewed. This field study showed that in situ grouting of simulated TRU waste with an ultrafine particulate cement, using the dynamic compaction grouting technique, will not result in hydrologic isolation of INEL's RWMC fine-grained soils. It was concluded that the INEL TRU buried waste would require a finer grout material and a larger injector/dynamic compactor. It was also suggested that the grout cements be combined with portland-type cement to yield high strength and impermeability.

3. DESIGN GUIDELINES

3.1 Functional Needs

The ISTE project supports the Buried Waste Program (BWP). While its primary objective is to support the remediation of buried waste at the Idaho National Engineering Laboratory, it will also assist other DOE Sites contaminated with buried waste in their remediation efforts, in support of the Buried Waste Integrated Demonstration Program (BWID).

Treatability studies of in situ treatments may be performed at the acid pit, soil vaults, low-level pits and trenches, and should have possible application at the TRU pits and trenches, or any other buried waste sites.

3.1.1 Treatability Study Objectives

The purpose of performing treatability studies is to reduce cost and performance uncertainties for treatment alternatives. A treatability study is required to produce sufficient data to permit the treatment alternative to be fully developed and evaluated. The results of treatability studies allow a treatment alternative to be considered for support of a remedial design for a selected alternative.[19]

3.1.2 Remedial Action Objectives

Remedial action objectives serve as goals that selected technologies must achieve. Preliminary objectives can be developed based on chemical- or location-specific requirements, and preliminary site characterization information. These objectives are established based on identified contaminants of concern, exposure routes, human and environmental receptors, acceptable contaminant range levels for each exposure route, and other requirements imposed upon the site. The objectives are refined during the feasibility study and development of alternatives. Once the alternatives are defined, action-specific remedial action objectives can be established.[19]

General objectives for chemical-specific and location-specific remedial action for the SDA include:

- Control or remove originating buried waste constituent source
- Minimize or eliminate saturation of the SDA by precipitation or run-off
- Control secondary sources of contaminants (contaminated soil, basalt bedrock, sedimentary interbeds) to protect the Snake River Aquifer Plain
- Minimize contaminant migration from the SDA
- Prevent contaminant migration from the INEL
- Minimize onsite worker exposure to chemical and radiological waste constituents
- Provide the RWMC and off-site users (if necessary) with sufficient, dependable, and safe potable water
- Provide a water supply at the RWMC that can meet potable water demand and fire flow requirements
- Comply with all applicable Federal and Idaho State requirements.[20]

3.1.3 Data Quality Objectives

The data quality required for analytical results of treatability tests greatly affects the cost and time required for the analyses. The results of bench and pilot studies are used to support selection of remedial alternatives, support the Record of Decision (ROD), and become part of the Administrative Record. Results of treatability testing may also be used on other sites with similar characteristics. Therefore, procedures followed in testing should be well documented.

Sampling and analyses for tests used to develop predictive results will need to be performed with the same level of accuracy and care that will be used during site characterization. Because cost and time required for analyses increase significantly with increased quality, potential savings can be derived by carefully determining the level(s) of data quality necessary for each analytical level required.

Table 4 presents the data quality required for the various analyses that may be performed during treatability investigations. Bench- and pilot-scale testing requires a mixture of moderate and high-quality data. Sufficient high-quality data are needed to document performance of the technologies considered for further evaluation.

Table 4. Data quality required for various analyses.[21]

Analytical Level	Field Data	Bench/Pilot Data
Level II, Level III	Feasibility Screening	Testing to optimize operating conditions, Monitoring, Predesign sizing
Level IV, Level V	Enforcement related evaluations and recommendation of alternatives	Establish design criteria establishing standards documenting performance in treatability studies to screen alternatives

3.2 Operational Parameters

3.2.1 Regulatory

Under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) [as amended by the 1986 Superfund Amendments and Reauthorization Act (SARA)] and the Resource Conservation and Recovery Act (RCRA) [as amended by the 1984 Hazardous and Solid Waste Amendments (HSWA)], treatability studies involving CERCLA wastes are subject to specific permitting and operating requirements. The location of the studies (onsite or offsite) governs the treatability study requirements.[21]

Onsite treatability studies under CERCLA may be conducted without any federal, state, or local permits [40 CFR 300.68(a)(3)]. However, these studies must observe Federal and state applicable or relevant and appropriate requirements (ARARs).[21]

Treatability studies conducted offsite require that any facility receiving CERCLA wastes must meet the following two requirements: (a) the facility must operate in compliance with applicable Federal and state laws; and (b) the facility must control any relevant releases of hazardous substances to the environment [per Section 121(d)(3) of CERCLA and the Revised Off-Site Policy (OSWER Directive 9834.11, November 13, 1987)].[21] Sample exemptions are covered under 40 CFR 261.4, 40 CFR 260.10, and DOE Order 5400.3.

3.2.2 Applicable or Relevant and Appropriate Requirements

ARARs are identified on a site-specific basis and are dependent on the characteristics of the particular site and the chemicals present at the site.

After review of Federal and State of Idaho laws and regulations, the following ARARs were determined to be potentially applicable to the location and contamination problems at the SDA:

- *Chemical-Specific ARARs*
  - Federal Drinking Water Regulations
  - Federal Ambient Water Quality Criteria
  - Idaho State Water Quality Standards
  - Federal Air Quality Standards
  - Idaho State Air Quality Standards
  - 10 CFR 20.
- *Location-Specific ARARs*
  - Floodplains
  - Activities Proximate to Drinking Water Wells (Idaho Drinking Water Regulations)

- Archaeological Resources and Antiquities

- *Action-Specific ARARs*

  - Resource Conservation and Recovery Act (RCRA) Regulations
  - 40 CFR 260-264, 268, and 270
  - Idaho Hazardous Waste Management Regulations
  - Title 1, Cpt. 5
  - DOE Orders 5480.1A, 5480.1B, and 5820.2
  - Treatment activities resulting in discharges to air, surface water, or the groundwater may need to comply with:

    -- Rules and Regulations for the Control of Air Pollution in Idaho

    -- Federal Clean Air Act

    -- Idaho Water Quality Standards and Wastewater Treatment Requirements (Title 1, Ch. 2)

    -- Licensing Requirements for Land Disposal of Radioactive Waste (10 CFR 61)

    -- Federal Clean Water Act

    -- Federal and State of Idaho Underground Injection Control Regulations

There are no ARARs for soil or basalt.[20]

Other requirements can be identified based on specific remedial technologies being considered for the SDA; they include all pertinent DOE-ID and EG&G Idaho requirements for design standards (seismic, tornado, etc.), operating requirements, and discharge/exposure limitations as well as compliance with the National Environmental Policy Act (NEPA).[20]

3.3 Site Development

Most necessary services-such as electricity and water-already exist at the site. The current status of these services, and any additional needs, are explained in this section.

3.3.1 Accessibility of the Site

The INEL is accessed via commercial air service and public highways. The closest city to the INEL with commercial air service is Idaho Falls, Idaho, 55 miles (88.5 km) from the RWMC. Two U.S. Highways, US-20 and US-26, cross the INEL and connect the RWMC with Idaho Falls and Pocatello, Idaho.

The INEL has its own railroad track and equipment for use within the site boundary. The site is also connected to the Union Pacific main lines. Freight truck service is provided by local, regional, and interstate commercial trucking firms.[22]

3.3.2 Parking

The INEL will provide parking for any necessary equipment and vehicles.

3.3.3 Utilities

The INEL will provide support utilities, i.e., water and power. Water is available within 300 ft (91.44 m) of the outer limits of the RWMC area. Three phase power, 12.5 kV, is available at the RWMC.[22] In summer (when demonstration tests are to be scheduled), the supply of power is 400-500 kW, but power lines are available only at Pad A. Lines may be run from Pad A to the demonstration site, but the cost and time required for this effort should be compared to that for obtaining small power generators.

Small diesel generators of 500 kW could be supplied by the INEL. Some type of containment (such as a berm with a plastic liner) under the generator would be required. The emissions from this caliber of diesel generator would pose neither significant risk nor require any special consideration.

3.3.4 Sampling and Analysis

Prior to initiating pilot-scale tests, a Sampling and Analysis Plan will be developed. The plan will be statistically designed to ensure that the appropriate test methods and confidence levels are identified, and that the results of the pilot-scale demonstrations are interpreted accurately. This is furthered discussed in Section 3.8.3.

3.3.5 Sewer

There are no sewer facilities available on the SDA. However, facilities do exist nearby at another area of the RWMC.

3.3.6 Fire Protection and Detection

The fire protection system of the SDA consists of an 8 in (20.32 cm) dry firewater line, two fire hydrants, and a post indicator valve that is kept closed.[23]

3.3.7 Equipment Needs

Vendors or universities will supply needed methods and equipment for their demonstrations. EG&G will supply sampling and analysis methods and equipment.

3.3.8 Communications

Telephones and FAX machines are available at the RWMC, and will be available for use.

3.3.9 Support Facilities

Any support facilities, such as trailers, must first be approved by management and security.

3.4 Process Requirements

3.4.1 Contaminants of Interest

Although characterization of the acid pit, soil vaults, and low-level pits and trenches has not been completed, several studies were previously done at the SDA. Based on waste characterization studies, soil gas, groundwater, and well vapor measurements performed there, carbon tetrachloride, trichloroethylene, 1,1,1-trichloroethane, chloroform, and tetrachloroethylene were determined to be the VOCs of primary concern. VOCs determined at lower concentrations of concern were 1,1,2-trichlorotrifluoroethane, 1,1-dichloroethane, 1,1-dichloroethylene, dichlorodifluoromethane, and toluene. All of these compounds, except toluene, are chlorinated hydrocarbons and are relatively resistent to microbial degradation.[1]

The radionuclides of concern include those isotopes that are on the ERP Target List of radionuclides, which is based on past operations and disposal records at the INEL, and also those that have been detected at the waste site.[4]

3.4.2 Soil Parameters

Table 5 presents results from tests conducted at the RWMC on soil and sediment samples in 1989:[23]

Table 5. Results from 1989 tests conducted on RWMC soil and sediment samples

Well No.	92	94	95	
Depth Interval-Top (ft in)	2 6	6 6	10	
Depth Interval-Bottom (ft in)	5	8 3	12 6	
Specific Gravity	2.65	2.67	2.66	
Bulk Density (g/cm^3)	1.87	2.02	1.70	
Porosity (percent) %	34.3	30.5	41.0	
Moisture Content (percent) %	12.9	16.4	13.2	
Vertical Hydraulic Conductivity (m/day)	5.5×10^{-4}	2.7×10^{-4}	7.9×10^{-3}	
				Median[a]
Particle Size Distribution (%) - Clay	21.2	38.7	38.5	35.9
Particle Size Distribution (%) - Silt	48.8	56.5	55.6	56.0
Particle Size Distribution (%) - Sand	30.1	4.8	5.9	7.3
Clay Minerals (%) Moisture-Kaolinite	2	3	1	2

Table 5. (continued)

Clay Minerals (%) Moisture-Illite	5	9	4	7
Clay Minerals (%) Moisture-Montmorilllonite	5	4	3	6
Cation Exchange Capacity (meg/100 g)	14	23	17	21

a. Median= median of 8 samples

3.5 Safeguards and Security

Most of the INEL is a controlled security area. All employees, visitors, and subcontractor personnel must obtain security access badges. All personnel entering the security area are required to present the proper security identification at guard check-points. Only INEL contractors, subcontractors, or visitors on approved official business are permitted access to the controlled area. Access to certain areas within the INEL requires that a person has the appropriate security clearance. Personnel without the necessary clearance may be admitted, but must be escorted at all times. These escorts will be supplied by EG&G Idaho.[22]

3.6 Environmental Considerations

Baseline risk assessments determine the need for remedial action based on the effects of the absence of action on human health and the environment. Risk assessments are generally divided into contaminant identification, exposure assessment, toxicity assessment, and risk characterization.[19] Because characterization of each waste site must be completed, baseline risk assessments for the acid pit, the soil vaults, and the low-level pits and trenches have not yet been developed. It is anticipated that the baseline risk assessments for these three sites will be completed during FY-92 and FY-93.

Remedial action objectives are established based on identified contaminants of concern, exposure pathways, human and environmental receptors, acceptable contaminant range levels for each exposure pathway, and other requirements imposed upon the site. Other environmental considerations also include these objectives.

3.7 Allowable Exposure

Allowable exposure to ionizing radiation is to be kept as low as reasonably achievable (ALARA), and as far below the limiting values, or DOE standards, as achievable. As shown in Table 6, EG&G Idaho uses Administrative Dose Guides (ADGs) with ALARA goals to ensure that exposures are maintained within DOE limits.[24] ADGs are established to limit dosage to no more than 30% of the DOE limits for the whole body, skin, extremities, and lens of the eye for radiation workers.

Table 6. EG&G Idaho Administrative Dose Guides[24]

Type of Exposure	Time Period	Annual Effective Dose Equivalent (rem)
Stochastic Effects		
Whole body	Calendar year	1.50
	Week	0.20
	Day	0.05
Nonstochastic Effects		
Lens of eye	Calendar year	4.50
	Week	0.60
	Day	0.15
Forearms, extremities, and skin of whole body	Calendar year	15.0
	Week	2.00
	Day	0.05

Individual ALARA goals in excess of 0.1 rem are appropriate only for those employees who are trained and qualified radiation workers. Goals in excess of 0.5 rem must be justified on the basis of the anticipated work load and the radiological environment in which the employee will be working.[25]

3.8 Project Plans

Work plans will be prepared by EG&G Idaho. Each company/university performing these tests will prepare a Sampling and Analysis Plan and a Health and Safety Plan that must be approved by EG&G Idaho. These plans are discussed in further detail below.

3.8.1 Work Plans

Work Plans will be prepared by EG&G, to set forth the proposed technical approach for completing the tasks outlined in the Work Assignment. Costs, schedule, and responsibilities are also outlined in the Work Plan. Elements of the Work Plan will include as follows:[21]

- Project description
- Remedial technology description
- Test objectives
- Experimental design and procedures
- Equipment and materials
- Sampling and analysis
- Data management
- Data analysis and interpretation
- Health and safety
- Residuals management
- Community relations
- Reports

- Schedule
- Management and staffing
- Budget.

3.8.2 Health and Safety Plans

Health and Safety Plans (HSPs) are required for all operations that may expose employees to safety or health hazards. The purpose of an HSP is to identify the hazards associated with each phase of operation and prescribe appropriate protective measures. Elements of the HSP should include the following:

- Hazard analysis
- Employee training
- Personal protective equipment
- Medical surveillance
- Personnel and environmental monitoring
- Site control measures
- Decontamination procedures
- Emergency response plan
- Confined-space entry procedures
- Spill containment program.

3.8.3 Sampling and Analysis Plans

Sampling and Analysis Plans (SAPs) are needed for all testing to ensure that samples obtained for characterization and testing are representative and that the quality of the analytical data generated is known. The SAP address sampling, characterization, and sampling and analysis of the residuals and treated wastes. There are two parts to the SAP: the Field Sampling Plan (FSP) and the Quality Assurance Project Plan (QAPjP). The plans' sections include as follows:[21]

- Field Sampling Plan

  1. Site background
  2. Sampling objectives
  3. Sample location and frequency
  4. Sample designation
  5. Sample equipment and procedures
  6. Sample handling and analysis.

- Quality Assurance Project Plan

  1. Project description
  2. Project organization and responsibilities
  3. Quality assurance objectives
  4. Site selection and sampling procedures
  5. Sample custody
  6. Calibration procedures and frequency
  7. Analytical procedures
  8. Data reduction, validation, and reporting
  9. Internal quality control checks
  10. Performance and systems audits
  11. Preventative maintenance
  12. Calculation of data quality indicators
  13. Corrective action
  14. Quality control reports to management
  15. References.

- Appendices

  1. Data quality objectives
  2. Example of standard operating procedure (SOP) for chain-of-custody procedures
  3. EPA methods used
  4. Standard operating procedure (SOP) for EPA methods used
  5. Quality Assurance Project Plan approval form.

3.9 Community Involvement

Community relations activities are required because treatability testing is potentially controversial within a community. An open forum assessment of issues and concerns the community may have about planned treatability testing will be conducted by the EG&G Community Relations Staff. This assessment will augment the previously prepared community relations plan for WAG-7. It will include a discussion of any issues unique to the proposed procedures such as onsite pilot testing, transporting contaminated materials offsite, schedule changes resulting from conducting bench or pilot tests, disposal of residuals, uncertainties pertaining to innovative technologies, and the degree of development of the technology being tested.[19]

Additional community relations implementation activities may be recommended in the assessment and may include a public meeting to explain the proposed bench or pilot test, the preparation of a fact sheet describing the technology and proposed test, a briefing to public officials about the treatability studies, and the conduct of small group consultations with members of the community concerned about actions at the site.[19]

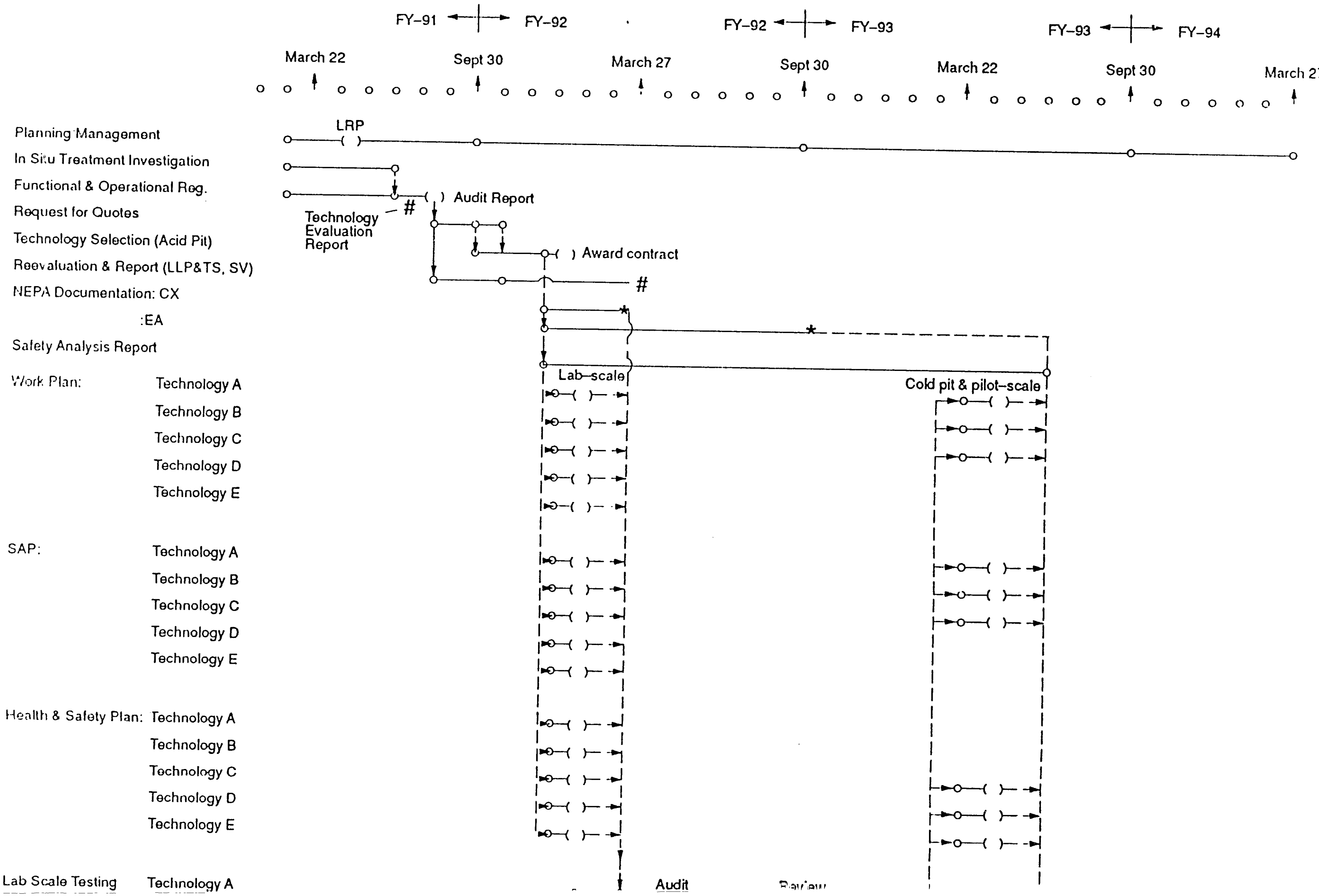
3.10 Proprietary Information

Responders to the Request For Quote (RFQ) may be asked to identify any proprietary information. If a Freedom of Information request form is filed, the responder will be notified and given the opportunity to react a copy of the information. In addition, if the responder wishes, a Nondisclosure form can be filed.

4. SCHEDULE

The ISTE project schedule is shown in Figure 2. As shown in the figure, a major emphasis has been placed on treatment investigation for FY-91. However, lab-scale tests will be performed in FY-92 and FY-93, and cold pit tests will be run in FY-93. Pilot-scale tests and field tests and evaluations will be performed in FY-94. This schedule assumes Environmental Restoration will provide ISTE with characterization information on the acid pit, soil vaults, and low-level pits and trenches as needed.

In Situ Treatment Evaluation Project Schedule



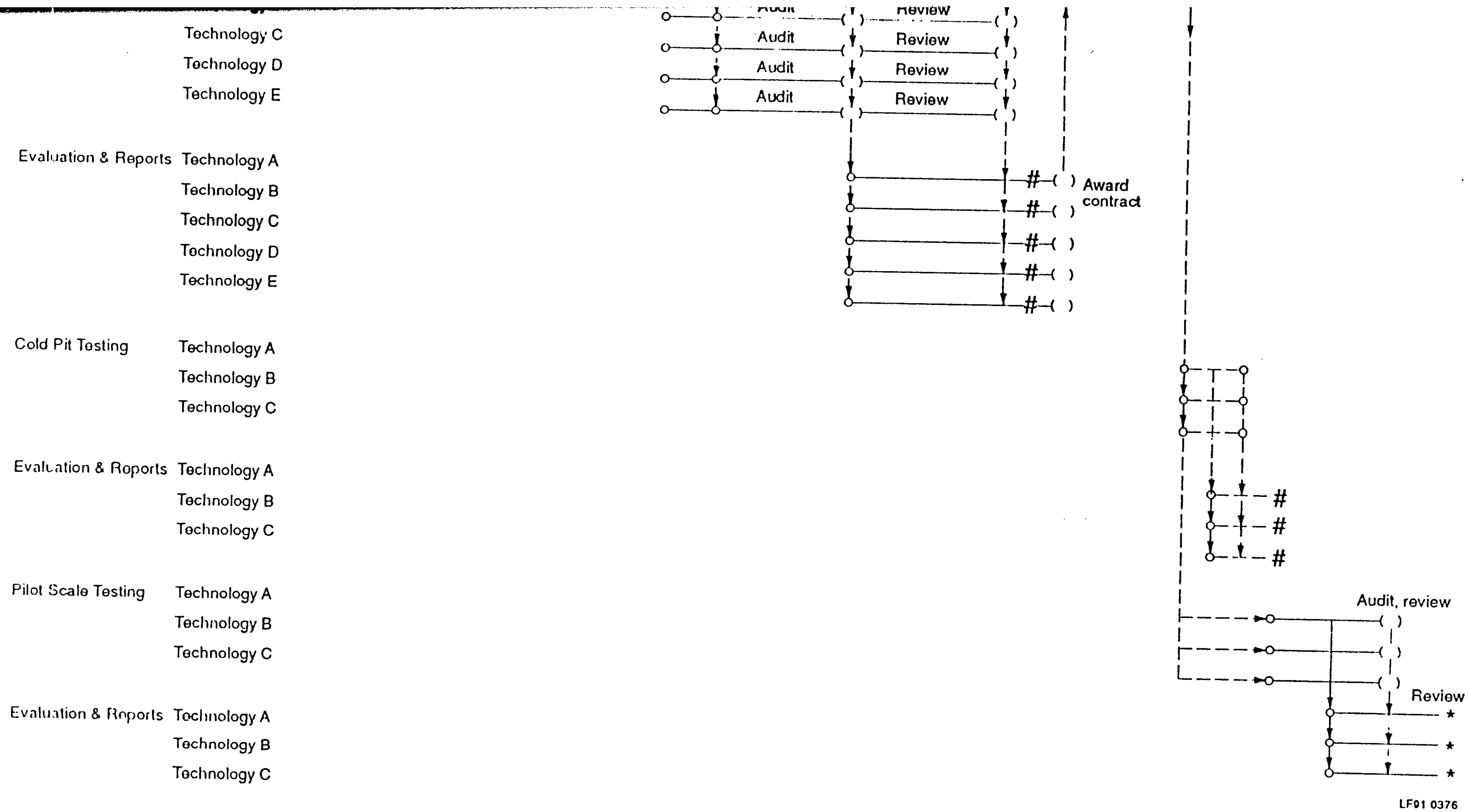


Figure 2. In Situ Treatment Evaluation Project Schedule.

5. RECOMMENDATIONS

This section presents the recommendations for in situ treatability studies for the acid pit, soil vaults, and low-level pits and trenches. Note that ex situ treatments were not included in this analysis. These recommendations are based on current information on the sites, and are contingent upon further site characterizations. Given further site characterization and/or additional information, the recommendations may change. Refer to Section 2 for technology description, evaluation, and ratings.

5.1 Acid Pit

5.1.1 Brief Site Description

The acid pit was excavated to the top of the basalt layer, then backfilled with 1 to 2 ft (.3 to .6 m) of soil. An estimated 6000 gal (22,500 L) of organic, inorganic, and radioactively contaminated wastes were released into the acid pit. It is assumed that no free liquids or rigid objects (such as metal drums, tools, vehicles, etc.) are currently present in the acid pit. Closure of the acid pit included a final soil cover, a few meters deep, with an overlaying vegetated layer.[1]

5.1.2 Treatability Study Recommendations

Based on the technology evaluations of Section 2, the following in situ technologies are expected to be the most successful for treating the acid pit:

1. DETOXIFIER™
2. Radio Frequency Heating followed by Solidification/Stabilization
3. Simultaneous Injection, Extraction, and Recharge followed by Solidification/ Stabilization
4. Solidification/Stabilization
5. Solidification/Stabilization and a Cap

6. Steam/Air Stripping followed by Solidification/Stabilization

7. Vacuum Extraction followed by Solidification/Stabilization.

Note: These technologies are listed alphabetically, and not in order of anticipated performance. Final selection of a technology(ies) for treatability study testing will be made after the acid pit has been characterized.

5.2 Soil Vaults

5.2.1 Brief Site Description

The soil vaults were constructed by auguring cylindrical holes into the ground. When the auger reached the basalt level, two ft of backfill was placed in the bottom of the hole. Containers of waste were then placed in the cylindrical holes and covered with a minimum of 3 ft (1 m) of soil. The waste stored in the soil vaults has a high radiation level, usually greater than 500 mR/hr. The containers used to hold the waste vary in size, shape, and material. Typically, the containers were steel canisters 4 ft (1.22 m) in diameter and 8 ft (2.44 m) in height.

Because of the possibility that the waste in the soil vaults is unstable or explosive, a technology that physically or thermally disturbs (stirs, crushes, melts, etc.) the waste and/or the waste containers is considered undesirable. Because a technology that is both appropriate and available has not been found to treat the toxicity or volume of this type of waste, containing the waste in the soil vaults is recommended. If further treatment is desired, containment may be considered an interim solution until a more appropriate technology is developed for handling this complicated type of waste. In addition, containment will provide future remedial efforts with protection from contaminant migration during any necessary testing or treatment.

5.2.2 Treatability Study Recommendations

Based on the technology evaluations of Section 2, the following in situ technologies are expected to be the most successful in treating the soil vaults:

- Slurry Wall and Bottom Sealing
- Slurry Wall and a Cap
- Slurry Wall and Bottom Sealing and a Cap
- Slurry Wall followed by Steam/Air Stripping or Vacuum Extraction and a Cap
- Soil/Cement Wall and Bottom Sealing
- Soil/Cement Wall and a Cap
- Soil/Cement Wall, Bottom Sealing, and a Cap
- Soil/Cement Wall followed by Steam/Air Stripping or Vacuum Extraction and a Cap
- Steam/Air Stripping or Vacuum Extraction followed by the Fluidized-Bed Zeolite System
- Steam/Air Stripping or Vacuum Extraction followed by the Fluidized-Bed Zeolite System and a Cap.

Note: These technologies are listed alphabetically, and not in order of anticipated performance.

Final selection of a technology(ies) for treatability study testing will be made after the soil vaults have been characterized.

5.3 Low-Level Pits and Trenches

5.3.1 Brief Site Description

The SDA contains numerous types of waste containers. The containers stored in the SDA include, but are not limited to, steel drums, cardboard boxes, and wooden boxes.[a]

The SDA also contains numerous forms of waste. The waste stored in the SDA includes, but is not limited to the following: construction equipment and materials (such as lumber, fuse boxes, insulation, etc.); laboratory equipment and materials (such as hoods, glassware, solutions stabilized in concrete or plaster, etc.); process equipment (such as tanks, organic wastes, HEPA filters, etc.); maintenance equipment (such as hand tools, cranes, welders, etc.); decontamination materials (such as rags, floor sweepings, steel wool, etc.); and miscellaneous materials (such as sewer sludge, animal remains, jet engines, vehicles, Test Reactor Area fuel, etc.).[b] (Also see reference 3.)

Because of the possibility that the waste in the pits and trenches is unstable or explosive, a technology that physically or thermally disturbs (stirs, crushes, melts, etc.) the waste and/or the waste containers is considered undesirable. Because a technology that is both appropriate and available has not been found to treat the toxicity or volume of this type of waste, containing the waste in the pits and trenches is recommended. If further treatment is desired, containment may be considered an interim solution until a more appropriate technology is developed for handling this complicated type of waste.

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a. This listing is for the entire SDA. The makeup of the waste in the low-level pits and trenches is considered to be similar and is assumed for this work to be represented by this description.

b. This listing is for the entire SDA. For the purpose of this report, it is considered to be representative of the makeup of the low-level pits and trenches waste.

In addition, containment will provide future remedial efforts with protection from contaminant migration during any necessary testing or treatment.

5.3.2 Treatability Study Recommendations

Based on the technology evaluations of Section 2, the following in situ technologies are expected to be the most successful in treating the low-level pits and trenches:

- Slurry Wall and Bottom Sealing
- Slurry Wall and a Cap
- Slurry Wall and Bottom Sealing and a Cap
- Slurry Wall followed by Steam/Air Stripping or Vacuum Extraction and a Cap
- Soil/Cement Wall and Bottom Sealing
- Soil/Cement Wall and a Cap
- Soil/Cement Wall, Bottom Sealing, and a Cap
- Soil/Cement Wall followed by Steam/Air Stripping or Vacuum Extraction and a Cap
- Steam/Air Stripping or Vacuum Extraction followed by the Fluidized-Bed Zeolite System
- Steam/Air Stripping or Vacuum Extraction followed by the Fluidized-Bed Zeolite System and a Cap.

Note: These technologies are listed alphabetically, and not in order of anticipated performance.

Final selection of a technology(ies) for treatability study testing will be made after the low-level pits and trenches have been characterized.

6. REFERENCES

1. R. M. Lugar, *Radioactive Waste Management Complex Subpit Sampling and Analysis Plan*, Rev.1, EGG-WM-8934, September, 1990, pp. 1/1-1/12.

2. *RCRA Facility Investigation Work Plan*, Rev. 1, EGG-WM-8219, December 1988, pp. 6-20.

3. D. A. Arrenholz, J. L. Knight, *A Brief Analysis and Description of Transuranic Wastes in the Subsurface Disposal Area of the Radioactive Waste Management Complex at INEL*, EGG-WM-9438, February 1991.

4. R. M. Lugar, *Radioactive Waste Management Complex Subsurface Disposal Area Acid Pit Investigation: Sampling and Analysis Plan (Draft)*, EGG-WM-9638, May 1991, Rev. 0.

5. D. Varacalle, *Environmental Evaluation Study of INEL-Owned Heavy Equipment for TRU Waste Exhumation*, Environmental and Earth Sciences No. EE-87-004, May 1987, pp. 7-11.

6. USEPA, *Handbook on In Situ Treatment of Hazardous Waste-Contaminated Soils*, EPA/540/2-90/002, January 1990.

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10. Hayward Baker Environmental, *Environmental Contracting* (brochure).

11. Y. B. Acar, R. J. Gale, J. Courtney, and M. Scott, *Feasibility of Removing Plutonium from Soils by Electrokinetics (A Laboratory Study)*, as submitted to J. Weidner, EG&G Idaho, Inc., Baton Rouge, Louisiana, January 1991.

12. Y. B. Acar, and J. Hamed, "Electrokinetic Soil Processing in Waste Remediation/Treatment (Synthesis of Available Data)," *Transportation Research Board, 70th Annual Meeting, "Remediation of Contaminated Soil Session,"* Washington, D.C., January 1991.

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14. L. I. Khan and S. Pamukcu, "Validity of Electro-Osmosis for Soil Decontamination," *Environmental Engineering, Proceedings of the 1989 Specialty Conference*, Austin, Texas, July 10-12, 1989, American Society of Civil Engineers, New York, New York.

15. L. I. Khan, S. Pamukcu, and H. Y. Fang, "A New Theory to Electroosmosis in Soil," submitted to: *The Journal of the Geotechnical Engineering Division*, American Society of Civil Engineers, New York, New York.

16. J. Hamed, Y. B. Acar, and R. J. Gale, "Pb(II) Removal from Kaolinite by Electrokinetics," *Journal of Geotechnical Engineering*, Vol. 117, No. 2, February, 1991.

17. USEPA, *Inventory of Treatability Study Vendors*, Volume 1, EPA/540/2-90/003a, March 1990.

18. In Situ-Fixation Company, *The Technology and Application of Solidification/Stabilization Remedial Process.*

19. USEPA, *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA*, EPA/540/G-89/004, October 1988.

20. V. Hodge et al., *Final Report for Preliminary Remedial Action Objectives and Remediation Technologies for the Subsurface Disposal Area*, EGG-WM-8434, March 1989.

21. USEPA, *Guide for Conducting Treatability Studies Under CERCLA*, Interim Final, EPA/540/2-89/058, December, 1989.

22. System Design Study, *Requirements of Interim Containment (IC) at Radioactive Waste Management Complex (RWMC)*, Idaho National Engineering Laboratory (INEL).

23. C. Mullen et al., *Remedial Investigation/Feasibility Study Work Plan for the Subsurface Disposal Area, Radioactive Waste Management Complex at the INEL*, EGG-WM-8776, December 1989.

24. EG&G Idaho Inc., *Radiological Controls Manual*, No. 2, March 1991.

APPENDIX A

COMMERCE BUSINESS DAILY NOTICES

APPENDIX A

COMMERCE BUSINESS DAILY NOTICES

U. S. Department of Commerce
Commerce Business Daily
P. O. Box 5999
Chicago, IL 60680

Synopsis No.
EG&G Idaho, Inc., P. O. Box 1625, Idaho Falls, ID 83402-3930
An Expression of Interest for Remediation Technologies
Contact: D. E. Shropshire

EG&G Idaho, Inc. is requesting an expression of interest for providing treatability studies on environmental restoration technologies which are applicable to the treatment of buried waste. Interest is also desired for demonstration of nonintrusive characterization technologies applicable to subsurface contamination. The Environmental Restoration Program and the Technology Demonstration group at the Idaho National Engineering Laboratory (INEL) seek to evaluate technologies which may provide effective, timesaving, and cost effective remedial solutions for buried waste at the INEL, and support longer term DOE needs. The technologies should treat, all or in part, waste forms consisting of a wide variety of materials including barrels and boxes containing sludge, waste from Rocky Flats, organics (including oil and solvents), rags, papers, and other miscellaneous material which is contaminated with varying amounts of plutonium (probably as an oxide) and other radionuclides. Treatments that satisfy, in whole or part, the CERCLA objectives of toxicity reduction, volume reduction, stabilization, immobilization, etc., are needed for the conduct of treatability studies. Characterization needs include locating, characterizing, and three dimensional mapping of vadose zones, tracking the migration of contaminants, and characterization of soils. Individuals, industry, academic institutions, nonprofit organization, or other private entities are invited to respond to this announcement. Respondents should send their organizational capabilities and qualification, the stage of technology application, examples of prior use, references to previous treatability studies, to David E. Shropshire, EG&G

Idaho, Inc., P.O. Box 1625, Idaho Falls, ID 83415-3930. Any responses without the requisite qualifications statements may be considered nonresponsive. Thsi expression of interest may lead to future competitive solicitations between respondents. Organizations interested in cost-sharing the development and/or treatability study costs at DOE facilities should show their willingness, and the terms of such agreements. This solicitation is totally separate from all other solicitations requesting Environmental Restoration or Demonstration Test & Evaluation funding. This solicitiation will close 20 days after publication.

U. S. Department of Commerce
Commerce Business Daily
P. O. Box 5999
Chicago, IL 60680

Synopsis No.
EG&G Idaho, Inc., P. O. Box 1625, Idaho Falls, ID 83415-3416
An Expression of Interest for In Situ Remediation Technologies
Contact: R. A. Hyde

EG&G Idaho, Inc. is requesting an expression of interest for providing treatability studies on environmental restoration technologies which are applicable to In Situ treatment or containment of buried waste. The Environmental Restoration Program and the Technology Demonstration group at the Idaho National Engineering Laboratory (INEL) seek to evaluate technologies which may provide effective, timesaving, and cost effective remedial solutions for buried waste at the INEL to support DOE needs. The technologies should treat waste forms consisting of a wide variety of materials including barrels and boxes containing sludge, organics (including oil and solvents), rags, papers, and other miscellaneous material which is contaminated with varying amounts of plutonium (probably as an oxide) and other radionuclides. Treatments that satisfy, in whole or part, the CERCLA objectives of reduction of toxicity, mobility, and/or volume are needed for the conduct of treatability studies. Individuals, industry, academic institutions, nonprofit organizations, or other private entities are invited to respond to this announcement. Respondents should send their organizational capabilities and qualifications, the stage of technology application, examples (if any) of prior use, and references in writing to previous treatability studies to Reva Hyde, EG&G Idaho, Inc., P. O. Box 1625, Idaho Falls, ID 83415-3416. Any written responses without the requisite qualifications statements may be considered nonresponsive. This expression of interest may lead to future competitive solicitations between respondents. Organizations interested in cost-sharing the development and/or treatability study costs at DOE facilities should show their willingness and the terms of such agreements. This solicitation is totally separate from all other solicitations requesting Environmental Restoration or Demonstration, Test, & Evaluation funding. This solicitation will close 15 days after publication.

APPENDIX B

DETAILED INFORMATION ON SELECTED TECHNOLOGIES AND VENDORS

APPENDIX B

CONTENTS

APPENDIX B

DETAILED INFORMATION ON SELECTED TECHNOLOGIES AND VENDORS

INTRODUCTION

The information contained in this appendix was compiled from information prepared by the individual vendors/universities, correspondence with vendors/universities, and publicly available research information. It is noted where information was obtained from responses to the Commerce Business Daily solicitation (see Appendix A).

EG&G Idaho is not responsible for the accuracy of information supplied by vendors/universities.

TECHNOLOGY AND DESCRIPTION

Biological Treatment - Bioremediation/Bioaccumulation - Allied-Signal Aerospace

Bioremediation

The bioremediation process utilizes the natural activity of microorganisms such as bacteria or fungi to decontaminate polluted soils and groundwater. These microorganisms alter the contaminants to obtain nutrients or energy to sustain their own life cycles.

Reductive dechlorination is a specific bioremediation process recommended to treat chlorinated ethenes and ethanes in the acid pit. An aqueous remediating fluid with anaerobic microbes and a nutrient and reducing source is added to the soil. These microbes metabolically produce reducing equivalents that cleave chlorine atoms from chlorinated compounds. The resulting compounds adsorb to the soil particles less readily and can then be further biodegraded and removed.

The next step involves recovering these now less-chlorinated compounds by extracting the remediating fluid. The fluid is removed from the soil through extraction wells and treated in two above-ground bioreactors.

In the first reactor, the anaerobic reductive dechlorination process is completed. In the second, the solution is prepared to be used for in situ reduction and immobilization of the transition metals.

Bioaccumulation

Precipitation and immobilization of metals is a result of this process. The bacterial metabolism produces low concentrations of hydrogen sulfide that react with metals such as Fe, Cu, Zn, and Co to form insoluble metal sulfides. Cesium and strontium (also expected to exist in the acid pit) are less likely to form insoluble compounds; but with additional processes, may become immobilized by binding to polysaccharide coats of the reducing microbes.

Applications

Bioremediation is applicable for organic contamination; the reductive dechlorination process is recommended for soil contaminated with chlorinated solvents such as tetrachloroethylene, trichloroethylene, or carbon tetrachloride. Bioaccumulation has been applied to metal contaminated soils, ground water and surface water.

Effectiveness

In laboratory tests, bioremediation of chlorinated solvents have shown greater than 90% reduction of contaminants. Residual chlorinated solvent concentrations of less than 1 ppb may be achieved with an aggressive biotreatment protocol.

The mobility of toxic metals should be reduced by 90% or better by the proposed bioremediation/bioaccumulation process.

No exhaust gases or air emissions should result from biological treatments.

A physical containment, such as a cap and slurry wall or capture wells surrounding the site, should be implemented to prevent mobility and offsite migration of contaminants occurs.

EG&G Comments. The capability of different organics to biodegrade varies with each particular compound. For example, research suggests that the breakdown of carbon tetrachloride is difficult, while trichloroethylene, tricnloroethane, tetrachloroethylene, and tributylphosphate break down relatively easily. All of these contaminants are expected to exist at the INEL RWMC.

Implementability

In situ bioremediation may require 20 to 40 months for complete remediation.

Proper soil moisture, texture, density, and clay content are necessary environmental parameters for bioremediation and should have the following qualities:

- Soil pH of neutral to slightly alkaline
- Salinity less than 7%
- At least 1.7×10^{-1} lbm/gal (2 mg/L) of dissolved oxygen
- Inorganic and trace nutrients.

Most of these parameters can be manipulated during bioremediation. No problems are anticipated with construction or implementation.

EG&G Comments. Very in-depth site and waste characterization is needed for successful bioremediation. This is likely to take considerable time and incur high initial costs. A study should also be performed to determine the requirements for encouraging the biological process in order to assess the feasibility of using bioremediation.

The conditions that require definition are pH, osmotic tolerance, temperature, moisture, substrate/nutrients, analogue enrichment, enzyme induction, and enzyme catabolite repression. Actual data needed must be determined by laboratory study. Specifics regarding these conditions are listed as follows:

- The required pH is 7, but for specific organisms and organic compounds, it may range from 6 to 8
- Osmotic tolerance relates to the organisms' tolerance to salt concentration in the contaminated media and these organisms can become accustomed to a wide variation over a period of time
- The normal temperature range is 32°-77°F (0-25°C)

- The moisture, as measured in relative humidity, must be greater than 40%

- Substrate/nutrients act as the organism's carbon source. Nitrogen, phosphorous, carbonates, and sulfur provide energy

- In the breakdown or reduction/oxidation of the carbon source, an electron acceptor is required and may take the form of oxygen, nitrate, sulfate, carbon dioxide, or a specific organic. In cases of complex organic compounds, an analogue enrichment (addition of a simpler organic to assist in the breakdown) may be required

- Enzyme induction is the incorporation of compatible enzymes to increase the REDOX by the organisms

- Enzyme catabolite repression may occur if a suitable or highly metabolized organic is present. The desired organic for breakdown will be repressed by the microorganisms that will break the simpler organic down first

- The power requirements for bioremediation are negligible.

Cost

Rough cost estimates of remediating a site similar in size to the acid pit:

Capital Costs	$ 900,000
Indirect Costs	300,000
Annual O&M Costs	250,000
Total Costs	$1,450,000

Allied-Signal is not interested in providing necessary containment, but has estimated the cost of cap and slurry wall at $\$3/ft^2$ ($\$32/m^2$).

Vendor

Allied-Signal Aerospace
AiResearch LA Div.
6201 West Imperial Highway
Los Angeles, CA 90045
Tel: (213) 512-4600 (Susan Fuhs)

Contacts: Susan Fuhs, Bill Ferris, Yong Kim, Steve Lupton, Anil Trivedi.

Experience/Licenses

A conglomerate of a chemical company, an oil company, and two aerospace companies, Allied-Signal has been involved in cleaning up a variety of sites. Bioremediation is currently being developed by business units within the corporation for implementation of pilot scale tests this year.

Allied-Signal retains permits for offsite activities such as feasibility tests on contaminated soil.

Sources of Information

Private communication between Scott C. Manatt, Allied-Signal Aerospace Corporation, AiResearch Division, and David E. Shropshire, EG&G Idaho, Inc. (response to EG&G's January 25, 1991 CBD solicitations), April 1991.

Private communication between A. W. (Bill) Ferris, Allied-Signal Aerospace Corporation, AiResearch Division, and Reva A. Hyde, EG&G Idaho, Inc. (response to EG&G's April 5, 1991 CBD solicitations), April 1991.

Private communication between Dr. Susan Fuhs, Allied-Signal Aerospace Corporation, AiResearch Los Angeles Division, Torrence, California, and Stephanie Walker, EG&G Idaho, Inc., April 1991.

Private communication between Kurt M. Shewfelt, Allied-Signal Aerospace Corporation, AiResearch Los Angeles Division, Torrence, California, and Stephanie Walker, EG&G Idaho, Inc., April 1991.

Allied-Signal Inc., *A World Leader: Aerospace, Automotive, Engineered Materials*, Allied-Signal Inc., Morristown, New Jersey.

TECHNOLOGY AND DESCRIPTION

Biological Treatment - Bioremediation - Celgene Corp.

The bioremediation process utilizes the natural activity of microorganisms such as bacteria or fungi to decontaminate polluted soils and groundwater. These microorganisms alter the contaminants to obtain nutrients or energy to sustain their own life cycles.

Application

This process is best applied to organic contamination.

Effectiveness

The preliminary goal for destruction of organics is greater than 99.9%. Organics will be destroyed by this treatment to a target goal of less than 10 ppb residual compounds.

This process will leave any low-level radioactive waste as a treatment residual.

Controllable environmental impacts that may be associated with this technology include the existence of acid effluents, vapors contaminated with hazardous organics, and soils with low-level waste.

During construction, air quality will need to be monitored and dusts minimized.

EG&G Comments. The capability of different organics to biodegrade varies with each particular compound. For example, research suggests that the breakdown of carbon tetrachloride is difficult, while trichloroethylene, trichloroethane, tetrachloroethylene, and tributylphosphate break down relatively easily. All of these contaminants are expected to exist at the INEL RWMC.

Implementability

Although cold weather slows (or even stops) the bioremediation process, warm weather begins the process again without reapplication of microorganisms. Complete bioremediation of a site may require 1-3 years. Acceleration of this schedule is possible, but will increase costs.

Technologies are well-developed and are currently being applied to a number of project sites in both the private and government sectors.

No problems are anticipated with construction or implementation.

EG&G Comments. Very in-depth site and waste characterization is needed for successful bioremediation. This is likely to take considerable time and incur high initial costs. A study should also be performed to determine the requirements for encouraging the biological process.

The general conditions that require definition are pH, osmotic tolerance, temperature, moisture, substrate/nutrients, analogue enrichment, enzyme induction, and enzyme catabolite repression. Actual needed data must be determined by laboratory studies. Typical values for these conditions are listed as follows:

- The required pH is typically 7, but for specific organisms and organic compounds, it may range from 6 to 8
- Osmotic tolerance relates to the organisms' tolerance to salt concentration in the contaminated media and these organisms can become accustomed to a wide variation over a period of time
- The normal temperature range is 32-77°F (0-25°C)

- The moisture as measured in relative humidity must be greater than 40%

- Substrate/nutrients act as the organism's carbon source. Nitrogen, phosphorous, carbonates, and sulfur provide energy

- In the breakdown or reduction/oxidation of the carbon source, an electron acceptor is required and may be oxygen, nitrate, sulfate, carbon dioxide, or a specific organic. In cases of complex organic compounds, an analogue enrichment (addition of a simpler organic to assist in the breakdown) may be required

- Enzyme induction is the incorporation of compatible enzymes to increase the REDOX by the organisms

- Enzyme catabolite repression may occur if a suitable or highly metabolized organic is present. The desired organic for breakdown will be repressed by the microorganisms that will break the simpler organic down first

- The power requirements for bioremediation are negligible.

Cost

Site characterization was required by the Celgene, Corp. for cost estimates.

Vendor

Celgene Corp.(in association with Ebasco Environmental)
7 Powder Horn Drive
P.O. Box 4914
Warren, NJ 07059
Contact: Dr. George Pierce (Celgene)
Tel: (201) 805-3937

Experience/Licenses

Both Celgene and Ebasco have permits to handle hazardous wastes. Celgene also has a Nuclear Regulatory Commission (NRC) license for selected beta and gamma emitters.

Ebasco is currently applying bioremediation at a number of project sites in both the private and government sector. Ebasco is experienced in performing treatability studies, bench and pilot-scale testing and remedial design using bioremediation technologies as contract work for USEPA at numerous Superfund sites nationwide.

Sources of Information

Private communication between Dr. George Pierce, Celgene Corporation, and David E. Shropshire, EG&G Idaho, Inc. (response to EG&G's January 25, 1991 CBD solicitations), February 1991.

Private communications between Dr. George Pierce, Celgene Corporation, Warren, New Jersey, and Stephanie Walker, EG&G Idaho, Inc., April 1991.

TECHNOLOGY AND DESCRIPTION

Biological Treatment - Bioremediation - CEC, Inc.

The basic process proposed is to neutralize the pH and follow with bacteria inoculations. A proprietary bacteria culture will treat organic contamination, while heavy metals and radionuclides will require a separate treatment.

Application

The bioremediation process has been demonstrated to be effective in soils and groundwater contaminated with petroleum hydrocarbons. Indications are that similar results with halogenated compounds are possible, but this hasn't been demonstrated in the field.

Effectiveness

Bioremediation has been shown to degrade petroleum hydrocarbons to less than detectible limits. Lab studies indicate similar results should be possible with chlorinated hydrocarbons, but this has not been demonstrated in the field.

- The process has no effect on radionuclides or heavy metal contamination.
- Bioremediation is relatively safe for the public, the workers, and the environment.

EG&G Comments. The capability of different organics to biodegrade varies with each particular compound. For example, research suggests that the breakdown of carbon tetrachloride is difficult, while trichloroethylene, trichloroethane, tetrachloroethylene, and tributylphosphate break down relatively easily. All of these contaminants are expected to exist at the INEL RWMC.

Implementability

Bioremediation requires more time than many other remedial technologies. However, the technology is fairly well developed and has worked successfully on treating petroleum hydrocarbons. Difficulties with implementing this process should be minimal.

Implementation of this technology requires the addition of liquid to the soil. To prevent the spread of contamination, the site needs to be contained.

The amount of time for remediation of a site the size of the acid pit is estimated to be from 6 months to 1 year.

EG&G Comments. Very in-depth site and waste characterization is needed for successful bioremediation. This is likely to take considerable time and incur high initial costs. A study should also be performed to determine the requirements for encouraging the biological process.

The conditions that require definition are pH, osmotic tolerance, temperature, moisture, substrate/nutrients, analogue enrichment, enzyme induction, and enzyme catabolite repression. Actual data needed must be determined by laboratory study. Specifics regarding these conditions are listed as follows:

- The required pH is typically 7, but for specific organisms and organic compounds, it may range from 6 to 8
- Osmotic tolerance relates to the organisms' tolerance to salt concentration in the contaminated media and these organisms can become accustomed to a wide variation over a period of time
- The normal temperature range is 32-77°F (0-25°C)
- The moisture as measured in relative humidity must be greater than 40%
- The substrate/nutrients are the carbon source, also may include nitrogen, phosphorous, carbonates, and sulfur, which the organisms require for their energy source

- In the breakdown or reduction/oxidation of the carbon source, an electron acceptor is required and may take the form of oxygen, nitrate, sulfate, carbon dioxide, or a specific organic. In cases of complex organic compounds, an analogue enrichment (addition of a simpler organic to assist in the breakdown) may be required

- Enzyme induction is the incorporation of compatible enzymes to increase the REDOX by the organisms

- Enzyme catabolite repression may occur if a suitable or highly metabolized organic is present. The desired organic for breakdown will be repressed by the microorganisms that will break the simpler organic down first

- The power requirements for bioremediation are negligible.

Cost

Estimated costs of remediating a site the size of the acid pit are as follows:

Direct capital costs: $130,000 to $170,000

Indirect capital costs: $280,000 to $300,000

Annual operating costs: $1,580,000 to 1,950,000

Total project cost is estimated to be between $1,200,000 and $2,420,000.

Vendor

Certified Environmental Consulting, Inc. (CEC)
140 West Industrial Way
Benicia, CA 94510-1016
Phone: (707) 745-0171
Contact: Joseph S. Staska, Paul LeCheminant

Experience/Licenses

CEC was formed in 1988 and personnel have experience in conducting hazardous waste site assessment and remedial action programs for contaminated soil and groundwater.

Sources of Information

Private communication between Joseph S. Staska, CEC, Benicia, California, and Stephanie Walker, EG&G Idaho, Inc., April 1991.

Private communication between Paul LeCheminant, CEC, Benicia, California, and Stephanie Walker, EG&G Idaho, Inc., April 1991.

TECHNOLOGY AND DESCRIPTION

Biological Treatment - Biodegredation Accelerating Agent - H_2O Chemists

H_2O Chemists, Inc. has developed a base product called Nutri-Bio 1000; a hydrocarbon biodegradation accelerating agent that stimulates the growth of indigenous microbes. Nutri-Bio 1000 may be applied to water or soil.

Microbes capable of biodegrading organic contaminants occur naturally at a polluted site, but without help, the process will be slow and necessary conditions for degradation may not persist.

Application

This process is best applied to organic contamination.

Effectiveness

Organics are completely eliminated or detoxified.

The success of bioremediation is site-specific, and not all sites are suitable for the treatment.

Biodegradation rate is dependent on many factors, such as composition and size of soil microbial populations, energy sources, pH, temperature, moisture, nutrient elements, organic chemical concentrations, oxygen and redox potential, and adsorption.

EG&G Comments. The capability of different organics to biodegrade varies with each particular compound. For example, research suggests that the breakdown of carbon tetrachloride is difficult, while trichloroethylene, trichloroethane, tetrachloroethylene, and tributylphosphate break down relatively easily. All of these contaminants are expected to exist at the INEL RWMC.

Implementability

The feasibility of in situ biological treatment depends on the permeability and conductivity of the soil as well as the ability to control and contain the area of treatment.

Nutri-Bio 1000 has extensive laboratory testing and is planning a number of field applications.

EG&G Comments. Very in-depth site and waste characterization is needed for successful bioremediation. This is likely to take considerable time and incur high initial costs. A study should also be performed to determine the requirements for encouraging the biological process.

The general conditions that require definition are pH, osmotic tolerance, temperature, moisture, substrate/nutrients, analogue enrichment, enzyme induction, and enzyme catabolite repression. Actual needed data must be determined by laboratory study. Specifics regarding these conditions are listed as follows:

- The required pH is typically 7, but for specific organisms and organic compounds, it may range from 6 to 8
- Osmotic tolerance relates to the organisms' tolerance to salt concentration in the contaminated media and these organisms can become accustomed to a wide variation over a period of time
- The normal temperature range is 32-77°F (0-25°C)
- The moisture as measured in relative humidity must be greater than 40%
- The substrate/nutrients are the carbon source, also may include nitrogen, phosphorous, carbonates, and sulfur, which the organisms require for their energy source
- In the breakdown or reduction/oxidation of the carbon source, an electron acceptor is required and may take the form of oxygen, nitrate, sulfate, carbon dioxide, or a specific organic. In cases of complex organic compounds, an analogue enrichment (addition of a simpler organic to assist in the breakdown) may be required

- Enzyme induction is the incorporation of compatible enzymes to increase the REDOX by the organisms

- Enzyme catabolite repression may occur if a suitable or highly metabolized organic is present. The desired organic for breakdown will be repressed by the microorganisms that will break the simpler organic down first

- The power requirements for bioremediation are negligible.

Cost

No cost estimates have been made.

Vendor

H_2O Chemists, Inc.
N62 W22632 Village Drive
Sussex, WI 53089
Contact: Carol Wilson
Tel: (414) 246-6922
(800) 833-2334

or

1548 North Tech Blvd., Suite 103
Gilbert, Arizona 85234
Contact: Neil Stillman
Tel: (602) 497-3898
(800) 446-3107.

Experience/Licenses

H_2O Chemists, Inc. is the research, development, and consulting affiliate of A&V Incorporated, and employs 45 people.

The company is usually brought in after the preliminary site analysis is completed and contamination type and quantity is established.

The principals of the company have over 40 years of combined experience in water treatment.

Sources of Information

Private communication between Carol Wilson, H_2O Chemists, Inc., Gilbert, Arizona, and Stephanie Walker, EG&G Idaho, Inc. May 1991.

TECHNOLOGY AND DESCRIPTION

Biological Treatment - Dual Auger System - In-Situ Fixation Co.

The In-Situ Fixation Company uses a *dual auger system* to drill into contaminated soils and inject microorganism mixtures, water, and nutrients.

Application

This process is applicable to soils contaminated with organics.

Effectiveness

This process increases the quality and speed of biodegradation in contaminated soils.

Alkaline or acidic conditions, high concentrations of heavy metal, or nonbiodegradable organics could interfere with the process.

Volatile organics may volatilize during the process. This problem can be solved by capturing the gases with an added hood around the auger system. The gases can then be treated separately.

Soil more than 100 ft (30.48 m) deep can be treated.

The mixing action of this auger system eliminates pockets of contamination that other methods may bypass.

EG&G Comments. The capability of different organics to biodegrade varies with each particular compound. For example, research suggests that the breakdown of carbon tetrachloride is difficult, while trichloroethylene, trichloroethane, tetrachloroethylene, and tributylphosphate break down relatively easily. All of these contaminants are expected to exist at the INEL RWMC.

Implementability

A standard backhoe powers and carries the 5-ft (1.5-m) diameter auger system. The auger has hollow shafts through which the microorganism and nutrient mixture passes, and mixing blades blend the soil and mixture. The system mixes in an overlapping manner to treat the soil completely.

EG&G Comments. Very in-depth site and waste characterization is needed for successful bioremediation. This is likely to take considerable time and incur high initial costs. A study should also be performed to determine the requirements for encouraging the biological process.

The general conditions that require definition are pH, osmotic tolerance, temperature, moisture, substrate/nutrients, analogue enrichment, enzyme induction, and enzyme catabolite repression. Actual needed data must be determined by laboratory study. Typical values for these conditions are listed as follows:

- The required pH is typically 7, but for specific organisms and organic compounds, it may range from 6 to 8
- Osmotic tolerance relates to the organisms' tolerance to salt concentration in the contaminated media and these organisms can become accustomed to a wide variation over a period of time
- The normal temperature range is 32-77°F (0-25°C)
- The moisture as measured in relative humidity must be greater than 40%
- The substrate/nutrients are the carbon source, also may include nitrogen, phosphorous, carbonates, and sulfur, which the organisms require for their energy source
- In the breakdown or reduction/oxidation of the carbon source, an electron acceptor is required and may take the form of oxygen, nitrate, sulfate, carbon dioxide, or a specific organic. In cases of complex organic compounds, an analogue enrichment (addition of a simpler organic to assist in the breakdown) may be required
- Enzyme induction is the incorporation of compatible enzymes to increase the REDOX by the organisms

- Enzyme catabolite repression may occur if a suitable or highly metabolized organic is present. The desired organic for breakdown will be repressed by the microorganisms that will break the simpler organic down first

- The power requirements for bioremediation are negligible.

Cost

No cost estimates have been made.

Vendor

In-Situ Fixation Company
P.O. Box 516
Chandler, Arizona 85244-0516
Contact: Richard P. Murray
Technology Developer
Tel: (602) 821-0409

Experience/Licenses

The In-Situ Fixation Company also uses the dual auger system to solidify/stabilize inorganic contaminated soils by injecting reagent slurry into the soil.

Sources of Information

Brochure from the In-Situ Fixation Company, Division of the Richard P. Murray Co., Inc., no title. For further information, contact:

Richard P. Murray
Technology Developer
In-Situ Fixation Company
Chandler, Arizona 85244-0516
Tel: (602) 821-0409

TECHNOLOGY AND DESCRIPTION

Containment Methods - Polymer Concrete Barrier - 3M Corp.

This is a containment technology that uses high strength, impervious polymer concrete to create an in situ barrier. Sealant materials are used that consolidate an earth/sand/gravel matrix into a high strength, impervious polymer concrete useful for the formation of barriers in the earth. These materials have very good chemical resistance and are typically two or three times stronger than structural concrete. Permanently installed monitors such as pH sensors and radiation detectors installed around the exterior of the perimeter of the site can be used to ensure that the waste does not breach the barrier.

Application(s)

This technology is effective for the containment of most contaminated waste. Residual risk from the untreated waste is greatly reduced once contained within a perimeter barrier with a sealant cap (it may also be composed of polymer concrete). This technology could be used in conjunction with other in situ technologies.

Effectiveness

Addresses the principal threat by containing waste materials to ensure they do not migrate beyond the barrier, around the perimeter, or through the top.

No material will be destroyed or treated. It will simply be contained.

Residual risk from the untreated waste and the mobility of the contaminants will be greatly reduced.

Implementability

Equipment, specialists, and materials are available in the industry today.

Although the basic chemistry for this technology is commercially available, full demonstration has not been conducted, and further refinement may be necessary.

Cost

Assuming a 3 ft (.9 m) thick by 18 ft (5.5 m) deep perimeter barrier with a 6 in. (15 cm) thick cap in soil with a porosity of 10%, a rough estimate of materials cost is about $1.5 to $2 million.

Equipment, labor, and site development costs are estimated at $0.5 million.

More costs will be incurred if a bottom barrier is required.

Engineering, administration, product refinement and testing, coordination, and shakedown are estimated to cost $0.5 to 1 million.

Vendor

3M Corporation
Federal Systems Department
Building 224-2S-25
St. Paul, MN 55144-1000
Tel: (612) 733-4043
Contact: John (Jack) F. Evert

Experience/Licenses

3M has about 89,000 employees worldwide with very broad expertise. Specifically related to remediation projects, 3M has over 20 years of development and field experience in water proofing and sealing systems. Experience of personnel involved in this area is extensive. The company has been intensively involved in waste handling, treatment, and remediation primarily on an internal basis.

Sources of Information

Private communication with Mr. Jack F. Evert, 3M Corporation, to Mathew W. Roy, EG&G Idaho, Inc., April 12, 1991.

Private communication with Mr. Jack F. Evert, 3M Corporation, to David E. Shropshire, EG&G Idaho, Inc. (response to EG&G's January 25, 1991 CBD solicitation), February 12, 1991.

TECHNOLOGY AND DESCRIPTION

Containment Technology - Cryogenic Barrier - Concept RKK, Ltd.

Cryogenic barriers are a containment technology that involves installing freezing pipes around the circumference of a contaminated site. Refrigerant is pumped down the outside pipe and returned through the inner pipe. The double wall design allows the entire volume between walls [40 to 50 ft (12.2 to 15.2 m) thick] to freeze solid, thus containing the site. If necessary, another in situ treatment could then be applied with little risk of contaminant migration. This technology is reversible. The vendor's trade name for this technology (as appears below) is CRYOCELL.

EG&G Comments. If the barrier is formed outside the zone of contamination, there will be no possibility of attack upon the ice by either radioactive or hazardous contaminants during the freezing process.

Application(s)

This technology can be used to isolate or contain all contaminant types and can be used on all media states in which freeze pipes can be installed. Because of the high operational costs associated with this technology, it appears to be more cost effective when used for temporary containment rather than as a permanent remedy. Under certain circumstances, containment for a relatively short period of time is sufficient in itself. For example, containment may be used to await the development of an appropriate technology, while still preventing the contaminant volume from growing into a cleanup problem that is economically impossible. Often the containment may be used to assist another technology while it is being applied. Cryogenic barriers are compatible with most other in situ technologies.

Effectiveness

The contaminants are not treated or destroyed; they are simply contained. There is zero migration potential.

EG&G Comments. If salt comes in contact with runoff or ground water and migrates to the ice barrier, corrosion of the ice barrier is possible. Part of the function of the site evaluation for suitability to this method should be testing of representative soil with anticipated contaminants to ensure no damage will occur to the frozen barrier with prolonged contact to the contaminants.

Implementability

All materials, equipment, and supplies for this technology are commercially available.

Process has been successfully field tested and is ready for immediate full-scale implementation.

Diagonal drilling of the refrigeration pipes was suggested. This would require considerable free space around the site, which could prevent using it at many sites.

Power must be supplied continually to maintain the containment.

EG&G Comments. Approximately 100 kW of power will be needed.

Cost

All costs for full containment, including construction, electric power, and maintenance, are roughly \$3 to \$5 dollars per yd^3 (\$3.90 - \$6.50/m^3) of containment for a 30-year period. This cost estimate includes engineering, startup, shutdown, and contingencies.

Vendor

Concept RKK, Ltd.
851 108th Ave. N.E.
Bellevue, WA 98004
206-451-2577

Contact: Ronald K. Krieg

Experience/Licenses

Concept RKK, Ltd. is very experienced with cryogenics, having done work previously for DOE, EG&G, and Nuclear Remediation Technologies Corporation. The president of the company and inventor of CRYOCELL (Ronald K. Krieg) has been involved in construction supervision and management for over 25 years.

Sources of Information

Private communication between Ronald K. Krieg, Concept RKK, Ltd., and David E. Shropshire, EG&G Idaho, Inc. (response to EG&G's January 25, 1991 CBD solicitation), February 2, 1991.

Private communication between Ronald K. Krieg, Concept RKK, Ltd., and Mathew W. Roy, EG&G Idaho, Inc., April 4, 1991.

TECHNOLOGY AND DESCRIPTION

Containment - Fluidized-Bed Zeolite System - WHC

This technology uses a fluidized-bed system. The system utilizes zeolite- and particulate/solution polymer-based grouts for in situ stabilization and isolation of radioactive and hazardous chemical waste materials that have been disposed of in, and proximal to, underground waste disposal and containment structures. The fluidized-bed will provide chemical fixation by mechanically homogenizing and incorporating waste tank residuals (tank bottoms and sludges) with granular zeolite (or equivalent) materials. Particulate- and solution-polymer based materials are then incorporated into the interstitial void volume of the granular zeolite and surrounding geologic media to provide chemical isolation and physical stabilization.

Applications

This system could be used for remediation of subsurface waste storage/disposal structures such as underground storage tanks, cribs, caissons, piping, and buried sites. This technology will produce a physically stable structure wherein contaminated materials contained within and proximal to disposal structures are isolated from the environment over hundreds to thousands of years. This technology will significantly reduce cost of in-place treatment and accelerate schedules for closure of waste storage/disposal structures.

Effectiveness

The result of this system is complete stabilization and chemical isolation of contaminants.

The technology will produce a physically stable structure wherein contaminated materials contained within and proximal to disposal structures are isolated from the environment over hundreds to thousands of years.

Utilization of the fluidized-bed zeolite system for in situ remediation is predicted to significantly reduce the cost of in-place treatment and accelerate schedules for closure of waste storage/disposal structures.

Implementability

Preconceptual design of the fluidized-bed zeolite system has been completed. Further conceptual and prototype design activities will be completed in FY-91. Procurement of system components will be initiated in FY-91 and completed in FY-92. Initial prototype design drawings and systems operations and operational specifications will be completed in FY-91.

Cost

No exact figures were given. However, current data suggest that this system will significantly reduce cost of in-place treatment of waste storage/disposal structures.

Vendor

Westinghouse Hanford Company
345 Hills / H4-21
Richland, WA 99352
Contact: Steve Phillips
(FTS) 444-1720.

Experience/Licenses

No specifics were given. However, Westinghouse Hanford is a well-known company with a vast amount of experience.

Sources of Information

Personal communication between Steve Phillips, Westinghouse Hanford Co., and Thomas W. Garrison, EG&G Idaho, Inc., February 20, 1991.

TECHNOLOGY AND DESCRIPTION

Containment Technology - In Situ Vitrified Barriers - Battelle

In situ vitrification is a thermal treatment technology in which a region of soil volume is melted. Upon cooling, the product is a glass and crystalline monolith resembling natural obsidian. The process involves inserting electrodes in the ground and placing a conductive starter path between them. The soil is melted when an electric potential is applied to the electrodes causing the starter path to heat up above the melting point of the soil. This process has been used to produce vertical and horizontal barriers. The vitrified walls and floors can be joined as needed to isolate waste sites from transport mechanisms or to totally contain them, if necessary (e.g., for additional in situ treatment). The vitrified soil block is extremely leach resistant and possesses approximately ten times the strength of unreinforced concrete. It is predicted to be stable for geologic periods of time.

Applications

This technology can be used to isolate or contain all contaminant types and can be used on all media states. It can be used to permanently contain a waste site or to temporarily contain a waste site while another method of in situ remediation is applied.

Effectiveness

The waste is only isolated or contained.

The area may require groundwater monitoring to establish the effectiveness of the barrier and/or the need for additional barriers.

Vitrified soil from each demonstration has remained a solid, nearly crack-free block until purposefully fractured for analysis.

The properties of vitrified soil make it an extremely attractive barrier candidate.

Implementability

Over 100 ISV tests have been performed, including 6 large-scale field demonstrations.

Four engineering-scale (laboratory) vitrified underground barrier experiments have been made.

Underground startup and control of the ISV process was successfully accomplished. A subsurface, planar, horizontal structure was generated.

Methods for directing the shape of vertical melts was also demonstrated. Pilot- and large-scale development is planned.

EG&G Comments. In the presence of acids and salts, there is one concern that must be addressed with ISV technologies. Acids and salts can cause the soil to have an abnormally high electrical conductivity (hence, a low electrical resistance), which is generally more pronounced as the moisture content of the soil increases. This low resistance will require the application of more electrical energy to the treatment area in order to achieve a vitrified melt. This will also probably result in a much higher melt temperature.

Cost

Cost estimates have been made for the ISV process; however, the special needs of ISV application to vitrified barriers have not been addressed and a detailed economic analysis has not been performed. Costs will be site specific.

The following estimate assumes an off-gas processing system will not be required. The major component of a large-scale ISV system is the electrical transformer. Total costs are estimated at $500K for equipment with line power. A portable, 4.5 MVA generator is estimated at $2.3M. Operating costs are estimated to be on the order of $100 per ton ($0.11/kg) of soil vitrified and depend significantly on power costs.

Vendor

Battelle, Pacific Northwest Laboratories
Battelle Boulevard
P.O. Box 999
Richland, WA 99352
Contact: Steven Slate
(509) 375-3977.

Experience/Licenses

No specifics are available. However, this company does appear to have a large amount of experience and is well known throughout the United States.

Sources of Information

Private communication between Steven Slate, Battelle, Pacific Northwest Laboratories, and Monica M. Patterson, EG&G Idaho, Inc., March 25, 1991.

TECHNOLOGY AND DESCRIPTION

Containment Technology - Plasma Arc Glass Cap - SAIC

Plasma arc technology uses a plasma "torch" to generate a high heat flux in the vicinity of the disposal site surface. This vitrifies the surface soil and creates an impermeable glass cap. Depending on how the torch is operated, the cap may be anywhere from 1-6 in (2.54 -15.24 cm) in depth.

Application(s)

This is a containment technology. The mobility of the toxic contaminants will be greatly reduced by the presence of an impermeable glass cap over the site. Moisture from rain and snow melt will be shielded from the waste, eliminating any leaching or migration of the contaminants. Contaminants will also be constrained from migrating upward. This technology can be used with all contaminants and soils that can be vitrified.

Effectiveness

This technology does not treat or reduce the toxicity of the hazardous waste.

The mobility of the toxic contaminants will be greatly reduced by the presence of an impermeable glass cap over the site.

Moisture from rain and snow melt will be shielded from the waste, eliminating leaching and resulting transport of the contaminants.

Contaminants will also be constrained from migrating upward.

Little data on the effectiveness of plasma caps exist because the concept is new.

Laboratory studies have shown that vitrification of soil by plasma torch is feasible.

Implementability

Little historical data exist on the process because it's new.

There are very few parts needed to perform this technology.

Implementation should be simple.

Laboratory screening is needed.

EG&G Comments. 300-1000 kW of power will be needed; diesel generators are recommended.

Cost

Exact cost figures cannot be accurately quoted at this time based on available information. However, this concept will be far less expensive to build and operate than a full treatment concept.

Vendor

Science Applications International Corporation (SAIC)
2300 N. Yellowstone
Idaho Falls, ID 83401
Tel: (208) 522-5526
Contact: Ray Geimer.

Experience/Licenses

SAIC is an employee-owned company that applies science and technology to solving problems of national concern. SAIC currently has over $1.2 billion in annual sales, and more than 12,000 employees. Their experience encompasses all aspects of waste management, including characterization and certification, waste treatment evaluation, waste treatment development, waste management facility and process design, disposal, long-range planning, packaging, and transportation. They have been directly involved in the design, construction, and operation of the Low-level Waste (LLW) treatment development work at INEL's WERF Facility. They are currently contracted through the DOE Office of Technology Development (OTD) to perform a demonstration of plasma arc technology as a potential treatment process for TRU waste.

Sources of Information

Personal communication between Ray Geimer, SAIC, and David Shropshire, EG&G Idaho, Inc. (response to EG&G's January 1, 1991 CBD solicitation), February 2, 1991.

Personal communication between Ray Geimer, SAIC, and Mathew W. Roy, EG&G Idaho, Inc., April 4, 1991.

TECHNOLOGY AND DESCRIPTION

Containment Technology - Slurry Wall - NRT Corp.

Slurry walls are subsurface barriers that are used to reduce groundwater flow in unconsolidated earth materials. Slurry wall construction involves excavating a narrow vertical trench through pervious soils, and then backfilling the trench with an engineered material. The backfill material is usually a mixture of soil and bentonite or cement and bentonite. The cement-bentonite slurry initially provides trench support (also prevents high fluid losses to the surrounding soil) and then sets to form an impervious barrier. Some slurry walls also use geomembrane liners to help prevent the migration of contaminants.

Application(s)

This is a containment technology. Slurry walls can be used to contain most contaminants with a few exceptions. Soil-bentonite slurry walls are not suitable for leachate or contaminated groundwater containing strong acids/bases and alcohols. Also, cement-bentonite slurry walls are not applicable for wastes or leachates containing chlorinated hydrocarbons, organic acids, or acid chlorides. Barrier walls are not totally impermeable to water and can only inhibit the spread of contaminants. Soil-bentonite walls have the lowest installation cost, the widest range of chemical compatibilities, and the lowest permeabilities, however, they are the most prone to failure of all slurry type options. The cement-bentonite slurry walls provide better trench support because of the strength provided by the cement mixture.

Effectiveness

If contained properly, the waste will be essentially 100% immobilized. This will depend to a large degree on their ability to ensure closure of basalt fractures.

Bentonite slurry will neutralize the acid component of treated material along margins.

Implementability

Technologies are well developed. No problems are anticipated with construction or implementation.

Any migration through basalt fractures may be difficult to monitor.

Air and water permits from the State of Idaho must be obtained for this process.

Cost

Approximate costs for the containment are listed as follows:

- Bentonite slurry wall — \$ 10/ft^3 (\$353/m^3) = \$360/linear foot
- Cap — \$4-6/ft^2 (\$43 - \$64.6/m^3)
- Permits — \$10K
- In situ sensors — \$50K
- Startup — \$20K
- Operation and maintenance — \$ 2K/month
- Engineering — 20% of total cost.

Vendor

Nuclear Remediation Technologies (NRT) Corp.
3550 General Atomics Court
San Diego, CA 92121
Tel: (619) 455-3230 [San Diego office]
(208) 522-0090 [Idaho Falls office]
Contact: James Allen.

Experience/Licenses

NRT (formed in 1989) and its parent affiliates, General Atomics (formed in 1958) and Canonie Environmental Services (formed in 1979) have access to approximately 2,500 employees of which 35% have degrees as engineers and scientists. Their company has over 13 years of waste remediation experience and over 30 years of experience in technology development and implementation. NRT, through its Canonie affiliate, has just completed an essentially identical project involving approximately 4 acres of volatile organic and heavy metal contaminated soil in the San Francisco Bay area. They have worked with the government on several previous occasions.

Sources of Information

Private communication between James R. Allen, NRT Corp., and David E. Shropshire, EG&G Idaho, Inc. (response to EG&G's January 25, 1991 CBD solicitation), February 13, 1991.

Remedial Technology Information System (RTIS), Version 1.0, Idaho Falls, Idaho: EG&G Idaho Inc., 1991.

TECHNOLOGY AND DESCRIPTION

Physical Chemical Treatment - Electrokinetics - Electrokinetics, Inc.

Electrokinetic soil processing uses electricity to remove/separate organic and inorganic contaminants and radionuclides from the soil.

The four types of electrokinetic phenomena in soils are electro-osmosis, electrophoresis, streaming potential, and sedimentation potential. In this discussion, the term "electrokinetics" is used for the combination of electro-osmosis (the movement of water) and electrophoresis (the movement of particles). These phenomena are direct results of the application of direct current to a porous medium. Streaming potential and sedimentation potential refer to the generation of a current due to the physical forces, and are not relevant to this effort.

Low direct current is run between an anode and a cathode inserted in a soil mass saturated with deionized water. This results in an acid front at the anode and a base front at the cathode. In tests with an open electrode configuration, the acid front advances toward the cathode and eventually flushes across the specimen and neutralizes the base at the cathode. The movement of the acid front results in desorption of contaminants from the soil, allowing the contamination to be carried toward the cathode with the water. The contaminated water is then removed, and must be disposed of as a hazardous waste.

Application

This process is an in situ separation/removal technique for extracting heavy metals and organic contaminants from soils and sediments composed of silt and/or clay.

Suggested uses for electrokinetics include dewatering of waste sludges, creating flow barriers, forming leak detection systems, injecting grouts, providing nutrients In Situ for biodegrading microcosm, generating reactants for cleanup and/or electrolysis of contaminants, and decontaminating soils and groundwater.

Effectiveness

Electrokinetic separation is effective in the removal of Pb(II) and is expected to remediate ^{90}Sr, ^{137}Cs, ^{60}Co, uranium, and TRU radionuclides (contaminants expected to exist in the acid pit). Accurate estimates of separation efficiencies cannot be made for these metals.

Electrokinetic soil processing has also been used successfully for the removal of water soluble organic compounds from clays. Studies are also being performed on water insoluble halogenated hydrocarbons and these results are expected within one to two months.

Tests on Pb(II) in Kaolinite clay soil show 75-95% removal. The pH of the soil impacts the effectiveness of the process and can be controlled with additives to the deionized water.

Containment around a site, such as a slurry wall, is needed to control contaminant migration problems likely to occur as a result of adding liquid to the soil.

Contaminants are usually unevenly distributed and therefore, monitoring the contaminant species is complicated by seepage patterns.

Some volatile hydrocarbons will be lost to the atmosphere.

Field studies in Europe have been reasonably successful for heavy metals remediation.

EG&G Comments. Electrokinetics is a separation/removal technology and therefore only moves the contamination problem from one location to another. Contaminated soil is cleansed, but contaminated water is produced.

There is also a concern about the presence of other ions in the soil that may interfere with the desorption and dissolution of the contaminant species. No information was found to address the situation of removal of ppm-range heavy metals and/or VOCs in the presence of percent-range sodium, chloride, or carbonate ion.

Implementability

The amount of time required to remediate a site is highly dependent on the size of the site; a 370,000 ft^2 (34,373 m^2) site is estimated to require 1/2 - 2 months. Secondary treatments may be beneficial or required.

This technology may leave the soil at pH of 2-3, making further treatment necessary. The acidity of the soil may be reduced by such techniques as soil stabilization.

Electrokinetics, Inc. provides only the volume reduction/separation technology. Therefore, storage and disposal of concentrated wastes from the process would remain the responsibility of the waste owner.

Electrokinetics, Inc. provides electrodes and equipment. Water and electricity need to be available onsite.

This is an emerging technology, and Electrokinetics, Inc. has not yet performed pilot-scale tests. However, they are ready for pilot-scale tests and are currently bidding to remediate a leaking mixed waste holding tank at the Savannah River Site.

EG&G Comments. The important factors that influence electroosmosis are interrelated and include as follows: solvation, pH, and cation exchange capacity of the soil.

Possible problems that must be considered are the solubility of the contaminants, the quantity and source of the required water, and disposal of the contaminated water removed from the remediation site.

The soil pH is changed significantly by this process, but information on the actual effect is often conflicting. EPA reports pH values greater than 13 as a result of electrokinetic processing, while Electrokinetics, Inc. reports resulting pH values of 2-3.

The power required for electrokinetic processing is estimated to be less than 400 kW. The power available on the SDA during the summer is approximately 400-500 kW, and use of such a large portion must be coordinated with other projects. In addition, power lines do not run to the site(s) considered for pilot-scale tests and must be added. For this reason, generators would be recommended for demonstration tests of electrokinetics, if chosen.

Cost

The energy cost in the bench-scale tests at Louisiana State University was \$.65 to \$19.60/yd^3 (\$.50 - \$15.00/m^3) of soil. A limited pilot-scale study in Holland also indicates that the energy cost may run up to \$19.60/yd^3 (\$15/m^3) of soil.

Other costs, such as labor and overhead, cannot be estimated at this time, but should be similar to those of other technologies.

Vendor

Electrokinetics, Inc., (Louisiana State University)
Louisiana Business and Technology Center
Louisiana State University
South Stadium Drive
Baton Rouge, LA 70803-6100
Tel: (504) 388-3992
Contacts: Dr. Yalcin B. Acar, Dr. Robert Gale, Dr. John Courtney

Experience/Licenses

Bench-scale tests at Louisiana State University have demonstrated the feasibility of removing Pb, Cr, Cd, Ni, Cu, Zn, As, and organic compounds.

Limited pilot-scale field tests have demonstrated that the process removes Zn and As from clays and sandy clayey deposits. Pb and Cu were also removed from dredge sediments.

Commercial use of electrokinetics may require license from LSU.

Sources of Information

J. Hamed, Y. B. Acar, and R. J. Gale, "Pb(II) Removal from Kaolinite by Electrokinetics," *Journal of Geotechnical Engineering*, Vol. 117, No. 2, February 1991.

Y. B. Acar, and J. Hamed, "Electrokinetic Soil Processing in Waste Remediation/Treatment (Synthesis of Available Data)," *Transportation Research Board, 70th Annual Meeting*, "Remediation of Contaminated Soil" Session, Washington, D.C., January 1991.

Y. B. Acar, R. J. Gale, J. Courtney, and M. Scott, *Feasibility of Removing Plutonium from Soils by Electrokinetics (A Laboratory Study)*, proposal submitted to J. Weidner, EG&G Idaho, Inc., Baton Rouge, Louisiana, January 1991.

Private communications between Dr. Robert Gale, Electrokinetics, Inc., Louisiana State University, Baton Rouge, Louisiana, and Stephanie Walker, EG&G Idaho, Inc., March-May 1991.

Private communications between Dr. Yalcin Acar, Electrokinetics, Inc., Louisiana State University, Baton Rouge, Louisiana, and Stephanie Walker, EG&G Idaho, Inc., March-May 1991.

Additional Sources

H. W. Olsen, "Osmosis and Geotechnical Processes," presented at Clay Minerals Society Annual Meeting, Baton Rouge, La., 1984, referenced in Pamukcu, Sibel, Lutful I. Khan, and Hsai-Yang Fang, "Zinc Detoxification of Soils by Electro-Osmosis," *Transportation Research Record, No. 1288*, Transportation Research Board, Washington, D.C., 1990, p. 41.

USEPA, *Handbook on In Situ Treatment of Hazardous Waste-Contaminated Soils*; EPA/540/2-90/002, January 1990.

TECHNOLOGY AND DESCRIPTION

Physical/Chemical Treatment - Electrokinetics - ARA

Electrokinetic soil processing uses electricity to remove/separate organics, inorganics, and radionuclides from soil.

Application(s)

This process can remove heavy metals and organic contaminants from soils and sediments composed of silt and/or clay.

Effectiveness

Until the preliminary design effort is completed for a given site/contaminant, the removed percentage is unknown. The goal is to remove 100% of the contaminant from the soil; how efficient the treatment is can only be evaluated for preliminary research.

Contaminants not removed by the electrokinetic treatment are locked in the soil structure and thus their mobility is significantly reduced.

EG&G Comments. Electrokinetics is a separation/removal technology and therefore only moves the contamination problem from one location to another. Contaminated soil is cleansed, but contaminated water is produced.

There is a concern about the presence of other ions in the soil that may interfere with the desorption and dissolution of the contaminant species. No information was found to address the situation of removal of ppm-range heavy metals and/or VOCs in the presence of percent-range sodium, chloride, or carbonate ion.

Implementability

Laboratory tests and small-scale tests are required to develop the parameters necessary to design a system with a high potential for success.

Laboratory analyses indicate that electrokinetics is feasible, but field programs have not been performed. Additional research is required to determine if the technology can be efficiently applied to specific sites.

Electrokinetics should not be used in the field where metal objects are adjacent. This includes water and gas lines, metal drums, or other metal objects. However, cathodic protection systems are available to protect metal objects that cannot be removed or avoided.

EG&G Comments. The important factors that influence electroosmosis are interrelated and include as follows: solvation, pH, and cation exchange capacity of the soil.

Possible problems that must be considered are the solubility of the contaminants, the quantity and source of the required water, and disposal of the contaminated water removed from the remediation site.

The power required for electrokinetic processing is estimated to be less than 400 kW. The power available on the SDA during the summer is approximately 400-500 kW, and use of such a large portion must be coordinated with other projects. In addition, power lines do not run to the site(s) considered for pilot-scale tests and must be added. For this reason, generators would be recommended for electrokinetic demonstration tests, if chosen.

Cost

The cost of remediation using electrokinetics is extremely site dependent. Exact costs will remain unknown until actual contaminants are known.

As an illustration, the cost to partially stabilize an expansive clay test site with electrokinetics was approximately $10,000. The site was 40 x 15 x 6 ft (12.2 x 4.6 x 1.8 m) deep. Of the $10,000, $5,000 was the one-time cost of a rectifier (the onsite ac power was converted to dc). The above costs do not include the cost associated with the design of the system or the electricity used.

Vendor

Applied Research Associates, Inc. (ARA)
4300 San Mateo Blvd. NE, Suite A220
Albuquerque, NM 87110
Tel: (505) 883-3636
Contact: Frank Maestas

Experience/Licenses

ARA has experience in professional engineering and also in research and development. The company specializes in site characterization and modeling, probabilistic systems analysis and optimization, and defining material properties of soil, rock, and structural materials. ARA is a small business employing approximately 85 professionals on a full-time basis, plus consultants as required. The company was formed in 1979, and has produced large, complex, technical studies for a broad range of clients. Some of their clients include: the U.S. Air Force, Argonne National Laboratory, Brookhaven National Laboratory, Lawrence Livermore National Laboratory, Lockheed, Sandia National Laboratory, and SRI International. ARA concentrated on transferring research efforts into practice.

Sources of Information

Private communication between John F. Gibbons, Applied Research Associates, Inc. and David E. Shropshire, EG&G Idaho, Inc. (response to EG&G's CBD January 25, 1991 solicitation), February 1991.

Private communication between Frank A. Maestas, Applied Research Associates, Inc., Albuquerque, New Mexico, and Mathew W. Roy, EG&G Idaho, Inc., April 1991.

TECHNOLOGY AND DESCRIPTION

Physical/Chemical Treatment - Electrokinetics - Electro-Petroleum

Electrokinetic soil processing uses electricity to remove/separate organics, inorganics and radionuclides from the soil.

Electrical current (dc) is applied through the earth to treat soils without removing them. This application of power provides electrokinetic and electroosmotic forces that can be used to move contaminated water through the soil. By this process, soils can be dewatered or can be swept by the pumping of water through them.

Either ac and/or dc power can be used to increase the ambient soil temperature and thereby assist in the desorption of organics.

The dc power will move the contaminated water through the soil to a location where it may be removed and disposed.

Electrokinetics can also be used to remove various metals from soil.

Application

Electrokinetics has been used by Electro-Petroleum to increase oil production and remediate waste sites. Electro-Petroleum has field experience with both organics and inorganics, and has performed laboratory tests with heavy metals.

Effectiveness

This technology has been used to increase oil production. During demonstration tests for Husky Oil Company, average production of oil was doubled.

Containment around the pit, such as a slurry wall, is needed to control contaminant migration problems likely to occur as a result of adding liquid to the soil.

EG&G Comments. Electrokinetics is a separation/removal technology and therefore only moves the contamination problem from one location to another. Contaminated soil is cleansed, but contaminated water is produced.

There is a concern about the presence of other ions in the soil that may interfere with the desorption and dissolution of the contaminant species. No information was found to address the situation of removal of ppm-range heavy metals and/or VOCs in the presence of percent-range sodium, chloride, or carbonate ion.

Implementability

Electro-Petroleum, Inc. has been using this technology since 1979. This experience should eliminate many implementation problems, and provide the necessary equipment and manpower. Pilot-scale tests have been performed.

EG&G Comments. The important, interrelated factors that influence electroosmosis are solvation, pH, and cation exchange capacity of the soil.

Possible problems that must be considered are the solubility of the contaminants, the quantity and source of the required water, and disposal of the contaminated water removed from the remediation site.

The power required for electrokinetic processing is estimated to be less than 400 kW. The power available on the SDA during the summer is approximately 400-500 kW, and use of such a large portion must be coordinated with other projects. In addition, power lines do not run to the site(s) considered for pilot-scale tests and must be added. For this reason, generators would be recommended for electrokinetic demonstration tests, if chosen.

Cost

Costs are highly dependent on the size of the site and the type and degree of contamination. Power may represent a cost concern.

Vendor

Electro-Petroleum, Inc.
Suite 1118
996 Old Eagle School Road
Wayne, PA 19087
Tel: (215) 687-9070
Contacts: J. Kenneth Wittle.

Experience/Licenses

Electrokinetics has been used by Electro-Petroleum to increase oil production and remediate waste sites. The company has field experience with both organics and inorganics, and has performed laboratory tests with heavy metals.

Electro-Petroleum first field tested electrokinetics for oil recovery between June 1974 and January 1979 in California, and again for Husky Oil Company in Canada in 1985.

The company has used electrokinetics to dry mud pits and to dewater chemical waste sludges. This technologies can also be used in the treatment of lagoons and contaminated soils to remove and/or assist in the removal of liquid and adsorbed contaminants.

Sources of Information

Private communication between Dr. J. Kenneth Wittle, Electro-Petroleum, Inc., and Reva A. Hyde, EG&G Idaho, Inc. (response to EG&G's April 5, 1991 CBD solicitation), April 1991.

Private communications between Dr. J. Kenneth Wittle, Electro-Petroleum, Inc. Wayne, Pennsylvania, and Stephanie Walker, EG&G Idaho, Inc., April-May 1991.

Additional Sources

S. Pamukcu, L. I. Khan, and H. Y. Fang, "Zinc Detoxification of Soils by Electro-Osmosis," *Transportation Research Record, No. 1288, Geotechnical Engineering*, 1990, Transportation Research Board, National Research Council, Washington, D.C. 1990.

L. I. Khan and S. Pamukcu, "Validity of Electro-Osmosis for Soil Decontamination," *Environmental Engineering, Proceedings of the 1989 Specialty Conference*, Austin, Texas, July 10-12, 1989, American Society of Civil Engineers, New York, New York.

L. I. Khan, S. Pamukcu, and H. Y. Fang, "A New Theory to Electroosmosis in Soil," submitted to: *The Journal of the Geotechnical Engineering Division*, American Society of Civil Engineers, New York, New York.

TECHNOLOGY AND DESCRIPTION

Physical/Chemical Treatment - Simultaneous Injection, Extraction, and Recharge - ARA

This process involves the remediation of unsaturated soils by injection of a medium to strip and transport contaminants to an extraction well(s). Water and steam are commonly used media. In unsaturated soil, steam will condense at some distance from the injection point and form a diffuse front consisting of a transient saturated zone with soil permeated by condensing steam on one side and relatively cool, unsaturated soil on the other side. This front is a region of radical contrasts in electromagnetic properties. The placement of injection points and extraction wells are designed to allow injection fronts to coalesce and move the contaminant to strategically located extraction wells. After being transported to the extraction wells, the contaminants would have to be removed and treated.

Application(s)

This technique addresses the removal of contaminants that can be mobilized by steam or water from unsaturated soil. It is anticipated that volatile organics will probably be very efficiently removed by this methodology. Highly soluble or volatile contaminants in transmissive soils will be the fastest remediated.

Effectiveness

Extractive efficiency will vary with soil type and contaminant.

Volatile organics will probably be very efficiently removed by this methodology.

EG&G Comments. ARA does not consider the treatment of the extracted contaminants in their response. Exact effectiveness is unknown at this time.

In most cases, the removal of contaminant from a soil by flowing steam through the soil has the potential to remove or immobilize all of most contaminants amenable to this approach.

Implementability

The components of this technology are at varying degrees of development.

All of the necessary technology is available or developed.

Some adaptation, redesign, and fabrication is necessary.

Handling, separation, and disposal of hot contaminated water, steam, or other products of extraction would need to be addressed by a contractor other than ARA.

Cost

ARA was unable to supply estimates of cost at this time. The costs are site and contaminant specific.

Vendor

Applied Research Associates, Inc. (ARA)
4300 San Mateo Blvd. NE, Suite A220
Albuquerque, NM 87110
Tel: (505) 883-3636
Contact: Frank Maestas, Ph.D., PE.

Experience/Licenses

ARA has experience in professional engineering and also in research and development. The company specializes in site characterization and modeling, probabilistic systems analysis and optimization, and materials properties of soil, rock, and structural materials. ARA is a small business employing approximately 85 professionals on a full-time basis, plus consultants as required. The company was formed in 1979, and has produced large, complex, technical studies for a broad range of clients. Some of their clients include: the U.S. Air Force, Argonne, Brookhaven, Lawrence Livermore, and Sandia National Laboratories, Lockheed, and SRI International. ARA concentrated on transferring research efforts into practice. ARA just completed an EPA funded phase 1 project for this process. There are patents involved with this process, and ARA is in negotiation with Sandia National Laboratory for use of these patents.

Sources of Information

Private communication between Frank Maestas, Applied Research Associates, Inc., and David E. Shropshire, EG&G Idaho, Inc. (response to EG&G's January 25, 1991 CBD solicitation), February 13, 1991.

Private communication between Frank Maestas, Applied Research Associates, Inc., and Mathew W. Roy, EG&G Idaho, Inc., April 4, 1991.

TECHNOLOGY AND DESCRIPTION

Physical/Chemical Treatment
Vapor Vacuum Extraction - NRT

Vacuum extraction systems involve the extraction of air containing contaminants from unsaturated soils. Clean air is injected into the contaminated soil, and a vacuum apparatus is used to extract the vapor-filled air from recovery or extraction wells. Volatile contaminants are extracted, and the soil is decontaminated to levels required by regulatory agencies. The established air flows are a function of the equipment used and soil characteristics. Spent carbon and contaminated water are residuals of this treatment, and further treatment of the recovered liquids and condensate is necessary.

The vendor suggests combining vapor vacuum extraction with Bentonite slurry wall (with a high density polyethylene vertical liner) and in situ grout for containment.

Application(s)

Vacuum extraction is used for the treatment of soils, sediments, sludges, and ground water contaminated with volatile or semivolatile organic compounds at ambient temperatures. This technology is effective on VOCs and SVOCs with total concentration ranging from 10 ppb to 100,000 ppm by weight. For effective removal, contaminants should have a Henry's constant of 0.001 or higher. The use of vapor extraction systems is typically limited to permeable unsaturated soils such as sands, gravels, and coarse silts; diffusion rates through dense soils, such as compacted clays, are much lower than through sandy soils. Clayey soils usually lack the conductivity necessary for effective vapor extraction, unless they are first fractured.

Effectiveness

The slurry wall and in situ grout will essentially immobilize 100% of the contaminants.

The effectiveness of the in situ grout for sealing the basalt fractures will be determined by what condition the basalt layer is in.

The vacuum vapor extraction process will very effectively remove the organics in the soil.

EG&G Comments. Vacuum Extraction is an effective means to remove volatile organic compounds (VOCs) from the subsurface. The technique is only applicable to unsaturated soils. The higher the vapor pressure of the VOCs, the easier the remediation by vacuum extraction. The relative speed that the pit can be remediated will be determined by the transport of the VOCs through the soil. Another system is usually used along with this technology in order to remove the VOCs in the air stream prior to release. This technology has been demonstrated to be effective and can be a viable technology for consideration.

Inorganic and radioactive elements will be left in the soil to be removed by another technology.

The possibility that nitrated organic compounds exist in the acid pit must also be considered. When nitric acid comes in contact with organic compounds or cellulose fibers, there is a chance that nitrification will occur and thus form a potentially explosive mixture. This is especially true for cellulose materials (rags, towels, paper, boxes), where nitrocellulose, a high-explosive, can be a by-product. For this reason, thermal techniques should not be considered for the acid pit or for any other site where these compounds may exist.

Implementability

These technologies are proven and have been used in conjunction with each other on many occasions. The necessary equipment and specialists are available. One concern would be the ability to ensure 100% closure of basalt fractures. This depends on the shape the basalt layer is in.

EG&G Comments. Less than 500 kW of power will be required.

Cost

The only estimate available was for the slurry wall as follows:

Material costs	$10/ft^3$ ($353/m^3$)
Cap	$4-6/ft^2$ ($43-65/m^3$)
Permits	$10K
In situ sensors	$50K
Startup	$20K
O & M	$2K/month.

Vendor

Nuclear Remediation Technologies (NRT) Corporation
3550 General Atomics Court
San Diego, CA 92121
Tel: (619) 455-3230 [San Diego office]
(208) 522-0090 [Idaho Falls office]
Contact: James Allen.

Experience/Licenses

NRT (formed in 1989) and its parent affiliates, General Atomics (formed in 1958) and Canonie Environmental Services (formed in 1979) have access to approximately 2500 employees of which 35% have degrees as engineers and scientists. Their company has over 13 years of waste remediation experience and over 30 years of experience in technology development and implementation. NRT, through its Canonie affiliate, has just completed an essentially identical project involving approximately 4 acres (16,200 m^2) of volatile organic and heavy metal contaminated soil in the San Francisco Bay area. They have worked with the government on several previous occasions.

Sources of Information

Private communication between James R. Allen, NRT Corp., and David E. Shropshire, EG&G Idaho, Inc. (response to EG&G's January 25, 1991 CBD solicitation), February 13, 1991.

Private communication between James R. Allen, NRT Corp., and Stephanie Walker, EG&G Idaho, Inc., April 4, 1991.

TECHNOLOGY AND DESCRIPTION

Solidification/Stabilization - IN SITU DETOXIFIER™ - KLM Technologies

An IN SITU DETOXIFIER™ is a mobile, thermal-mechanical process that detoxifies hazardous waste (organic and inorganic) contaminated sites to a depth of 30 ft (9.14 m), without soil excavation.

The proposed remediation technique involves: (a) the treatment and removal of VOCs, (b) precipitation of nonvolatile compounds and certain radionuclides, (c) and the lime/pozzolonic cementing encapsulation (solidification) of the remaining radionuclides into a nonpermeable matrix.

Application(s)

This technology is applicable for radioactive, hazardous, and mixed waste sites, whereby hazardous chemicals are removed or stabilized In Situ, and the remaining radionuclides are solidified into a nonpermeable matrix.

Effectiveness

Based upon previous field remediation actions on hazardous waste sites, hazardous compound (VOCs) removal rates exceed 96%. Inorganic insoluble levels after precipitation and treatment exceeded the current EPA toxicity and TCLP requirements.

The residuals remaining will primarily consist of 4-5% of the organic compounds. At least 95% of the inorganics of chlorinated hydrocarbons will be in the form of a nonsoluble precipitant matrix, while the radionuclides will be in a precipitant from the lime treatment. Other radionuclides are expected to be bound in the impermeable pozzolonic matrix. Typical impermeabilities of solidified waste are measured at 3.28×10^{-8} ft/s to 3.28×10^{-9} ft/s (10^{-6} to 10^{-7} cm/s).

Implementability

Potential problems or delays are seen as those associated with incomplete site characterization.

Adequate treatment services are currently available to support the IN SITU DETOXIFIER™ technology. Adequate equipment and specialists are available to support the remediation project with the IN SITU DETOXIFIER™.

Cost

It is not possible to develop an accurate cost estimate based upon the known information. Cost estimates can be prepared after site characterization data are available and exact requirements of the in situ remediation project are set.

Vendor

KLM Technologies
P.O. Box 30306
Walnut Creek, CA 94598
Tel: (415) 945-6788
Fax: (415) 945-0131
Contact: George Kniazewycz

Experience/Licenses

KLM has a broad experience base in nuclear waste management and explosive and hazardous treatment technologies. These include planning and execution of decontamination, decommissioning, and nuclear modification projects.

The technology (IN SITU DETOXIFIER™) has a State of California permit, allowing onsite treatment. The technology is patented in the U.S. and in over 35 countries.

Sources of Information

Personal communication from KLM Technologies, Inc., *An Introduction to the DETOXIFIER™ In Situ Remediation Technology*, as submitted to EG&G Idaho, Inc., Attn: Mr. Robert B. Piper, May 1991.

TECHNOLOGY AND DESCRIPTION

Solidification/Stabilization - Fluid Tech/Geo Con

Aquaset, Aquaset II, Petroset, Petroset II are solidification agents that were developed for the efficient disposal of liquid wastes. They are slightly alkaline, inert, noncorrosive, and nonbiodegradable. The waste fluid along with dissolved and suspended solids are fixed in a nonpourable, flexible matrix that will not undergo brittle fragmentation under accidental conditions. These solidification agents immobilize wastes via complex bonding mechanisms and result in homogeneous waste solids with excellent leach resistance.

Application(s)

Aquaset: used for aqueous liquids containing small amounts of dissolved and suspended solids, detergents, chelating agents, resins, and up to 5% oils.

Aquaset II: used for aqueous solutions high in dissolved solids such as neutralized acids and bases and those organic liquids that are water soluble and miscible.

Petroset: used for a mixture of water and oils when the oils are in excess of 5%.

Petroset II: used for liquids that are essentially 100 volume percent oils, solvents, and/or other immiscible organics.

Effectiveness

Aquaset, Petroset, Aquaset II, and Petroset II have completed many EPA TCLP tests and the ANSI 16.1 leach tests that show that the products exhibit excellent leach stability.

Radioactive waste liquids solidified with Fluid Tech products are acceptable for disposal at the U.S. Ecology Low-Level Radioactive Disposal Sites at Richland, Washington and Beatty, Nevada.

EG&G Comments. Fluid Tech reagents appear to be more applicable to liquid wastes. If used in soils, liquid must be added.

Implementability

Fluid Tech, Inc. produces and sells the solidification agents that solidify radioactive and hazardous liquids.

Fluid Tech, Inc. will work with a site remediation contractor of our choice, and furnish their materials and technical consultation.

Cost

$15.75 - $106.00 per 50-lb (22.7 kg) bag of Fluid Tech's solidification agents.

Vendor

Fluid Tech, Inc.
4335 West Tropicana
Las Vegas, Nevada 89103
Tel: (702) 871-1884
Fax: 702-871-3629
Contacts: Dean Roswell or John Gayton

Geo-Con, Inc.
1764 National Ave.
Hayward, CA 94545
Tel: (415) 887-2002
Fax: 415-887-3091
Contact: Dave Brown.

Note: Geo-Con, Inc. is a site remediation contractor that uses the solidification agents produced by Fluid Tech, Inc.

Experience/Licenses

Geo-Con has extensive remediation experience in the following areas:

1. In Situ Stabilization/Solidification

   a. Deep soil mixing [up to 150 ft (45.7 m)]

   b. Shallow soil mixing [up to 40 ft (12.2 m) while capturing any vapors or dusts that are produced]

   c. Backhoe operated sludge stabilizer

   d. Mechanical mixing (mechanical backhoes and pugmill style mixers).

2. Onsite Services

   a. Onsite water treatment

   b. Groundwater collection

   c. Bioremediation

   d. VOC extraction.

3. Pollution Containment Systems

   a. Vertical barrier techniques (slurry walls)

   b. Liner construction.

Sources of Information

Geo-Con, Inc. a full service Geotechnical Construction Company Hazardous Waste Remediation and Containment with a Professional Approach, written by Geo-Con, Inc.

Reva A. Hyde letter to David E. Shropshire, RAH-03-91, *Information on Fluid Tech*, January 24, 1991.

Technical Fact Sheet for Fluid Tech, Inc. Solidification Agents, written by Fluid Tech, Inc., date unknown.

TECHNOLOGY AND DESCRIPTION

Solidification/Stabilization - HET

Solidification/stabilization involves using an in situ soil blender (a large vertical shaft crane-mounted machine) with 6-ft (1.8 m) diameter mixing head with integral fluid jets. The soil blender is designed to intimately blend soil with a liquid/slurry stabilizing agent. After solidification/stabilization is complete, an impermeable cap is recommended.

Applications(s)

This technology can be applied to hazardous liquids and sludges, nonhazardous oil field waste, certain radioactive wastes, and contaminated soils.

Effectiveness

Efficiency of the process is affected by many factors but is considered to be in excess of 99%.

99.99% or greater of the contaminated material is treated. Untreated fractions are encapsulated into treated material.

Mobility of the toxic contaminant is reduced by several orders of magnitude. The final product material will typically have lower than 10^{-7} cm/sec permeability and be a large monolithic mass.

Treated product contains all original contaminants in a more stable physical or chemical form.

Actual volume of product material may be 20% greater than the original volume.

The effects of cement based stabilization are considered to be 100% irreversible at ambient temperatures.

Implementability

Negotiation of a contract 3 months in advance of the job will ensure proper allocation of resources and that the project teams will be prepared and have site specific equipment needs met.

The stabilization technology is a composite of existing state-of-the-art technology.

Halliburton Environmental Technologies (HET) is currently working on a similar project at another DOE site; however HET approaches each stabilization project as a unique project. The mixing technology is simply a refinement of existing technology with much greater mixing power and process control. The actual equipment recommended has been used on one other project. The treatment slurry production equipment is standard field type equipment (a large vertical shaft crane-mounted machine) that is known worldwide for its reliability.

Cost

Direct costs are expected to include construction and equipment costs but no land or site development costs. Buildings are expected to include setup of portable offices and decontamination trailers as well as an equipment decontamination pad and tent. No relocation costs or disposal costs are anticipated. Indirect costs are expected to include engineering, startup, and contingency costs.

Vendor

Halliburton Environmental Technologies, Inc.
5950 North Course Drive
P.O. 721110
Houston, Texas 77272
Tel: (713) 561-1556
Fax: 713-561-8138
Contacts: Ernie Carter and Gerald Motl.

Experience/Licenses

Halliburton is staffed by personnel who have extensive project and program management backgrounds and experience in managing complex environmental projects and trained field supervisors and technicians who have experience in handling waste in compliance with Occupational Safety and Health Administration (OSHA) and environmental regulations.

Sources of Information

Halliburton Environmental Technologies, Inc., General Qualifications, written by Halliburton Environmental Technologies.

Personal communication between Ernie Carter, Halliburton Environmental Technologies, Inc., and Robert B. Piper, EG&G Idaho, Inc., April 10, 1991.

TECHNOLOGY AND DESCRIPTION

Solidification/Stabilization - In-Situ Fixation Co.

In situ cementitious/pozzolanic matrix based solidification/stabilization using dual auger soil remediation system. The dual auger system provides for the controlled injection and thorough blending of specially-formulated fixation reagent into the soil through multiple overlapping drill bit assemblies of the dual auger system.

Application(s)

This technology may be applied to the following hazardous/toxic waste types: a) heavy metals in metallic or cationic forms, b) inorganics in anionic form, c) water-soluble organics, and d) water-soluble organics. The waste media that can be treated includes aqueous solutions, sludges, and contaminated soils.

Effectiveness

There should be no remaining sources of risk after remediation, because all classes of sources will be addressed through VOC removal and in situ solidification/stabilization.

If exclusion of any contact with groundwater is required, a slurry wall can be installed in situ, utilizing the dual auger system, at any time during remediation. If additional protection is needed, an impermeable floor tied into the slurry wall system can also be constructed. This would completely isolate the contaminated mass.

Implementability

Because the dual auger system has been designed to utilize existing and readily available power-train and material delivery equipment, it is not anticipated that technical problems would result in any schedule delays.

Abnormal weather and/or the presence of large foreign objects or boulders may cause delays.

The In-Situ Fixation Company has the capabilities not only to construct barrier slurry walls, but also to construct an impermeable floor tied to the wall system, thus completely isolating the contaminated mass.

Based upon the information provided by EG&G on the acid pit and remediation process proposed, the In-Situ Fixation Company does not anticipate that any future remediation action would be necessary.

Cost

Because the information submitted to the In-Situ Fixation Company was limited, some of the costs will need further evaluation.

Direct Costs

Construction costs - \$25-\$60 per yd^3 (\$33 - \$78 per m^3).

Indirect Costs

Engineering expense will include administration, construction supervisor, and treatability testing costs. The cost per yd^3 is estimated to range between \$10-\$20 per yd^3 (\$13 -\$ 26 per m^3).

Startup/shakedown - The mobilization and shakedown costs are estimated at \$3-\$10 per yd^3 (\$4 - \$13 per m^2).

Contingency Allowance - 5-10%

Vendor

In-Situ Fixation Company
P.O. Box 516
Chandler, Arizona 85224-0516
Tel: (602) 821-0409
Fax: 602-786-3184
Contact: Dick Murray.

Experience/Licenses

In-Situ Fixation Company is an in situ bioremediation and solidification/stabilization firm with consulting, design, development, feasibility study, research, remediation construction, and closure capabilities.

Sources of Information

The Technology and Application of Solidification/Stabilization Remedial Process, written by In-Situ Fixation Company.

Personal communication between Dick Murray, In-Situ Fixation Company, and Robert B. Piper, EG&G Idaho, Inc., Response to Questionnaire, April 10, 1991.

TECHNOLOGY AND DESCRIPTION

Solidification/Stabilization - Laidlaw

Pozzolanic material based solidification/stabilization with a possible impermeable membrane cap.

The solidification/stabilization is a series of processes, most of which employ pozzolanic reactions to chemically alter and/or physically entrap contaminants.

The mixture of pozzolanic materials is determined in the laboratory, so the solution for each solidification/stabilization problem is custom designed and tested prior to each application.

Application(s)

This technology may be applied to soils containing hazardous, radioactive, and mixed waste.

Effectiveness

Because each solution is designed and tested in the laboratory, positive results are assured.

The remedial design usually employs a clay or impermeable membrane cap and may require groundwater monitoring.

Long-term operation and maintenance is limited to those activities associated with cap maintenance and groundwater monitoring.

Implementability

Solidification/stabilization is a well established, broadly applied technology.

The difficulties associated with its application are related to site geology, to waste and soil matrix characterizations, or to site layout.

Site geology can pose engineering challenges, but solutions generally are a function of economics not technology.

Waste/soil characteristics that affect the application of solidification/stabilization are identified in the laboratory and solutions are developed.

Cost

Capital costs will include engineering and testing associated with the identification of the treatment program required to meet the treatment goals, process equipment purchase, modification or depreciation, mobilization of personnel and equipment to the site, construction of site facilities, and installation of process equipment, performance of a pilot test.

Vendor

Laidlaw Environmental Services, Inc.
1415 Woodside Drive
P.O. Box 14964 (27415)
Greensboro, NC 27405
Tel: (919) 272-0185
Fax: 919-373-0308
Contact: Don Lowe.

Experience/Licenses

Laidlaw Environmental Services was founded in 1969, and began major site remediation work in 1980 with the Bluff Road Superfund Site in South Carolina. The Site Remediation Services Group is now a major branch of the company, with 384 full-time personnel based in 11 locations nationwide.

The Laidlaw Site Remediation Services Group holds appropriate permits to conduct their services in virtually all states in which permits for site remediation are required.

Sources of Information

Personal communication between Mike Jump, Laidlaw Environmental Services, Inc., and Robert B. Piper, EG&G Idaho, Inc., April 12, 1991.

TECHNOLOGY AND DESCRIPTION

Solidification/Stabilization - Wastech

Chemical pretreatment followed by stabilization with cement-like materials. Utilizing a patented chemical treatment process, organic and inorganic hazardous components are conditioned and encapsulated in a cement matrix and stabilized.

Application(s)

This technology can be applied to soils, sludges, and raw organic streams, such as lubricating oil, aromatic solvents, evaporator bottoms, chelating agents, and ion exchange resins. It can also be applied to mixed wastes containing radioactive materials along with organic and inorganic contaminants.

Effectiveness

The stabilized wastes have very low leachability and meet the requirements of EPA and NRC for land disposal.

The resulting concrete matrix has very high compressive strength and can be used in various construction applications.

Implementability

The Waste Technologies Group process can be applied In Situ, as well as by conventional processing technologies.

Additional in situ treatment information is currently being gathered on Waste Technologies Group.

Cost

Assuming all support services and analytical requirements are provided by EG&G, a "ballpark" price for processing mixed wastes is in the range of \$30-\$90 per ft^3 (\$1060 - \$3180 per m^3). This price estimate may not apply to in situ treatment cost (because of the processing aspect).

Vendors

Waste Technologies Group, Inc.
100 Cresent Centre Parkway
Suite 200
Atlanta (Tucker), Georgia 30084
Tel: (404) 723-1600
Contact: Mike Jump

Wastech, Inc.
P.O. Box 1213
Oak Ridge, Tennessee 37831-1213
Tel: (615) 483-6515
Fax: 615-483-4239
Contact: Benny Peacock.

Note: Waste Technologies Group is a licensee of Wastech. Additional in situ treatment information is currently being gathered on the Waste Technologies Group. It appears that Waste Technologies Group is licensed to perform the actual waste treatment for Wastech.

Experience/Licenses

Waste Technologies Group provides mobile processing services for the treatment and stabilization of hazardous material. Waste Technologies Group is affiliated with several major companies having a wide variety of experience and stability in the waste processing and heavy construction business.

Sources of Information

Personal communication between Mike Jump, Waste Technologies Group, Inc., and Robert B. Piper, EG&G Idaho, Inc., April 9, 1991.

The Superfund Innovative Technology Evaluation Program: Technology Profiles; EPA/540/5-89/013, November 1989.

TECHNOLOGY AND DESCRIPTION

Thermal Treatment - In Situ Vitrification - Geo Safe Corp.

In situ vitrification (ISV) involves the electric melting of contaminated soils in place. ISV uses an electrical network consisting of four electrodes, placed in a square pattern and at the desired depth, to electrically heat and melt contaminated soils and solids at temperatures of 2921 to 3632°F (1600 to 2000°C). Organic pollutants are destroyed by pyrolysis and inorganic pollutants are immobilized within the vitrified mass, which has properties of glass. Both the organic and inorganic airborne pyrolysis by-products are captured in a hood, which draws the contaminants into an off-gas treatment system that removes particulates and other pollutants of concern.

Application(s)

ISV can be used to destroy or remove organics and/or immobilize inorganics in contaminated soils or sludges. On saturated soils or sludges, the initial application of the electric current must reduce the moisture content before the vitrification process can begin. This increases energy consumption and associated costs. Also, sludges must contain a sufficient amount of glass-forming material (nonvolatile, nondestructible solids) to produce a molten mass that will destroy or remove organics and immobilize inorganic pollutants.

Effectiveness

In situ vitrification is effective on aqueous media, organic liquid, sediments, soils, and sludges contaminated with halogenated volatiles, halogenated nonvolatiles, nonhalogenated volatiles, nonhalogenated nonvolatiles, pesticides, dioxins/furans, organic cyanides, organic corrosives, volatile metals, nonvolatile metals, and PCBs.

EG&G Comments. The possibility that nitrated organic compounds exist in the acid pit must also be considered. When nitric acid comes in contact with organic compounds or cellulose fibers, there is a chance that nitrification will occur and thus form a potentially explosive mixture. This is especially true for cellulose materials (rags, towels, paper, boxes), where nitrocellulose, a high-explosive, can be a by-product. For this reason, thermal techniques should not be considered for the acid pit or for any other site where these compounds may exist.

Implementability

ISV is limited by the following factors: (a) individual void volumes in excess of 150 ft^3 (4.25 m^3), (b) buried metals in excess of 5% of the melt weight or continuous metal occupying 90% of the distance between two electrodes, (c) rubble in excess of 10% by weight, and (d) the amount and concentration of combustible organics in the soil or sludge. These limitations must be addressed for each site.

Since 1980, Pacific Northwest Laboratory has been developing and refining ISV. Using a 4000 kW power source, tests have been completed on organics, inorganics, radioactive (including TRU), and mixed waste.

EG&G Comments. In the presence of acids and salts, there is one concern that must be addressed with ISV technologies. Acids and salts can cause the soil to have an abnormally high electrical conductivity (hence, a low electrical resistance), which is generally more pronounced as the moisture content of the soil increases. This low resistance will require the application of more electrical energy to the treatment area in order to achieve a vitrified melt. This will also probably result in a much higher melt temperature.

Cost

ISV costs between $250 to $350 per ton ($.28 to $.39 per kg) of material processed. Mobilization/demobilization of equipment is typically $100,000 to $200,000; the primary cost factor for full operation is power, which is typically 4000 kW for 5 ton/hr (4536 kg/hr) equipment.

Vendor

GeoSafe Corporation
303 Park Place
Suite 126
Kirkland, WA 98033
(206) 822-4000.

Experience

No information as of June 1991.

Sources of Information

USEPA, *The Superfund Innovative Technology Evaluation Program: Technology Profiles*, (EPA/540/5-89/013), November 1989.

Remedial Technology Information System (RTIS), Version 1.0, Idaho Falls, Idaho: EG&G Idaho Inc, 1991.

USEPA, *Handbook on In Situ Treatment of Hazardous Waste-Contaminated Soils*; EPA/540/2-90/002, January 1990.

USEPA, *Inventory of Treatability Study Vendors*, Volume 1, EPA/540/2-90/003a, March 1990.

TECHNOLOGY AND DESCRIPTION

Thermal Treatment - Radio Frequency and Electromagnetic Heating -IITRI

In situ radio frequency (RF) heating is a rapid process that uniformly heats soil without excavation or digging. This process uses electromagnetic wave energy in the range of 45 Hz to well over 10 GHz to heat soil. Exciter and guard electrodes are placed in the ground, and the temperature rise occurs due to ohmic or dielectric heating mechanisms. The RF technology is capable of heating soils to temperatures in excess of 212°F (100°C) (boiling point of water). The gases and vapors formed in the soil are recovered at the surface or through vented electrodes used for the heating process. A vapor containment cover collects volatilized organics for incineration or carbon absorption. This process is also referred to as electromagnetic (EM) heating. The only major difference between RF and EM is in the choice of frequency of the applied power. The EM technology is suitable for heating soils only to the boiling point of water.

Application(s)

RF and EM heating works on sludges, other solids, soils, and sediments contaminated with volatile and semivolatile contaminants, including dioxins/furans, pesticides, halogenated volatiles, halogenated nonvolatiles, radioactive materials, PCBs, nonvolatile metals, volatile metals, nonhalogenated nonvolatiles, and nonhalogenated volatiles. This technology can be used in saturated or unsaturated soil. Both of these technologies have the potential for economic and efficient remediation of soils at hazardous waste sites contaminated with organic compounds.

Effectiveness

These technologies remove volatile and semivolatile organic contaminants from soils.

Laboratory, pilot, and limited field data show that up to 99% of the organics can be removed.

Considering that the original concentrations are in the range of 1000 to 5000 ppm, the residual soil may contain approximately 10 to 100 ppm of organics. This depends on the nature of contaminants and other site characteristics.

EG&G Comments. The removal of the organics will depend on the type of organics, volatility of the organics, and physical characteristics of the site. For example, buried metallic objects, such as drums, will distort the applied field. Therefore, these metallic objects will need to be removed or isolated.

This process only removes the organics. Another process will be required to collect the organics and to destroy the recovered organics. Inorganic materials such as heavy metals and the radionuclides will remain in the soil. The temperatures found in this process will probably not volatilize volatile heavy metals or radionuclides.

Implementability

The RF technology has been field tested successfully to remove fuels from soil.

Bench and pilot data show that a large number of organic contaminants can be removed from soil.

Preliminary designs for commercial-scale equipment has been developed. But fabrication, design, and testing of full-scale equipment is yet to be accomplished.

The EM technology needs to be tested in the field, pilot-scale.

The equipment and specialists needed for these technologies are available.

EG&G Comments. RF or EM remediation technologies require 500 to 700 kVA of 3-phase electrical energy near the site. Diesel generators would be needed for demonstration tests.

Cost

Direct capital costs are expected to be in the range of $1 to $2 million for the first commercial system to process 70 to 100 tons per day including design costs. Indirect capital costs are expected to be about $1 million. Operating costs are estimated to be in the range of $50 per ton ($.06/kg) of soil for typical applications. Assuming a 60% utilization, annual operating costs are in the range of $2 million.

Vendor

IIT Research Institute
10 West 35th Street
Chicago, IL 60616-3799
Tel: (312) 567-4232
Contact: Guggliam C. Sresty.

Experience/Licenses

IITRI is a 50-year-old, nonprofit Research and Development (R&D) corporation with about 1700 employees. IITRI's principal research is contract R&D and has an annual revenue of over $110 million. IITRI will license the RF and EM technologies to one or more companies that are in the remediation business to offer this service on a commercial basis. IITRI holds an EPA Research Development and Demonstration (RD&D) permit, and have recently applied for a Toxic Substances Control Act (TSCA) permit.

Sources of Information

Personal communication between Guggilam C. Sresty, ITTRI, and David E. Shropshire, EG&G Idaho, Inc. (response to EG&G's January 25, 1991 CBD solicitation), February 5, 1991.

Personal communication between Guggilam C. Sresty, ITTRI, and Mathew W. Roy, EG&G Idaho, Inc., April 4, 1991.

APPENDIX C

TECHNOLOGY EVALUATION CRITERIA

APPENDIX C
TECHNOLOGY EVALUATION CRITERIA

After screening the technologies to a reasonable number, as discussed in Section 2.3.3, the technologies and vendors were further evaluated. Each technology was rated (1-5) for effectiveness, implementability, and cost. In addition, each vendor was rated (1-5) for experience, capital, and establishment. The higher the rating, the better the technology or vendor/university satisfied that criterion. Following is a discussion of each criterion and what factors would effect the rating of that criterion.

Effectiveness

The effectiveness of a technology was assessed based on the following factors: (a) magnitude of residual risks, (b) adequacy and reliability of controls, (c) protection of the community during remedial actions, (d) protection of workers during remedial actions, (e) environmental impacts, time until remedial response objectives are achieved, (f) treatment process and remedy, (g) amount of hazardous material destroyed or treated, (h) reduction in toxicity, mobility, or volume, (i) irreversibility of the treatment, and (j) the type and quantity of treatment residual. Each technology was rated from 1-5 based on the following upper and lower limits:

Poor effectiveness (1)
The technology does not ensure that exposure to workers, the community, and the environment (during and after remedial actions) is within regulatory limits. The technology destroys and/or immobilizes an unacceptable portion (mass, volume) of contaminated material. Implementing this technology could yield a greater risk than performing no remedial action.

Excellent effectiveness (5)
The technology ensures that exposure to workers, the community, and the environment (during and after remedial actions) is within regulatory limits. The technology destroys and/or immobilizes most or all of the contaminated material. There is no need for long-term management controls for continued protection from residuals.

The elements composing the effectiveness criterion are discussed below.

Magnitude of residual risks

This factor assesses the residual risk remaining from untreated waste or treatment residuals at the conclusion of remedial activities. The potential for this risk may be measured by numerical standards such as cancer risk levels or the volume or concentration of contaminants in waste, media, or treatment residuals remaining on the site. The characteristics of the residuals should be considered to the degree that they remain hazardous, taking into account their volume, toxicity, mobility, and propensity to bioaccumulate.

Adequacy and reliability of controls

This factor assesses the adequacy and suitability of controls, if any, that are used to manage treatment residuals or untreated wastes that remain at the site. It may include an assessment of containment systems and institutional controls to determine if they are sufficient to ensure that any exposure to human and environmental receptors is within protective levels. This factor also addresses the long-term reliability of management controls for providing continued protection from residuals. It includes the assessment of the potential need to replace technical components of the alternatives, such as a cap, a slurry wall, or a treatment system; and the potential exposure pathway and the risks posed should the remedial action need replacement.

Protection of the community during remedial actions

This aspect of short-term effectiveness addresses any risk that results from implementation of the proposed remedial action, such as dust from excavation, transportation of hazardous materials, or air-quality impacts from a stripping tower operation that may affect human health.

Protection of workers during remedial actions

This factor assesses threats that may be posed to workers and the effectiveness and reliability of protective measures that would be taken.

Environmental Impacts

This factor addresses the potential adverse environmental impacts that may result from the construction and implementation of an alternative and evaluates the reliability of the available mitigation measures in preventing or reducing the potential impacts.

Treatment process and remedy

This factor includes whether the treatment process employed addresses the principal threats and if there are any special requirements for the treatment process.

Amount of hazardous material destroyed or treated

This factor addresses what portion (mass, volume) of contaminated material is destroyed and what portion (mass, volume) of contaminated material is treated.

Reduction in toxicity, mobility, or volume

This criterion addresses the extent the total mass of toxic contaminants is reduced, the extent the mobility of toxic contaminants is reduced, and the extent the volume of toxic contaminants is reduced.

Irreversibility of the treatment

This includes the extent the effects of treatment are irreversible.

Type and quantity of treatment residual

This factor addresses the residuals that remain including quantities and characteristics and their risks.

Implementability

The implementability of a technology was assessed based on the following factors: (a) ability to construct and operate the technology, (b) reliability of technology, (c) ease of undertaking additional remedial action if necessary, (d) monitoring considerations, (e) administrative feasibility, and (f) the availability of services and materials. Each technology was rated from 1-5 based on the following upper and lower limits:

Poor implementability (1)

The technology has many critical technical difficulties and unknowns. Construction and/or operation of the technology will not be possible for many years.

Excellent implementability (5)

The technology is proven and available; it has no technical difficulties or unknowns and there is little likelihood that any problems will lead to schedule delays. Process time is less than 3 months.

The elements composing the implementability criterion are discussed below.

Ability to construct and operate technology

This relates to the technical difficulties and unknowns associated with a technology.

Time until remedial response objectives are achieved

This factor includes an estimate of the time required to achieve protection for the site.

Reliability of technology

This focuses on the likelihood that technical problems associated with implementation will lead to schedule delays. Questions addressed include: What is the likelihood that technical problems will lead to schedule delays? What are some potential causes for delays? and what can be done to prevent any delays?

Ease of undertaking additional remedial action if necessary

This includes a discussion of what, if any, future remedial actions are necessary and how difficult it would be to implement such additional actions.

Monitoring considerations

This addresses the ability to monitor the effectiveness of the remedy and includes an evaluation of the risks of exposure should monitoring be insufficient to detect a system failure.

Administrative feasibility

Activities needed to coordinate other offices and agencies (e.g., obtaining permits for offsite activities or rights-of-way for construction).

Availability of services and materials

This factor addresses the availability of adequate offsite treatment, storage capacity, and disposal services; necessary equipment and specialists, and provisions to ensure any necessary additional resources; and prospective technologies.

Cost

The cost of a technology was assessed based on capital costs and annual operating and maintenance costs. Each technology was rated from 1-5 based on the following upper and lower limits:

Poor cost (1)

The technology's cost is extremely high.

Excellent cost (5)

The technology's cost is the lowest of all in situ technologies.

The elements composing the cost criterion are discussed below.

Capital Costs

This factor addressed capital costs (construction costs, equipment costs, land and site-development costs, buildings and services costs, relocation expenses, disposal costs) and indirect capital costs (engineering expenses, license or permit costs, startup and shakedown costs, contingency allowances).

Annual Operating and Maintenance Costs

This factor included operating labor costs, maintenance materials and labor costs, auxiliary materials and energy, disposal of residues, purchased services, administrative costs, and licensing costs.

Experience

The vendor experience was assessed based on ex situ waste treatment experience and in situ waste treatment experience. Each vendor was rated from 1-5 based on the following upper and lower limits:

Insufficient experience (1)

The vendor has insufficient in situ or ex situ waste treatment experience.

Excellent experience (4)

The vendor has very extensive in situ and/or ex situ waste treatment experience. The vendor has many years of experience with waste remediation and has proven their competence by successfully completing some major projects.

The elements composing the vendor experience criterion are discussed below.

Ex Situ Waste Treatment Experience

This factor addresses the vendor's ex situ waste treatment experience (ex situ biological treatment, ex situ chemical treatment, ex situ physical treatment, ex situ phase separation, ex situ solidification/stabilization/encapsulation treatment, and ex situ thermal treatment).

In Situ Waste Treatment Experience

This factor addresses the vendor's in situ waste treatment experience (in situ biological treatment, in situ chemical treatment, in situ physical treatment, in situ phase separation, in situ solidification/stabilization/encapsulation treatment, and in situ thermal treatment).

Establishment/Capital

The vendor establishment/capital was assessed based on the vendor's current possession of services, necessary materials, necessary equipment, and specialists. Each vendor was rated based on the following scheme:

Poor establishment/capital (1)

The vendor insufficiently possesses the needed services, material, equipment, or specialists. The provisions to ensure the needed services, material, equipment, and specialists would require an immense amount of capital, effort, and time.

Excellent establishment/capital (5)

The vendor possesses all of the needed services, material, equipment, and specialists. The needed services, material, equipment, and specialists will be available for this project.

APPENDIX D

VENDOR/UNIVERSITY RATINGS FOR THE ACID PIT, LOW-LEVEL PITS AND TRENCHES, AND SOIL VAULTS

APPENDIX D
VENDOR/UNIVERSITY RATINGS FOR THE ACID PIT, LOW-LEVEL PITS AND TRENCHES, AND SOIL VAULTS

This appendix contains two tables of technologies and corresponding vendors/universities. The vendors listed are only those that responded to EG&G Idaho's *Commerce Business Daily* Notice. The companies experience and capital/establishment were ranked with an experience weighting of 40% and a capital/establishment weighting of 60%. Experience and capital are defined below.

- *Experience* was assessed according to both the company/university's experience with the technology and the experience of the personnel in the organization.
- *Capital* was evaluated as the amount of supporting equipment the company/university owns and would be available for testing, and establishment refers to the length of time the organization has been operating and its track record.

Some of the technologies listed are combined with other compatible technologies. The score given is a combination of participating companies.

Not all vendors who are listed in the technology descriptions in Section 2.2 are included in this evaluation. Tables D-1 and D-2 contain only the vendors of who responded to the ISTE CBD Notice with information on in situ buried waste remedial technologies or vendors who supplied the applicable information unsolicited. Other respondants to the CBD Notice that were not evaluated are discussed below.

Hazardous Waste Research Center

Louisiana State University's Hazardous Waste Research Center (HWRC) initially responded to the CBD solicitation with information on a number of technologies they are researching. However, as part of the university, the HWRC is prohibited from competing with private industry and cannot bid for actual treatability tests. The Director asked to withdraw the Center from consideration.

Spelman College, Department of Biology

Spelman College was eliminated from consideration because of the substantial addition of liquid (a "soil and water matrix") that is required for their process. Contaminants would be removed by "harvesting the floating microbial biomass" in a "pond system." While a containment may give added protection to systems that require the addition of liquid, it should not be relied upon.

Wastech, Inc. and Waste Technologies Group, Inc.

Wastech, Inc. and Waste Technologies Group, Inc. (a licensee of Wastech, Inc.) were eliminated from performing the treatability study because they did not send requested information regarding their solidification/stabilization capabilities. The reason cited for not sending the information was lack of waste characterization information from the waste areas.

Westinghouse Electric Company

Westinghouse Electric Company was also screened out for not sending information on their technologies. A phone contact revealed that their two main in situ technologies are solution mining and high frequency heating. Both technologies are still in the developmental stage.

Table D-1. Vendor/University Ratings for the Acid Pit

TECHNOLOGY	TECH TOTAL	VENDOR/UNIV	EXP	CAP EST	VENDOR SCORE	TOTAL SCORE
Weighting (%)	50		40	60	50	
DETOXIFIER™	93%	KLM	4	4	80%	86.5%
Electrokinetics with ISV Barrier	84.8%	Electro-Petroleum and Battelle	5	5	100%	92.4%
Electrokinetics with Slurry Wall and Bottom Sealing	85.2%	Electro-Petroleum, NRT, and Halliburton or NRT	5	5	100%	92.6%
Electrokinetics with Soil/ Cement Wall and Bottom Sealing	85%	Electro-Petroleum, NRT, and Halliburton or NRT	5	5	100%	92.5%
In Situ Vitrification	81.2%	Geosafe	4	4	80%	80.6%
Radio Frequency Heating with Solidification/ Stabilization	93%	IIT and Halliburton	5	4	88%	90.5%
Simultaneous Injection, Extraction, and Recharge with Solidification/ Stabilization	92.2%	ARA and Halliburton	5	3	76%	84.1%
Solidification/ Stabilization	92%	Fluid Tech/ Geo Con	4	4	86%	84%
		Halliburton	4.5	5	94%	92%
		ISF	4	5	92%	90%
		Laidlaw	4	5	92%	90%
		WTG/ Wastech, Inc.	4	4	86%	84%

Solidification/ Stabilization with ISV	85.8%	Halliburton and GeoSafe	4	4	79.3%	82.9%
Solidification/ Stabilization with Plasma Arc Glass Cap	88%	Halliburton and SAIC	5	4	90%	88%
Steam/Air Stripping with Solidification/ Stabilization	93%	NRT and Halliburton	4.5	5	96%	94.5%
VVE with Solidification/ Stabilization	93%	NRT and Halliburton	4.5	5	96%	94.5%

Table D-2. Vendor/University Ratings for the Low-Level Pits and Trenches and the Soil Vaults

TECHNOLOGY	TECH TOTAL	VENDOR/UNIV	EXP	CAP EST	VENDOR SCORE	TOTAL SCORE
Weighting (%)	50		40	60	50	
Slurry Wall with Bottom Sealing	78%	NRT and Halliburton	4.5	5	96%	87%
Slurry Wall with Cap	83%	NRT and SAIC	5	3	76%	79.5%
Slurry Wall with Bottom Sealing and Cap	75.6%	NRT, Halliburton, and SAIC	5	3	76%	75.8%
Slurry Wall with Bottom Sealing followed with Steam/Air Stripping (or VVE)	73%	NRT, Halliburton, and NRT	4.5	5	96%	84.5%
Slurry Wall with Bottom Sealing followed with Steam/Air Stripping and Cap	73%	NRT, Halliburton, NRT, and SAIC	4.5	4	84%	78.5%
Slurry Wall followed by Steam/Air Stripping (or VVE) and Cap	75%	NRT, NRT, and SAIC	5	3	76%	75.5%
Soil/Cement Wall with Bottom Sealing	77.6%	Halliburton and Halliburton	4.5	5	96%	86.8%
Soil/Cement Wall with Cap	82.6%	Halliburton and SAIC	5	3	76%	79.3%
Soil/Cement Wall with Bottom Sealing and Cap	75.2%	Halliburton, Halliburton, and SAIC	5	3	76%	75.6%

Soil/Cement Wall with Bottom Sealing followed by Steam/Air Stripping (or VVE)	72.6%	Halliburton, Halliburton, and NRT	4.5	5	96%	84.3%
Soil/Cement Wall with Bottom Sealing followed by Steam/Air Stripping (or VVE) and Cap	72.6%	Halliburton, Halliburton, NRT, and SAIC	4.5	4	84%	78.3%
Soil/Cement Wall followed Steam/Air Stripping (or VVE) and Cap	74.6%	Halliburton, NRT, and SAIC	5	3	76%	75.3%
Steam/Air Stripping (or VVE) with Fluidized-Bed Zeolite System	76.4%	NRT and Westinghouse Hanford	4.5	3	72%	74.2%
Steam/Air Stripping (or VVE) with Fluidized-Bed Zeolite System and Cap	79.4%	NRT, Westinghouse Hanford, and SAIC	4.5	3	72%	75.7%

END

DATE FILMED

01/03/92