DOE/EM-0251

Office of Environmental Management

Technology Development

LANDFILL STABILIZATION FOCUS AREA

Technology Summary

June 1995

THE LANDFILL STABILIZATION FOCUS AREA TECHNOLOGY SUMMARY

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INTRODUCTION

THE NEW APPROACH

PURPOSE

Although positive steps have been taken during the past three decades to remedy the world's environmental problems, the nation's ability to respond to many current and future environmental and economic challenges depends on technological advances produced by a well-organized and productive federal research and development program.

To ensure that such programs focus on the most pressing environmental restoration and waste management problems at the U.S. Department of Energy (DOE), the Assistant Secretary for the Office of Environmental Management (EM) established a Working Group in August 1993 to implement a new approach to environmental research and technology development. The goal of DOE's new approach is to conduct a research and technology development program that will overcome major obstacles in the cleanup of DOE sites. Integral to this new, solutions-oriented approach is an up-front awareness of program needs obtained from customers, users, regulators, and stakeholders. These needs can then be disseminated to the developers of technological solutions.

The key features of the new approach are:

- establishing five focus areas to address DOE's most pressing problems;
- teaming with the customers in EM to identify, develop, and implement needed technology;
- focusing technology development activities on major environmental management problems;
- coordinating management of scientific and development activities in support of EM;
- focusing resources in national laboratories more effectively;
- involving industry in developing and implementing solutions, including technology transfer into DOE and from DOE to the private sector;
- coordinating basic research by involving academia and other research organizations to stimulate technological breakthroughs; and
- enhancing involvement of regulators and stakeholders in implementation of technology development.

DOE has established a framework and strategy for coordinating efforts among DOE organizations, Management and Operations (M&O) contractors, the national laboratories, other government agencies, the scientific community, industry, academia, and the affected public. Full implementation of the new approach is planned for the FY 95/96 timeframe. The new strategy will build upon existing programs and will seek continual improvement of all EM operations and processes.

Prior to implementation of the new approach, EM's Office of Technology Development (OTD) carried out an aggressive national program of applied research and development to meet environmental restoration and waste management needs based on the concepts of Integrated Programs (IP) and Integrated Demonstrations (ID). These concepts, introduced in 1989, were engineered to manage the research, development, demonstration, testing and evaluation (RDDT&E) activities within EM.

An IP was the cost-effective mechanism which assembled a group of related and synergistic technologies to evaluate their performance to solve a specific aspect of a waste management or environmental problem. The problem could be unique to a site or common to many sites. An IP supported applied research to develop innovative technologies in key application areas organized around specific activities required in each stage of the remediation process (e.g., characterization, treatment, and disposal).

An ID was the cost-effective mechanism that assembled a group of related and synergistic technologies to evaluate their performance individually or as a complete system to correct waste management and environmental problems from cradle to grave.

BENEFITS

A keystone for implementation of the new approach is to encourage development of technologies that are better, faster, safer and more cost-effective than those currently available. More importantly, the new approach has been adopted to foster implementation of new and innovative environmental technologies, facilitating the national commitment to long-term environmental, energy, and economic goals.

An important benefit to the new approach is the creation of investment returns for developing new technologies — technology dividends. These technology dividends result from partnerships and leveraging within government and between government and the private sector. The partnerships can consist of technology developers, technology users, problem holders, and problem solvers.

EM technology dividends will include:

- Employment opportunities with new businesses and existing businesses
- Cleanup of sites posing the greatest threats to human health, safety, and the environment;
- Materials reused and recycled, instead of thrown away or freshly contaminated;
- Pollution prevented;
- More effective and efficient industrial processes, leading to greater U.S. competitiveness globally; and
- Technology transfer to other countries.

By implementing the new approach for the unique environmental problems associated with DOE sites, EM/OTD, scientists, and engineers at the national laboratories stand at the threshold of opportunity to develop new technologies. This work will enhance quality of life through a cleaner environment, improved global competitiveness, and ensure job opportunities for American workers.

FOCUS AREAS

Five major remediation and waste management problem areas within the DOE Complex have been targeted for action on the basis of risk, prevalence, or need for technology development to meet environmental requirements and regulations. Other areas may be added or currently identified areas further partitioned to ensure that research and technology development programs remain focused on EM's most pressing remediation and waste management needs. These major problem areas, termed "Focus Areas," are described below.

Contaminant Plume Containment and Remediation. Uncontained hazardous and radioactive contaminants in soil and ground water exist throughout the DOE Complex. There is insufficient information at most sites on the contaminants' distribution and concentration. The migration of some contaminants threatens water resources and, in some cases, has already had an adverse impact on the off-site environment. Many current characterization, containment, and treatment technologies are ineffective or too costly. Improvements are needed in characterization and data interpretation methods, containment systems, and in situ treatment.

Mixed Waste Characterization, Treatment, and Disposal. DOE faces major technical challenges in the management of low-level radioactive mixed waste. Several conflicting regulations, together with a lack of definitive mixed waste treatment standards hamper mixed waste treatment and disposal. Disposal capacity for mixed waste is also expensive and severely limited. DOE now spends millions of dollars annually to store mixed waste because of the lack of accepted treatment technology and disposal capacity. In addition, currently available waste management practices require extensive, and hence costly waste characterization before disposal. Therefore, DOE must pursue technology that leads to better and less expensive characterization, retrieval, handling, treatment, and disposal of mixed waste.

High-Level Waste Tank Remediation. Across the DOE Complex, hundreds of large storage tanks contain hundreds of thousands of cubic meters of high-level mixed waste. Primary areas of concern are deteriorating tank structures and consequent leakage of their contents. Research and technology development activities must focus on the development of safe, reliable, cost-effective methods for characterization, retrieval, treatment, and final disposal of the wastes.

Landfill Stabilization. Numerous DOE landfills pose significant remediation challenges. Some existing landfills have contaminants that are migrating, thus requiring interim containment prior to final remediation. Materials buried in retrievable storage pose another problem. Retrieval systems must be developed to reduce worker exposure and secondary waste quantities. Another high-priority need is in situ methods for containment and treatment.

Decontamination and Decommissioning. The aging of DOE's weapons facilities, along with the reduction in nuclear weapons production, has resulted in a need to transition, decommission, deactivate, and dispose of numerous facilities contaminated with radionuclides and hazardous materials. While building and scrap materials at the sites are a potential resource, with a significant economic value, current regulations lack clear release standards. This indirectly discourages the recovery, recycling, and/or reuse of these resources. The development of enhanced technologies for the decontamination of these materials, and effective communication of the low relative risks involved, will facilitate the recovery, recycle, and/or reuse of these resources. Improved material removal, handling, and processing technologies will enhance worker safety and reduce cost.

CROSSCUTTING TECHNOLOGIES

Crosscutting technologies are those which overlap the boundaries of the focus areas while providing simultaneous benefits. These technologies may be used in several or all focus area testing and evaluation programs, and include:

Characterization, Monitoring, and Sensor Technology. DOE is required to characterize more than 3,700 contaminated sites, 1.5 million barrels of stored waste, 385,000 m3 of high-level waste in tanks, and from 1,700 to 7,000 facilities before remediation, treatment, and facility transitioning commence. During remediation, treatment, and site closure, monitoring technologies are needed to ensure worker safety and effective cleanup. Cost-effective technologies are needed for all EM characterization requirements.

Efficient Separations and Processing. Separation and treatment technologies are needed to treat and immobilize a broad range of radioactive wastes. In some cases, separations technologies do not exist. In others, improvements are needed to reduce costs, reduce secondary waste volumes, and improve waste form quality. Separations technologies are also needed for environmental restoration of DOE sites, for groundwater and soils cleanup, and for decontamination and decommissioning of facilities. Many separations agents developed for waste treatment can be adapted for environmental restoration needs.

Robotics. DOE's waste disposal efforts have particular issues—access, safety, final disposal, and cost efficiency. Due to hazardous radiation, massive waste loads, and restricted entry ways, many sites are inaccessible for human labor. It is unsafe to expose humans to radiation, harmful chemicals, and injurious mechanical objects. Human labor requires higher compensation, the need for expensive protective clothing, and stringent decontamination procedures. Robotics systems are safe, efficient, and cost-effective means to automate the handling and processing of mixed waste and characterizing and/or retrieving storage tank waste. Systems can also be designed for surveillance, characterization, cleanup, and decommissioning of retired DOE facilities.

Innovative Investment Area. DOE has set aside funding to foster research and development partnerships within the public and private sector, and to introduce innovative technologies into OTD programs. The Innovative Investment Area supports two types of technologies: (1) technologies that show promise to address specific EM needs, but require proof-of-principle experimentation, and (2) proven technologies in other fields that require critical path experimentation to demonstrate feasibility for adaptation to specific EM needs.

Pollution Prevention. DOE and the Department of Defense (DoD) have similar waste stream pollution problems and common environmental concerns. By combining their resources, these agencies can develop a coordinated interagency environmental research and technology development program that produces cost-effective technological solutions, particularly in the areas of process change or in-process recycling.

Technical Task Plans

Technical Task Plans (TTPs) are used to identify and to summarize work funded and managed by OTD at headquarters, the field, and the national laboratories. These plans include a project summary, technical task description, budget schedule, and milestone schedule. The EM-50 FY94 Program Summary (DOE/EM-0216) lists TTPs current as of the date of this document.

All tasks require a TTP number. Each TTP number contains information on the fiscal year in which the task is first funded, the DOE Operations Office funding allotment code, and the laboratory/contractor/university designator. See appendix for further details.

EM Organizational Structure

The Office of Environmental Management (EM) is responsible for managing the cleanup of DOE wastes from past nuclear weapons production and current operations. The EM mission is to bring DOE sites into compliance with all environmental regulations while minimizing risks to the environment, human health and safety posed by the generation, handling, treatment, storage, transportation, and disposal of DOE waste. The EM organization was established to provide focus, accountability, and visibility for DOE's waste management and remediation efforts. See Figure A.

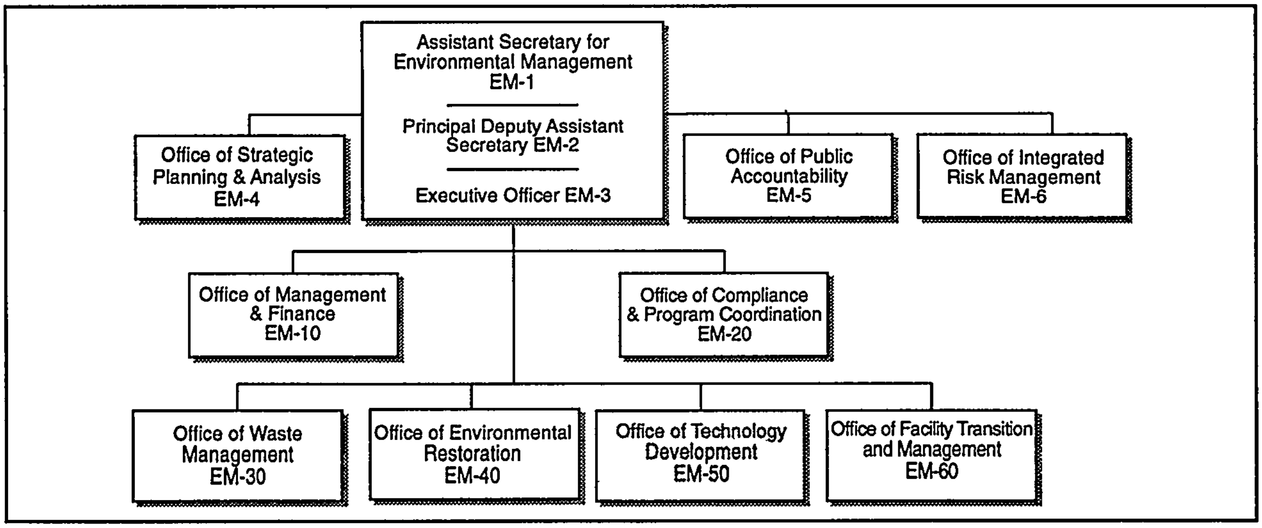

Figure A. The EM Organizational Structure as of May 1, 1994.

Office of Technology Development

The Office of Technology Development (EM-50) has the overall responsibility to develop technologies to meet DOE's goals for environmental restoration. OTD works closely with EM-30, -40, and -60 in identifying, developing, and implementing innovative and cost-effective technologies. Activities within EM-50 include applied research and development, demonstration, testing, and evaluation (RDDT&E), technology integration, technology transfer, and program support. See Figure B.

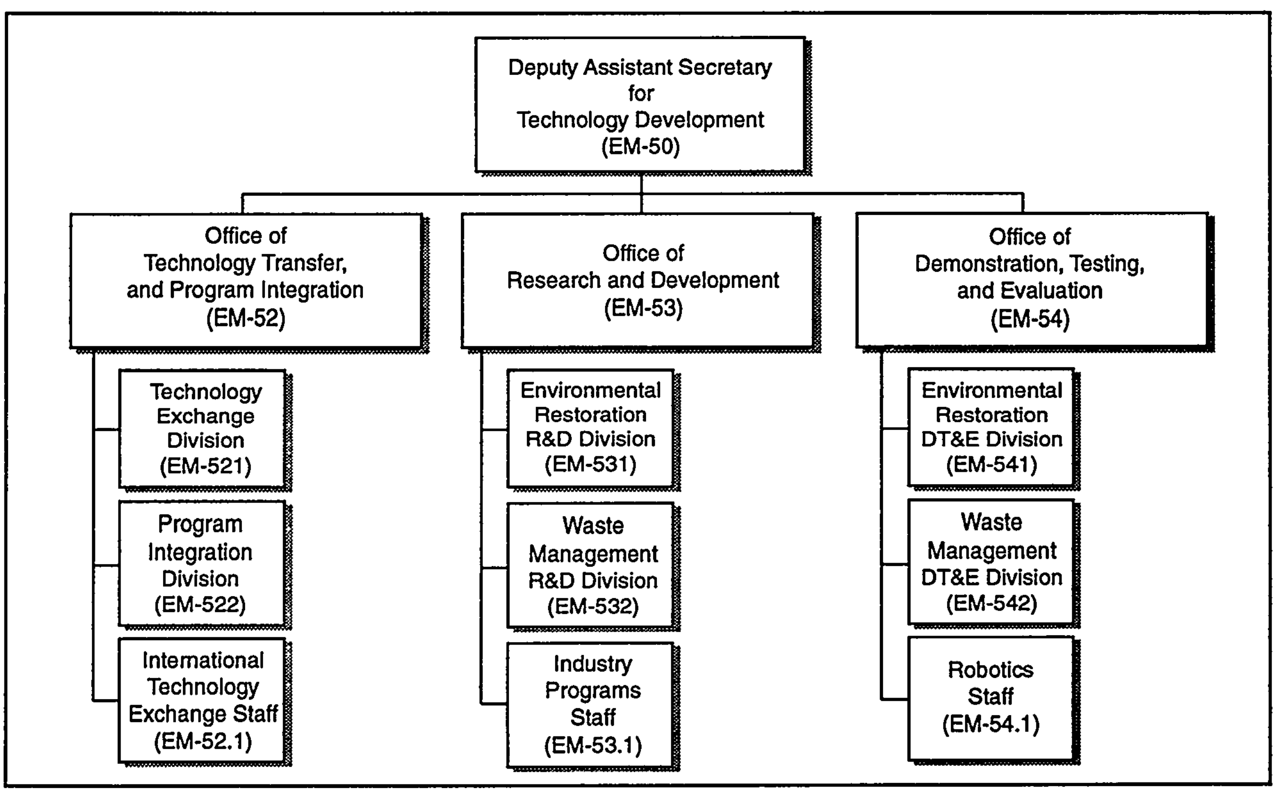

Figure B. The OTD Organizational Structure as of May 1, 1994.

EM-50 ORGANIZATION

The Office of Technology Transfer and Program Integration (EM-52) provides management, financial, and internal program support to line organizations that comprise EM-50. It also provides efforts to encourage and to facilitate the infusion and diffusion of innovative environmental technologies for internal and domestic application through collaborative partnerships with U.S. and foreign industry or organizations, the national laboratories, other federal agencies, and universities. Technology transfer and technology leveraging are important program components. Enhanced communication to internal and external stakeholders is a goal of this Office.

The Office of Research and Development (EM-53) is responsible for establishing applied research and development (R&D) program at DOE sites nationwide. Programs are designed to identify operational needs in environmental restoration, waste operations, and corrective activities, and to provide solutions to key technical issues that, if not solved in a timely manner, would adversely affect DOE's ability to meet its cleanup goal.

The Office of Demonstration, Testing, and Evaluation (EM-54) is responsible for identifying environmental management technologies in the research and development stage that are ready for transition to the demonstration arena. Those technologies are complete systems to demonstrate a solution to a specific problem area. Programs are conducted to advance selected technologies so they can be utilized by DOE to meet its cleanup goal in a cost-effective manner.

OTHER EM ORGANIZATIONS

The Office of Waste Management (EM-30) has program responsibilities for managing waste generated at all DOE sites during weapons processing and manufacturing, research activities, and site cleanup activities. This includes the treatment, storage, transportation, and disposal of several types of waste: transuranic, low-level radioactive, mixed, and solid sanitary wastes. EM-30 is also responsible for the storage, treatment, and processing of defense high-level radioactive waste (HLW), waste minimization efforts, and corrective activities at waste management facilities.

The Office of Environmental Restoration (EM-40) has program responsibilities for assessment and cleanup of inactive hazardous and radioactive facilities and waste sites at all DOE installations and some non-DOE sites. EM-40 oversees program activities to reduce or eliminate risks to human health and the environment.

The Office of Facility Transition and Management (EM-60) has the responsibility to ensure that shut-down facilities are brought to a deactivated state, are properly maintained, and are eventually decontaminated and/or decommissioned or released for other uses.

THE LANDFILL STABILIZATION FOCUS AREA OVERVIEW

THE PROBLEM

Landfills within the DOE Complex as of 1990 are estimated to contain 3 million cubic meters of buried waste. The DOE facilities where the waste is predominantly located are at Hanford, the Savannah River Site (SRS), the Idaho National Engineering Laboratory (INEL), the Los Alamos National Laboratory (LANL), the Oak Ridge Reservation (ORR), the Nevada Test Site (NTS), and the Rocky Flats Plant (RFP). Landfills include buried waste, whether on pads or in trenches, sumps, ponds, pits, cribs, heaps and piles, auger holes, caissons, and sanitary landfills.

Approximately half of all DOE buried waste was disposed of before 1970. Disposal regulations at that time permitted the commingling of various types of waste (i.e., transuranic, low-level radioactive, hazardous). As a result, much of the buried waste throughout the DOE Complex is presently believed to be contaminated with both hazardous and radioactive materials. DOE buried waste typically includes transuranic-contaminated radioactive waste (TRU), low-level radioactive waste (LLW), hazardous waste per 40 CFR 261, greater-than-class-C waste per CFR 61 55 (GTCC), mixed TRU waste, and mixed LLW.

The wastes at those various sites were disposed of directly or in containers such as steel drums, wooden boxes, and cardboard cartons. Coupled with the absence of release barriers, some of the waste containers have breached from degradation over time resulting in contamination of large volumes of surrounding soils. The wastes exist in the form of solids, liquids, or sludges, and have a diverse range of chemical constituents including radionuclides, polychlorinated biphenyls, heavy metals, organic solvents, and reactive compounds. Typical buried waste includes such items as construction and demolition materials (i.e., lumber, concrete blocks, steel plates, etc.), laboratory equipment (i.e., hoods, desks, tubing, glassware, etc.), process equipment (i.e., heat exchanger, valves, ion exchange resins, high-efficiency particulate air (HEPA) filters, etc.), maintenance equipment (i.e., handtools, cranes, oils and greases, etc.), decontamination materials (i.e., paper, rags, plastic bags).

THE SOLUTION

The mission of the Landfill Stabilization Focus Area is to develop, demonstrate, and deliver safer, more cost-effective and efficient technologies which satisfy DOE site needs for the remediation and management of landfills. The LSFA is structured into five technology areas to meet the landfill remediation and management needs across the DOE complex. These technology areas are:

- Assessment
- Retrieval
- Treatment
- Containment
- Stabilization

The expanded scope of the above technology areas is described below:

ASSESSMENT

Assessment primarily consists of two categories: 1) site characterization, and 2) waste characterization. Fundamental to both of these categories is the need to be able to identify, quantify, and locate wastes. The information provided by either category may determine the remediation and the treatment options evaluated. These categories are described below.

SITE CHARACTERIZATION

Characterization of the site is necessary to determine boundaries of the waste and to identify and locate specific waste forms such as drums, large metal objects, and voids. Site characterization is a prerequisite for the decision making process to launch containment/stabilization initiatives or excavation/treatment and disposal alternatives. It involves surveying and testing the site to generate a site contamination map. Subsurface buried waste characterization includes assessing the degree and extent of its lateral and vertical spread, and identifying the degree and extent of soil contamination.

Boring, drilling, digging, excavation, and other invasive techniques have been employed for this purpose. However, recent emphasis has been on non-invasive methods and those are currently being developed under an EM-50 mandate, in particular, for characterizing radioactive and mixed waste contaminated sites. Examples include: Landfill Characterization and Monitoring System, Holographic Impulse Radar Array and Imaging Infrared Interferometer.

WASTE CHARACTERIZATION

This activity is designed to identify and characterize the waste and determine the concentration of its constituents in contaminated areas. Typically, invasive methods have been used for this purpose. Sampling and analysis of excavated or retrieved waste/media have been the methods widely used for waste characterization and assessment of media (soil, water) contamination. Recent emphasis has been on development of non-invasive methods which are currently under development for characterization of some of the waste types and constituents, in particular, for radioactive and mixed waste. These non-invasive methods are preferred because of the time, cost, and safety advantages they offer over the invasive methods. Examples of these include the excavated waste assay and the waste assay measurement integration system.

RETRIEVAL

Retrieval involves excavation of waste/contaminated soil for ex situ/off-site treatment/disposal. When treatment occurs on site, the treated soil which is considered decontaminated may be backfilled in lieu of off-site disposal. Retrieval operations can be divided in two categories: (1) full-scale retrieval and (2) hot spot or selective retrieval. These categories are described below:

FULL-SCALE RETRIEVAL

Conventional drilling and excavation equipment are typically used for this purpose. However, currently, remote operated equipment is being developed and demonstrated for retrieval of waste, in particular, radioactive and/or mixed waste. The new technologies include: Remote Excavation System, Full-scale Remote Retrieval, Waste Conveyance and Innovative End Effector, Contaminated Material Excavation Handling and Retrieval System.

Hot Spot Retrieval

Alternatives to conventional hot spot retrieval techniques such as drilling and excavation are currently being developed. Selective retrieval using dual robotic arms is being developed to support the system concept of hot spot retrieval. Technology development in support of this concept includes the cooperative telerobotic retrieval.

Treatment

Ex situ treatment involves exhuming the waste followed by packaging and transport to a treatment facility. Treated waste may then be disposed of on site or at another site elsewhere. The ex situ processing may include four interrelated processes: pre-treatment; primary treatment; secondary treatment; and process controls/verifications. These processes are employed for the immobilization, detoxification, volume reduction, and/or stabilization of retrieved buried waste and contaminated soils.

Pre-treatment techniques are used to minimize the amount of waste to be treated and to optimize the primary treatment of the waste. Pre-treatments may include: cryofracture; conventional shredding; thermal technologies such as desorption; or, sorting of retrieved waste into waste types (soils, metals, combustibles) using advanced assaying methods.

The primary treatment of solid, mixed, hazardous, and radioactive waste encompassing combustibles, metals, soils, and sludges and their associated structures (i.e., drums, boxes, large metal objects) may be conducted using thermal, chemical, biological, and physical methods for all or part of the waste streams. The current emphasis is on high-temperature thermal treatments, although other treatment alternatives are being investigated. Thermal treatment techniques such as the Graphite DC Arc Furnace and Arc Melter Vitrification, and concepts such as Minimum Additive Waste Stabilization have been shown.

Pre-treatment and primary treatment technologies require additional ancillary systems. These techniques include feed systems, off-gas systems, process diagnostics, and secondary waste stream treatment. The technologies comprising these systems may need to be evaluated. These technologies include non-thermal plasma (NTP), dry high efficiency particulate air (HEPA) filters, various combinations of existing off-gas systems, and secondary waste recycle into the primary treatment. Some primary treatment technologies may be used to treat secondary waste and help reduce the amount of secondary waste.

Containment

Containment is the restriction/confinement of buried waste to a limited area to prevent its migration/leaching beyond its confined domain. This is typically achieved by 1) installation of surface caps or covers and 2) placement of engineered subsurface (vertical or horizontal) barriers/systems. The barrier materials are chosen on the basis of their long-term durability, inertness to acids and bases, resistance to corrosion and water impermeability. Placement of barriers around the waste is determined on the basis of site and waste characterization data. Containment may serve as an interim action to reduce/prevent contaminant migration pending future remedial decisions and actions or as a long-term measure for use as final remediation action. These categories are described below.

Surface Caps

Surface caps constructed of synthetic and/or natural geological materials like clay, control erosion, deep percolation and biological intrusion. The spectrum of designs vary from simple soil barriers that have optimum configurations, plant cover and surface slope to more complex multilayered cover profiles, incorporating engineered barriers that inhibit downward movement of soil moisture. Few of the designs have actually been constructed in the field and monitored in a way that allows a complete evaluation of performance characteristics. Those few that have been field-tested have been evaluated under very specific climate and environmental conditions.

The LSFA will take the initiative and lead efforts to develop field-tested, climate specific migration barrier cover designs which can serve as the sole containment technology or as a component of an integrated barrier system that incorporates other barrier concepts, along with cover, to contain wastes.

SUBSURFACE BARRIERS

Waste containment may also include emplacement of subsurface barriers (vertical and horizontal) to control water infiltration and contaminant release. The barriers are usually composed of grouting material such as concrete, soil-bentonite, or cement-bentonite slurry material. The current state-of-the-art for emplacement of subsurface barriers in near-surface soils lies primarily with vertically emplaced barriers. Subsurface horizontal to sub horizontal barriers that retard mass movement are not currently employed in the civil engineering application. New technology initiatives are geared toward the development of superplastic grouts and soil-cement of significantly superior mechanical, electrical and durability properties.

STABILIZATION

Stabilization of waste in situ involves altering its physical/chemical/toxicological properties and rendering it immobile and incapable of leaching under the most-stringent conditions. Grouting the waste/soil matrix to reduce water and contaminant migration through the waste matrix will stabilize a waste. Another example of the stabilization process is in situ vitrification which uses high temperatures (typically between 1100 and 3000°C) to chemically incorporate waste into a glasseous matrix while destroying organics.

LANDFILL ASSESSMENT

Section 1.0

1.1. BURIED WASTE DIGFACE CHARACTERIZATION

TASK DESCRIPTION

The digface characterization project demonstrates multiple sensors that can be used as part of a retrieval effort. The digface characterization technology will allow continuous and continually improving monitoring and characterization of the site being remediated. See Figure 1.1. The digface characterization technique is integrated into the remediation process itself. As retrieval progresses, sensor data interpretation capability improves by comparing interpreted data images with the retrieved targets.

Geophysical, chemical, and radiological sensors are being deployed by a robotic system. The sensors scan over the surface being remediated. As waste retrieval proceeds, the sensors are continuously deployed to characterize the remaining waste. Remediation proceeds in a methodical manner in which the characterization data are interpreted real-time in support of the retrieval process.

The primary objective is to develop and test geophysical, chemical, and radiological sensors to provide constant surveillance and screening for all categories of hazards at the digface during excavation.

TECHNOLOGY NEEDS

There is an urgent need to develop technology that can characterize contaminated sites without excavation or sampling. The technology must be cost-effective and result in the elimination or minimization of worker exposure. Excavation, sampling, and analysis of buried waste and contaminated soil are generally used for the purpose of characterizing hazardous waste sites. These methods are expensive, and in addition, pose safety hazards to remediation workers. The digface characterization technology under development that uses geophysical, chemical, and radiological sensors is expected to meet that need.

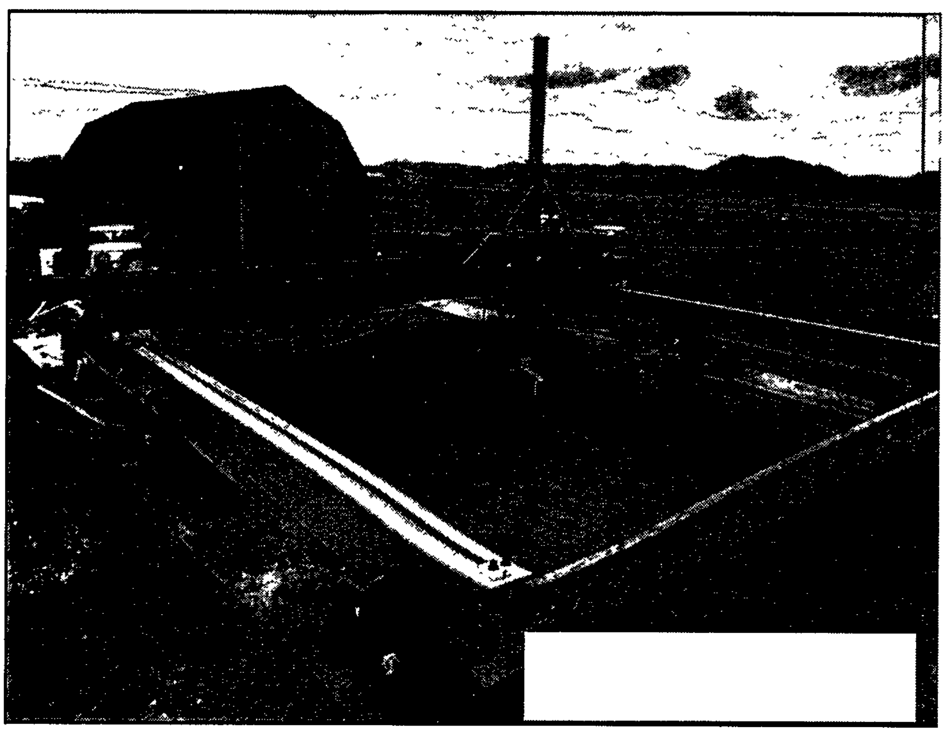

Figure 1.1. Pilot-scale Robotic Deployment of Digface Sensors Using a Soil Box to Simulate the Digface.

ACCOMPLISHMENTS

Three prototype sensors were developed for digface application: a gamma spectrometer, a dielectric permittivity sensor, and a focused electromagnetic induction sensor. Laboratory data for the dielectric permittivity and gamma spectrometer sensors indicate that both are feasible candidates for digface application.

The pilot-scale testing using a soilbox to simulate the digface is completed. Field testing of a prototype digface characterization system used a test trench at the Idaho National Engineering Laboratory (INEL) Cold Test Pit. The system's multiple sensors were deployed with a manual non-metallic gantry designed and constructed to support the collection of dense data sets in a non-interfering manner.

Data were obtained from several commercial sensors deployed over simulated targets in multiple passes. As soil layers were progressively removed the resolution capabilities of the sensors were also evaluated. Test results indicate that the sensors will be able to support real-time interpretation of targets during digface applications.

The prototype dielectric permittivity sensor, gamma spectrometer/chemical assay system, and test sensors along with the gantry crane and Schilling arm were built. The integrated system is ready for complete full-scale demonstration.

BENEFITS

The digface technology reduces environmental, health, and safety risks during cleanup of buried waste sites. Real-time data interpretation during the retrieval process allows for the incorporation of appropriate remediation equipment to maintain safety and environmental standards.

Development of an automatic and remote deployment capability, with refined data interpretation techniques to support rapid target identifications will be powerful features of this technology.

Cost savings have not been quantified. However, non-intrusive characterization systems can reduce the potential costs of intrusive sampling and analysis.

COLLABORATION/TECHNOLOGY TRANSFER

The successful completion of demonstrations will result in a proven concept that is ready for technology transfer. Vendors supplying the base instrumentation and equipment for the sensors (Geonics, Ltd.), those involved in waste cleanup and working with environmentally hazardous material (Ecology International), robotic programs (Buried Waste Robotics Program), and mining interests (Colorado School of Mines and USGS), have participated in the project. Individual sensors, as well as combined systems (sensors and robotic arm) have commercial potential in manufacturing, mining, and waste cleanup operations. Implementation of the data display hardware and software will provide private industry and other DOE partners with an easily adaptable system to specific site requirements. Disclosure of this research through professional journals and presentations at technical conferences will ensure transfer of this technology to a wider network of private-sector contractors that may be able to provide portions of the system, are performing waste site remediations, or have other remote-retrieval characterization needs.

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1.2 TENSOR MAGNETIC GRADIOMETER

TASK DESCRIPTION

The tensor magnetic gradiometer system (TMGS) non-intrusively measures the vector magnetic field and the magnetic gradient tensor at a waste site for use in site characterization. The system consists of a four-element array of high-sensitivity triaxial ringcore fluxgate magnetometers and supporting software. The TMGS measures five independent components of magnetic gradient and three components of the magnetic field.

The primary objective is to develop and demonstrate site characterization and object location using a tensor magnetic gradiometer applied specifically to DOE buried waste sites.

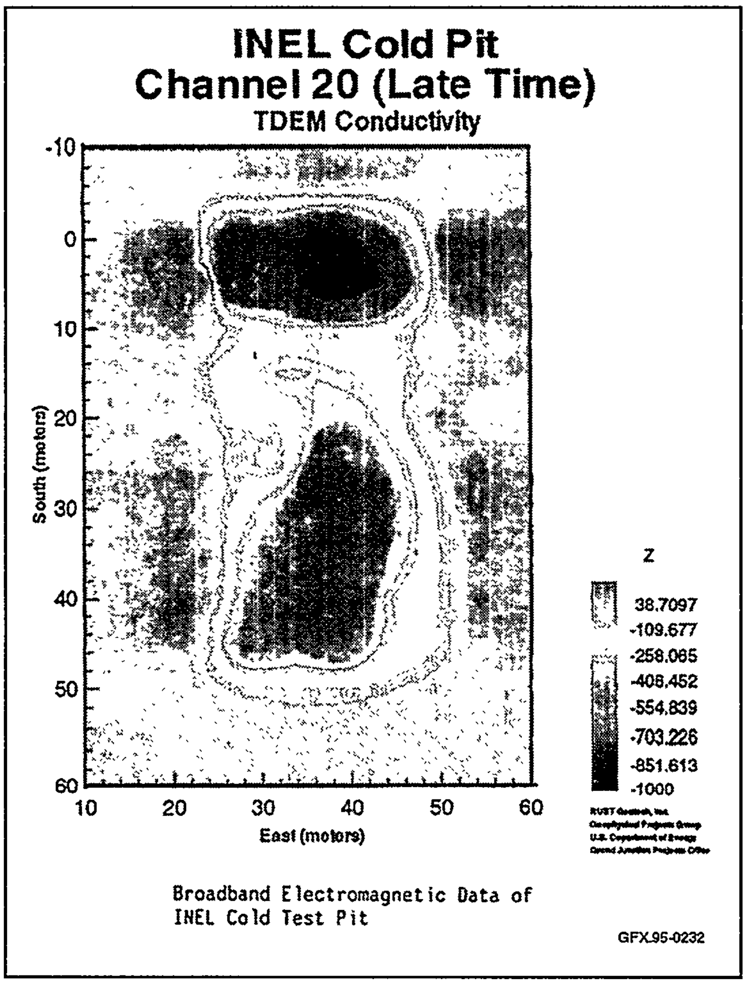

Figure 1.2. Tensor Magnetic Gradiometer (equipment).

TECHNOLOGY NEEDS

Development of non-intrusive waste and site characterization techniques is an urgent need at several DOE buried waste remediation sites. The advanced technology being investigated in this task is expected to significantly improve characterization capability and help expedite the remediation process.

ACCOMPLISHMENTS

The basic TMGS hardware was completed. Software for data acquisition, basic data reduction, and elementary interpretation was also completed. The system was field tested in FY94. The tensor magnetic gradiometer has been modified for mobile application, and basic TMGS hardware has been completed. Software for data acquisition, basic data reduction, and elementary interpretation has been completed.

BENEFITS

TMGS is a unique technology that is expected to provide significant improvements in interpretation compared with conventional instrumentation and interpretive methods for non-intrusive site characterization. It provides more information about near-surface geology and buried magnetic objects than measurements of a single component of the magnetic field or its gradient. It is intended to provide maps or images of the subsurface distribution in near real-time and will be deployed on a wheeled vehicle.

Although cost savings are difficult to quantify, non-intrusive characterization systems can reduce the potential cost of intrusive sampling and analysis. Sampling and analysis can run $500 per sample with a complete sampling plan requiring hundreds of samples. A savings of $20,000 to $70,000 is possible, including the unestimated reduced risk in worker exposure during sampling.

COLLABORATION/TECHNOLOGY TRANSFER

The TMGS testing and mobile deployment will result in a proven concept that is ready for technology transfer. Vendors supplying the bases instrumentation and equipment for the TMG, firms involved in buried waste cleanup, companies interested in locating buried objects such as mining and oil companies, and Department of Defense (DoD) contractors locating buried unexploded ordnance provide some of the markets and interest in this concept. Additionally, the USGS has also been a participant in the project. Disclosure of this research through professional journals and presentations at technical conferences will enhance transfer of this technology to a wider network of private-sector contractors, which may be able to manufacture or enhance portions of the system or find applications beyond buried object location.

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1.3 INVERSE SCATTERING GROUND PENETRATING RADAR IMAGING OF BURIED OBJECTS

TASK DESCRIPTION

The three-dimensional scanner, which was developed by TechniScan with funding through LSFA, is an inverse scattering ground penetrating radar (GPR) system. It produced quantitative, distortionless images analogous to a computer automated tomography (CAT) system. See Figure 1.3a. It is intended to generate images of buried waste objects in INEL soil.

The primary objective is to demonstrate imaging of buried objects in INEL soil with the three-dimensional scanner developed by TechniScan.

TECHNOLOGY NEEDS

Development of this technology could characterize buried waste at the INEL's Radioactive Waste Management Complex (RWMC) and other DOE sites. Specifically, it could identify buried objects by shape, orientation, size, dielectric properties, and location.

ACCOMPLISHMENTS

During FY93 and FY94, TechniScan, Inc. (TSI) performed a series of laboratory inverse scattering experiments to produce images of known objects in air as well as the objects buried in high purity sand and INEL soil. Based on these experiments, TSI developed data sheets for future research activities, including:

- Image quality as a function of accuracy in modeling the electromagnetic fields of the antennas.
- General methods for calibrating antennas.
- A procedure for calibrating ridged horn antennas.
- A theory for using soil coupled antennas for improving imaging.

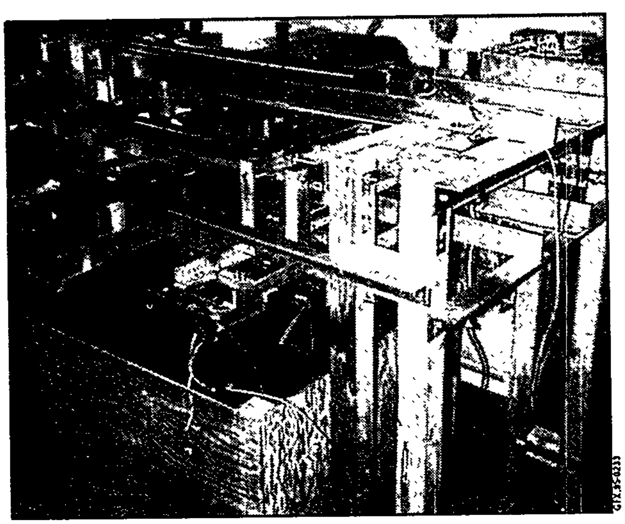

Figure 1.3a. Scale Model of Ground Penetrating Radar Scanner.

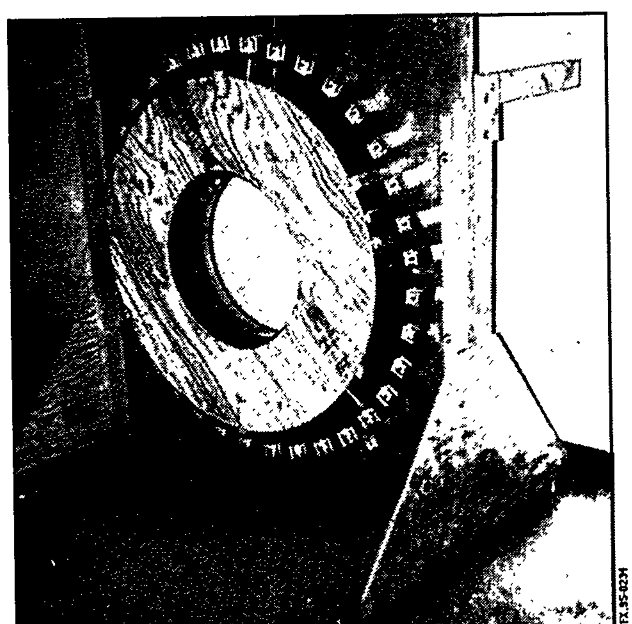

Figure 1.3b.Tomographic Microwave Scanner.

Benefits

The unique advantages of this technology compared to more conventional approaches for characterization of buried waste are its high spacial resolution, self-focusing properties, reverberation free images, and quantitative images of dielectric properties.

Collaboration/Technology Transfer

A successful demonstration of this technology will enable TechniScan to market the system throughout the DOE Complex and at other waste sites, including Superfund buried waste characterization and remediation projects. Companies interested in locating buried objects, such as mining and oil companies, and DoD contractors locating buried unexploded ordnance also might use this technology.

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Bibliography of Key Publications

None at this time.

1.4 INEL Non-Intrusive Characterization Studies - GPR

Task Description

A multi-discipline assessment of underground radar performance and the geophysical characteristics at INEL's RWMC was performed to understand those issues that have, up until now, compromised this technology's performance at INEL. See Figures 1.4a and 1.4b.

The primary objective is to perform a multi-discipline assessment of existing underground radar surveys and mineralogy data at the INEL and publish a final report on the dielectric properties and attenuation as a function of radar wave frequency.

Technology Needs

A viable underground radar survey of RWMC, combined with dielectric properties and attenuation information gathered during this project, provides critical data about the waste pits that would result in an estimate of the depth to the basalt at pit boundaries and depth to overburden/waste interface, as well as location of the original excavation boundaries.

Benefits

This research can result in improvement of underground radar data at the INEL RWMC. Possible solutions could be found in such areas as unique data processing, optimum excitation wave shapes, excitation wave frequency content, excitation signal coupling, and signal processing. Results of this research will be transferable to other sites, particularly those sites with high clay content soils.

Collaboration/Technology Transfer

No hardware or software was developed for this effort. All information obtained through these studies is contained in these reports, which are excellent references for researchers when they develop the operational waste characterization systems for use at

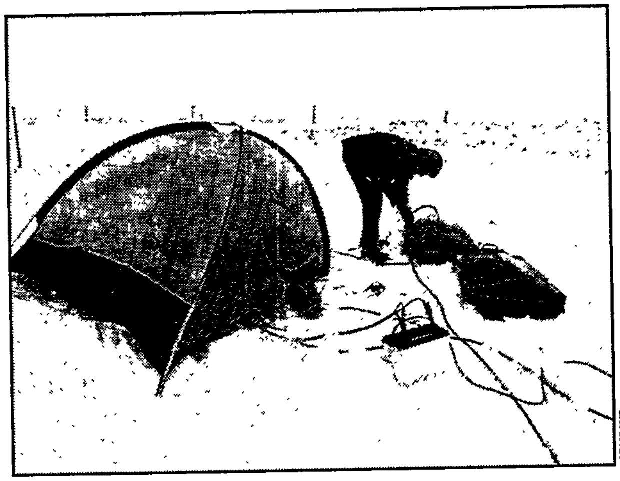

Figure 1.4a. Ground Penetrating Radar Survey Conducted by South Dakota School of Mines and Technology.

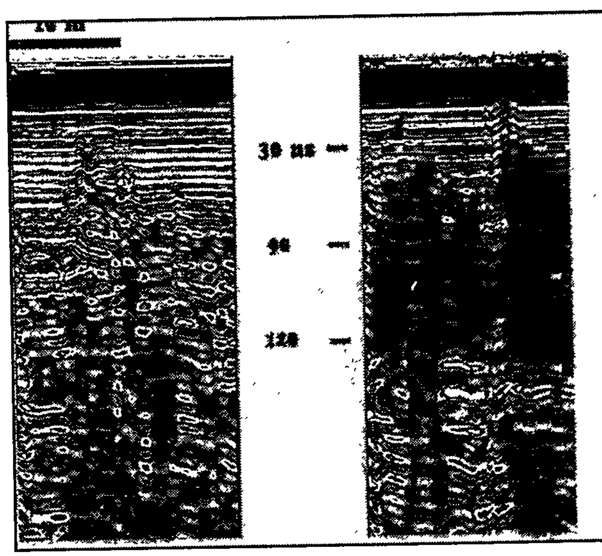

Figure 1.4b. Ground Penetrating Radar Data of INEL Cold Test Pit.

RWMC and elsewhere. The methodology relating underground radar and geophysical properties and possible solutions to lack of use have potential applications in transferring technology to other DOE and Superfund sites.

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BIBLIOGRAPHY OF KEY PUBLICATIONS

None at this time.

1.5 VERY EARLY-TIME ELECTROMAGNETIC SYSTEM

TASK DESCRIPTION

Figure 1.5. A Prototype of Very Early-Time Electromagnetic System Developed by the USGS.

The very early-time electromagnetic (VETEM) system will collect and interpret data from the shallow subsurface. See Figure 1.5. This instrument will operate in the region of the electromagnetic spectrum ranging from low frequency electromagnetic induction to ground-penetrating radar (GPR) frequencies. This region of operation allows the system to be used at sites where GPR has little success. Physical and numeric models developed determined instrument design criteria and test processing and interpretation algorithms. Additional modeling, interpretation, and imaging algorithms must be developed to account for both diffusion and transmission effects.

The primary objective is to design a high resolution electromagnetic imaging system for shallow environmental problems (less than 10 meters) such as buried waste sites. Specifically, this system will be developed for use at waste sites where traditional electromagnetic equipment and interpretation techniques do not produce satisfactory results. FY95 research focuses on completing three-dimensional modeling, physical modeling, and field testing of instrumentation.

TECHNOLOGY NEEDS

This technology could characterize buried waste at INEL's RWMC and other DOE sites. Specifically, it could contribute to identifying buried objects by shape, orientation, and location.

ACCOMPLISHMENTS

One-dimensional numerical modeling algorithms were developed and tested. The algorithms are being used in physical analysis of the buried waste, interpretation of field data, and systems analyses devoted to instrument design. An optimal system was designed using physical modeling and a prototype transmitter loop was fabricated. The instrumentation and interpretation systems were field tested at the INEL Cold Test Pit. A one-dimensional analysis of the high-frequency sounder data produced realistic estimates of the thickness, dielectric permittivity, and electrical conductivity properties of the cap covering the Cold Test Pit waste.

An upgraded prototype time-domain electromagnetic instrument and the second generation frequency-domain high-frequency sounder were fabricated and field tested. The one-dimensional code, with a graphical user interface, will be transferred to industry at the close of the project.

BENEFITS

The resulting system, along with interpretation and imaging software, enhances resolution of the shallow subsurface. Additionally, this system will operate at sites where the physical properties of the soils make high resolution GPR difficult.

These systems will acquire data in a tenth of the time required by the first generation instruments. Cost savings can be estimated based on sampling and analysis costs of $300 per sample. If the use of non-intrusive characterization systems can reduce the intrusive sampling and analysis load by 75 percent of the samples, a typical sampling plan requiring 1,000 samples can be limited to 250 at a cost savings of $225,000 per site, reducing risks in worker exposure.

COLLABORATION/TECHNOLOGY TRANSFER

Many outside universities, companies, and national laboratories are collaborating in developing this technology. The participants include the University of California-Berkeley, the University of Arizona, University of Utah, the Colorado School of Mines, RUST Geotech, Inc., Lawrence Berkeley Laboratory, and SNL. During the final stages of development, private companies will be solicited to commercially manufacture and use the system.

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TTP Numbers: ID142004, ID042002

BIBLIOGRAPHY OF KEY PUBLICATION

Pellerin, L., *Very Early Time Electromagnetic Test plan for Data Acquisition and the INEL Cold Test Pit,* (EGG-WTD-11354), 1994.

1.6 Virtual Environment Generation of Buried Waste

Task Description

Simulation-based planning and design (SBPD) is the concept of applying computer simulation tools to the engineering process. See Figure 1.6. A full-featured SBPD incorporates intelligent, integrated, automated, real-time control of the design process. Advanced visualization and computing, including virtual reality, multimedia techniques, and parallel processing must be effectively implemented into the design and analysis process. Using site characterization data, physics-based modeling will allow virtual prototyping.

The primary objective is to investigate the issues, requirements, and feasibility of developing a computer-generated virtual environment of buried waste artifacts for remediation of buried waste sites.

Technology Needs

The use of site characterization data to support advanced visualization and generation of virtual environments is a key part in SBPD systems. Ultimately, a full-featured SBPD system will be useful for site characterization analysis and design of actual remediation efforts and systems. An SBPD also supports worker training techniques for hazardous waste remediation.

Accomplishments

Three different rapid prototype environments were constructed using the INEL Cold Test Pit as a basis. Included were a walk-through of the Characterization Cell, a visual database of the Characterization Cell, and an example three-dimensional data display.

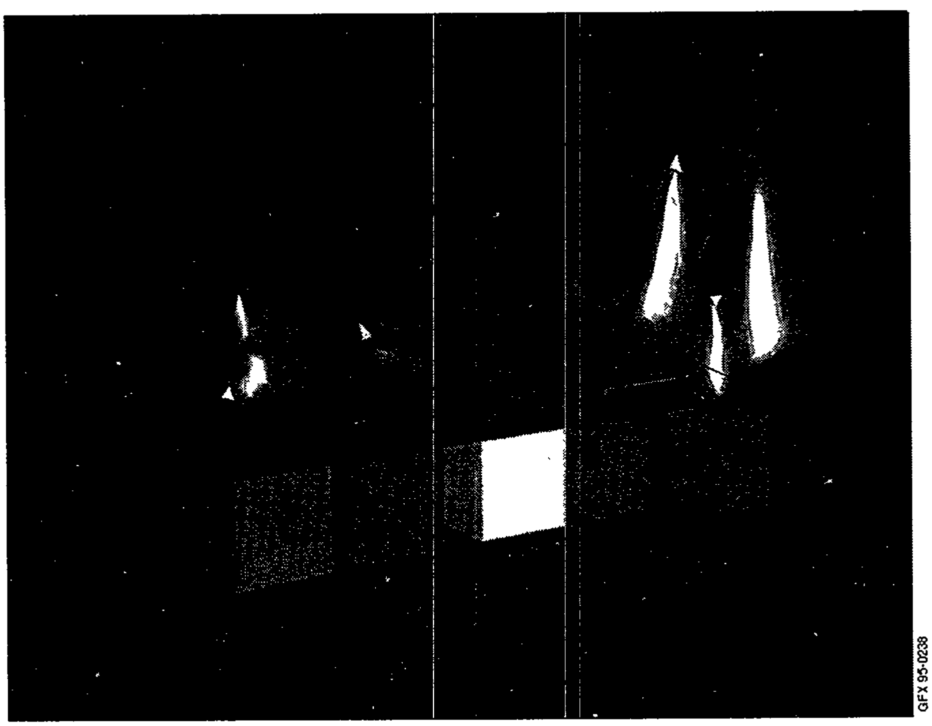

Figure 1.6. A Computer-Generated Virtual Environment Depiction of Objects in the INEL Cold Test Pit.

A hardware system was designed that integrates different functionality into a single overall platform. The prototype system has access to data, database information, and analysis tools that are of interest or use to buried waste characterization activities.

An Automatic Target Recognition (ATR) system was evaluated to assist data interpretation of sensor data obtained during the digface characterization process. The ATR system performed well for the data interpretation application. Although there were some errors in distinguishing boxes from barrels, the system was capable of distinguishing target objects from background soil.

BENEFITS

Virtual environments and related visualization techniques have the potential to provide improved understanding of buried waste site characteristics. This improved understanding assists in developing a remediation strategy.

No cost savings have been quantified. However, the use of virtual environments augmented with characterization data can potentially increase operating efficiencies in hazardous waste operations.

COLLABORATION/TECHNOLOGY TRANSFER

The opportunity exists for private-sector involvement in the development of this technology. SBPD has applications for many engineering processes beyond buried waste remediation, such as various mining and manufacturing concerns. Research results will be published through professional journals and presented at technical conferences. The available markets for SBPD and its application to an actual buried waste site (INEL Cold Test Pit) should encourage private-sector contractors to improve, manufacture, and use this system for performing waste site remediation and other applications.

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BIBLIOGRAPHY OF KEY PUBLICATIONS

None at this time.

1.7 HIGH RESOLUTION IMAGING USING HOLOGRAPHIC IMPULSE RADAR ARRAY

TASK DESCRIPTION

The ground penetrating holographic radar (GPH) system consists of a 1-meter linear array of tapered slot antennae, a high-speed switching network, and relatively low-power impulse source operating over a large frequency bandwidth, approximately 2.5 to 7 GHz. See Figures 1.7a and 1.7b. The bistatic array system scans above the surface, gathers the subsurface target data, and processes the three-dimensional holographic images. Image length is continuous and is generated and displayed in real-time as the vehicle travels across the terrain with the array mounted perpendicular to the scan direction.

The primary objective is to develop and demonstrate a field prototype and test a GPH radar system using an air-coupled linear array that will generate real-time, three-dimensional images of shallow buried waste in low conductivity soils.

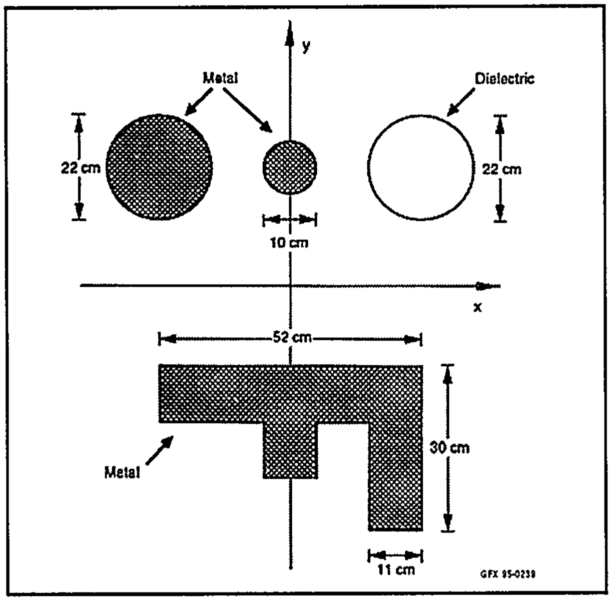

Figure 1.7a. Actual Size and Shape of Objects Through the Use of a Ground Penetrating Holographic Radar System.

TECHNOLOGY NEEDS

This technology could be applied to site characterization for buried waste in low conductivity soils. High-resolution images of buried targets (approximately one meter) in sand at the Hanford Site have been generated with this technology. The objective of this GPH application will be directed toward imaging shallow buried waste at Hanford, INEL, and Brookhaven National Laboratory.

ACCOMPLISHMENTS

The tapered slot antenna bistatic array and a mounting fixture for an array vehicle were made. Successful demonstration of a 5-GHz prototype ultra-wide band GPH was conducted on specific targets in a controlled environment composed of the INEL and Hanford soils. Modifications for field use were completed.

BENEFITS

This technology is expected to offer significant improvements with the three-dimensional volumetric imaging of buried targets using multi-frequency simultaneous transmitter/receiver holographic techniques. Lateral resolution is a factor of two greater than non-synthetic aperture imaging techniques. The multi-frequency holographic image is three-dimensional and provides an in-focus image at all depths.

No cost savings have been quantified. However, the use of non-intrusive characterization systems can reduce the potential costs of intrusive sampling and analysis.

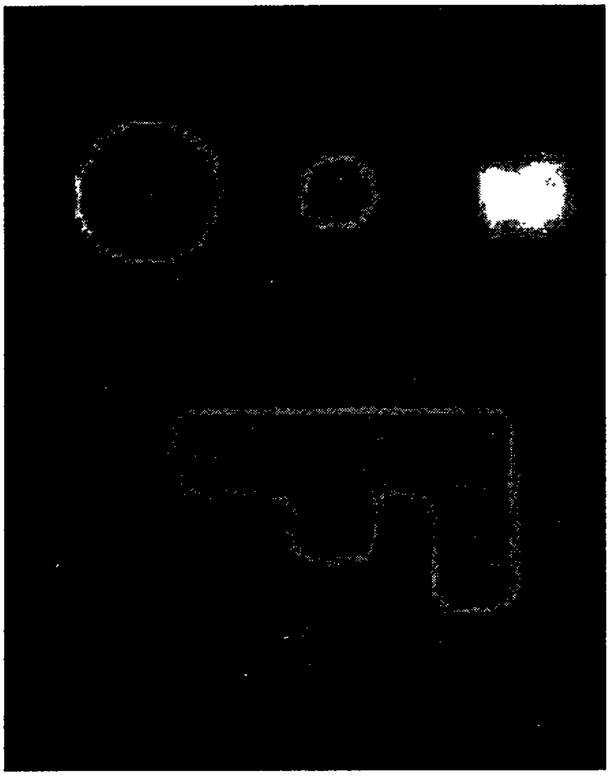

Figure 1.7b. Created Images: The Images on the Right Were Created.

COLLABORATION/TECHNOLOGY TRANSFER

The opportunity exists for private-sector involvement in the development of technology. GPH has applications beyond buried waste remediation. Various companies interested in locating other buried objects such as mining and oil companies, and DoD contractors locating buried unexploded ordnance provide some of the markets and interest in this concept. The implementation and interaction of the radar hardware and software with actual DOE waste sites is of interest to instrumentation manufacturers and software programmers.

Research results will be published through professional journals and presented at technical conferences. This effort will enhance transfer of this technology to a wider network of private-sector contractors beyond remediation, mining, and instrument-manufacturing concerns. The available markets for GPH and its application to actual buried waste sites should encourage private-sector contractors to improve, manufacture, and use this system.

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BIBLIOGRAPHY OF KEY PUBLICATIONS

None at this time.

1.8 IMAGING INFRARED INTERFEROMETER

TASK DESCRIPTION

Open-path fourier transform infrared (FTIR) spectrometers can monitor volatile organic compounds (VOCs) and toxic gases. To provide real-time imaging, a stand-off system is being developed using a real-time passive infrared imaging system with a Fabry-Perot interferometer. See Figure 1.8a. The imaging interferometer consists of a mercury cadmium telluride (MCT) infrared detector coupled to a Physical Sciences proprietary interferometer and a scan camera. The spectral region of 10.2-14.5 microns is passively sampled and a wavelength selective image constructed using a PC-based interface. VOC plume constituents are identified using an automated reference spectra searching routine. The system is enhanced specifically to monitor volatiles and off-gas contaminants from a waste remediation site. A computer controls the mirror spacings, alignment, and processing of the infrared images. This approach allows multi-spectral imaging of a 15-40 degree field of view.

The primary objective is to develop and test a variable wavelength infrared imaging system that can be used for stand-off site characterization and remediation monitoring.

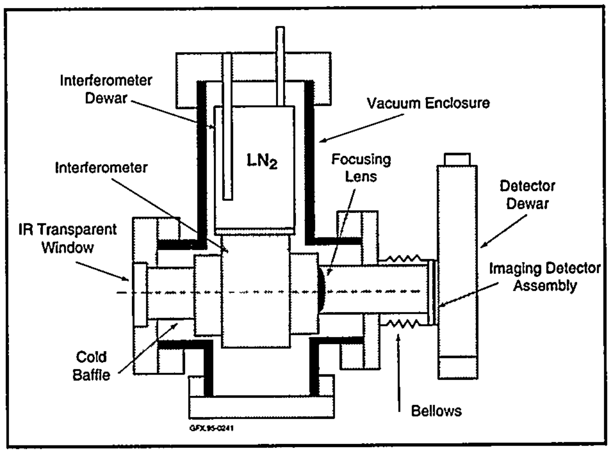

Figure 1.8a. Imaging Infrared Interferometer: The Imaging Infrared Interferometer Will be Used to Detect Volatile Organic Contaminants.

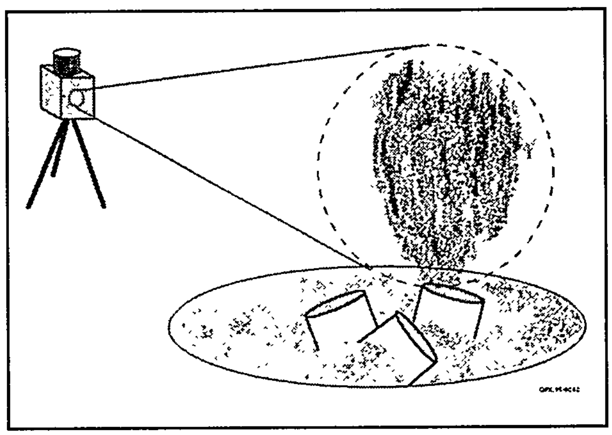

Figure 1.8b. A Fabry-Perot Infrared Interferometer Will be Used for VOC-Imaging of a Buried Waste Excavation Pit.

TECHNOLOGY NEEDS

This technology will enable real-time wide area monitoring of a waste remediation site for VOCs. This is particularly important for worker safety and keeping a remote operation clean enough to allow worker access for maintenance and repair.

ACCOMPLISHMENTS

Target gases were identified that are within instrument sensitivities and that might be present in buried waste. Calculations of these gases as to sensitivity in typical atmospheric conditions were performed. Results indicated that at a distance of 10-20 meters, VOCs can be detected at 10-ppm concentration in air within the spectral range of 10.2-14.5 microns. An emission rate of 1 g/min was assumed for this modeling program. The field demonstration will involve the unearthing of isopropanol (rubbing alcohol) placed within the soil/waste. The detected VOC plume will allow detection limits to be established and quantification of ranges for identifying organics to be determined.

BENEFITS

Major attributes of this technology are:

- The ability to identify point sources in a stand-off mode.
- The degree of sensitivity to these contaminants.
- The ability to image and monitor a wide area in near real-time. As this is a new technology, no baseline exists to compare costs savings. Cost savings will be realized by the technology's ability to provide real-time VOC characterization without manually or robotically deploying sensors to the source.

COLLABORATION/TECHNOLOGY TRANSFER

Physical Sciences, the private-sector partner, is the primary avenue for technology transfer and commercialization. Industries, EPA and DoD waste sites may have use for the technology. Non-waste interests (e.g., mining and chemical processing) may also be consumers of this technique.

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None at this time.

1.9 PLATFORMS FOR ELECTROMAGNETIC AND MAGNETIC SENSORS

TASK DESCRIPTION

A variety of potential sensor mobilizing platforms already exist (from push carts to helicopters). A list of operational and sensor constraints is used to establish platform evaluation criteria. Potential platform candidates are then evaluated as to their impact on sensor performance and site survey requirements.

The primary objective is to identify, develop, and evaluate various mobilizing platforms for electromagnetic and magnetic sensors at buried waste sites.

TECHNOLOGY NEEDS

The results of this study will provide DOE with a basis upon which to evaluate platforms for buried waste sites and a means of selecting electromagnetic and magnetic platforms appropriate for a specific site. This technology could be applied to the solution of characterizing buried waste at the INEL's RWMC and other DOE sites. Specifically, it could contribute to identifying buried objects by shape, orientation, and location.

ACCOMPLISHMENTS

These studies evaluated electromagnetic and magnetic sensor platforms. Preliminary sensor platform evaluation criteria were established based on operational and sensor constraints. These technologies were evaluated against these criteria. The completed final report, entitled Evaluation of Platforms for Electromagnetic Geophysical Sensors in Site Characterization, has been distributed as a USGS open file report.

BENEFITS

This study provided DOE with an evaluation of electromagnetic and magnetic sensor platforms. Evaluation criteria included cost of deployment, ease of use, availability, and suitability to buried waste problems. This study aided in determining which type of platform best fits the characterization system requirements of future buried waste projects.

COLLABORATION/TECHNOLOGY TRANSFER

At the completion of this study, the final report was distributed to DOE OTD so that it may be used to evaluate proposals received for consideration for funding in FY96.

The DoD could use this technology for unexploded ordnance, hazardous chemical weapon retrieval, site characterization, and D&D activities. The interaction of the sensor with the platform has robotic, ergonomic, and instrumentation ruggedness implications.

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BIBLIOGRAPHY OF KEY PUBLICATIONS

None at this time.

1.10 RAPID TRANSURANIC MONITORING LABORATORY

TASK DESCRIPTION

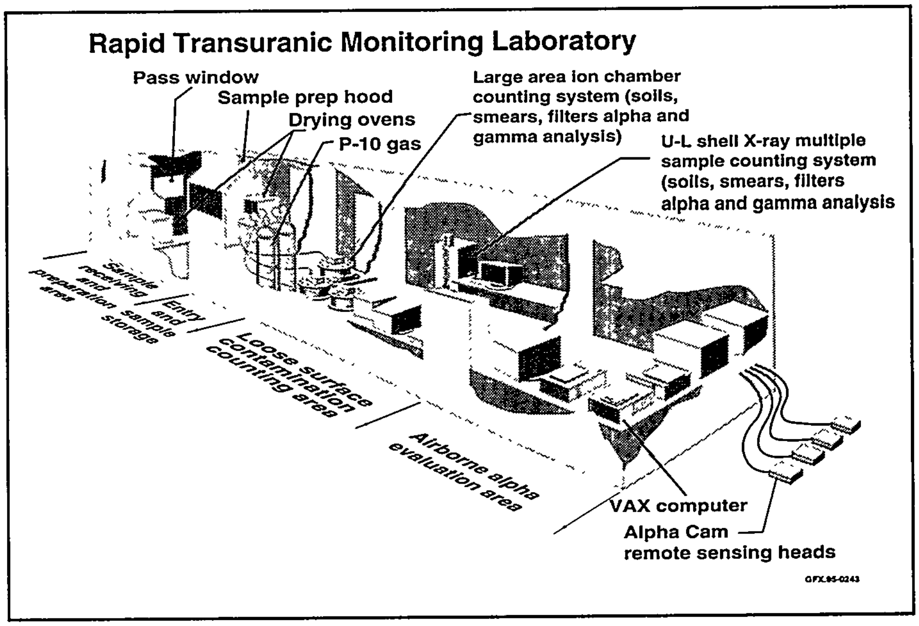

Figure 1.10a. Rapid Transuranic Monitoring Laboratory (RTML).

The Rapid Transuranic Monitoring Laboratory (RTML) is contained in two trailers, which are 8' x 24' and 8' x 48' in size. The smaller trailer houses a sample preparation laboratory. The larger trailer contains (a) one terminal that controls and displays spectral data from four alpha continuous air monitors (CAMs), (b) two Ordela large-area ionization chamber alpha spectrometers, (c) one thin-window gamma ray spectrometer and automatic sample changer, (d) one VAX 4000 Model 100 computer, and (e) computer terminals and two printers used to display and generate reports of analysis results. See Figure 1.10a.

The unit can process over 100 samples per day of soils, filters, and smears in a field setting. See Figure 1.10b. The lower levels of detection vary depending on the analysis system. The large area alpha ionization spectrometer can process 33 soil samples per day at 20 pCi/g (alpha). The U-L-Shell x-ray system can process 79 samples per day at 50 pCi/g (alpha) and 1-5 pCi/g (gamma). Simultaneously, the alpha CAMs can analyze air quality continuously at 1 DAC-hr.

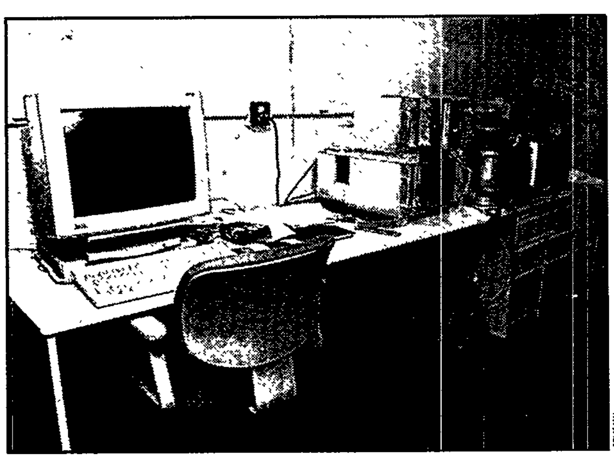

Figure 1.10b. Interior of RTML - Loose Surface Contamination Counting Areas.

The primary objective is to develop a field deployable RTML that can continuously monitor airborne transuranic (TRU) concentration and rapidly analyze soil, smear, and air filter samples for TRU isotopes, and fission and activation products in a cost-effective manner.

TECHNOLOGY NEEDS

The RTML is appropriate for any situation where there is a major problem with contamination of TRU that requires mitigation. The RTML can quickly evaluate situations and allow rapid remediation action to be taken that will prevent a situation from growing further out of control.

ACCOMPLISHMENTS

The system was successfully demonstration tested at the Cold Test Pit at INEL's RWMC during the summer of 1993.

An upgrade to incorporate screening capability for beta emitters and advanced screening technology for alpha emitters was completed in FY94.

BENEFITS

The RTML provides rapid on-site sample analysis at a lower cost per analysis than conventional methods. Samples can be processed in less than 1 hour for about $30 per sample using a technician-driven system. This compares to fixed laboratory results with radiochemists analyzing several samples per day at $200 to $300 per sample.

The unit can process over 100 samples per day of soils, filters, and smears in a field setting, compared to radiochemists at a fixed laboratory that can analyze only a few samples per day with conventional radiochemistry techniques.

COLLABORATION/TECHNOLOGY TRANSFER

The system consists of commercially available components. A commercial partner could begin manufacturing the integrated system. Disclosure of this research through professional journals and presentations at technical conferences will enhance transfer of this technology to private-sector contractors that may be performing waste site remediations. The INEL Environmental Restoration Program is planning to use the system as a screening tool during sitewide soil sampling in 1995.

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BIBLIOGRAPHY OF KEY PUBLICATION

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1.11 REAL-TIME MONITORING OF TRANSURANIC-CONTAMINATED DUST

TASK DESCRIPTION

A real-time dust monitor (RTDM) will detect TRU-contaminated dust based on laser-induced breakdown spectroscopy (LIBS) technology. See Figure 1.11. The RTDM will be correlated with an alpha continuous air monitor (CAM) system. An instrument will ultimately be developed for deployment to the field environment.

The primary objective is to develop and demonstrate a real-time, in situ instrument based on optical techniques for monitoring transuranic (TRU) contaminated dust. Incorporating alpha CAMs into the system to provide an improved radioactive assay capability for buried waste remediation sites is included in the objective. However, the LIBS technology may allow stand-alone analysis for the airborne TRU contaminants.

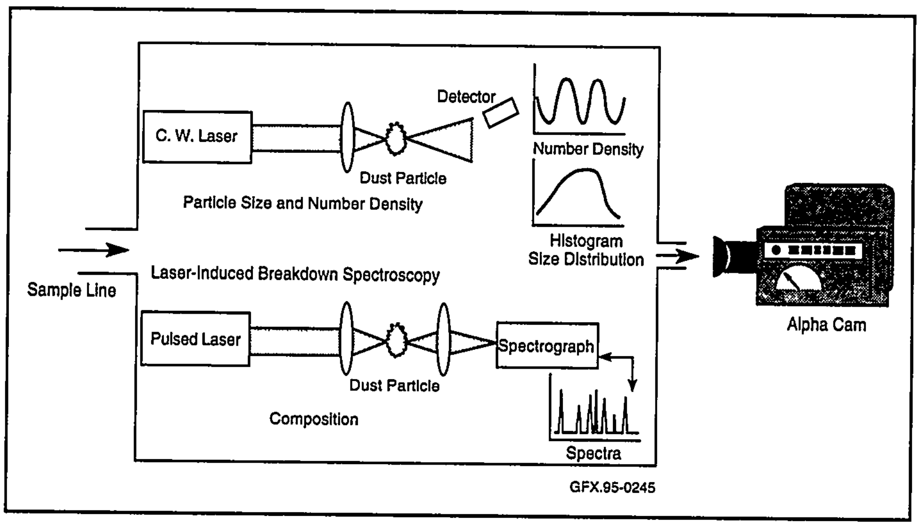

Figure 1.11. Real-Time Transuranic Contaminated Dust Monitor.

TECHNOLOGY NEEDS

The RTDM system is appropriate for any situation where there is a major problem with contamination of TRU that requires mitigation. The RTDM can quickly evaluate situations and allow rapid remediation action to be taken that will prevent a situation from growing further out of control.

ACCOMPLISHMENTS

- Design of prototype imager; and
- Initiated construction of prototype imager.

BENEFITS

The real-time monitoring aspects of this system will allow a potential contamination problem to be recognized as it develops, rather than waiting until after it occurs. The RTDM can be coupled with a CAM, giving complementary information to CAM measurements for accurate alpha determination such as particle density. With the LIBS system, however, many hazardous heavy metals and TRU contaminants can also be detected.

Currently, analyses of potential airborne contamination are typically performed by collecting particles over time in a filter and subsequently estimating particle density off line. Depending on the level of accuracy required, this process requires several minutes to half an hour. If the particle density is subject to rapid fluctuations, off-line monitoring may be inadequate. The proposed system's ability to perform real-time detection is a significant advantage. There are presently no commercially available real-time monitors for TRU dust.

Because this activity is a new research and development effort for FY94 there are no existing technologies that the RTDM can compare to in the area of cost savings.

It is estimated that some remediation activities may cost $1M/day to operate. Assuming a 10 hour shift, these costs are on the order of $100,000/hour. If the operation is shut down to evaluate the radiological hazards or control contamination for 2 hours /day, the associated costs are $200,000. It is anticipated that the RTDM could avoid much of this cost by providing real-time analyses to the operators.

COLLABORATION/TECHNOLOGY TRANSFER

The primary customers for this technology would be commercial nuclear reactor operators during decommissioning and decontamination phases of operation. However, the technology may also be applicable at any construction or decommissioning site where contaminated dust poses a potential health or environmental threat. Disclosure of this research through professional journals and presentations at technical conferences will enhance opportunities for transfer of this technology to private-sector industry for commercialization. In addition, an opportunity presently exists for a government/industry partnership to promote the development and marketability of this technology.

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BIBLIOGRAPHY OF KEY PUBLICATIONS

None at this time.

1.12 EXCAVATED WASTE ASSAY

TASK DESCRIPTION

The primary objective of this task is to develop a passive gamma-ray spectroscopy system to assay excavated and treated waste material for TRU content.

The system measurements are made by four subsystems designed to optimize quantification and throughput. A real-time radiograph determines an average attenuation coefficient. A very high sensitivity, gross count gamma scanner determines gamma activity. A high-energy-resolution gamma ray spectroscopy system identifies and quantifies TRU contamination. A passive neutron measurement system used for spontaneous fission events is the fourth subsystem.

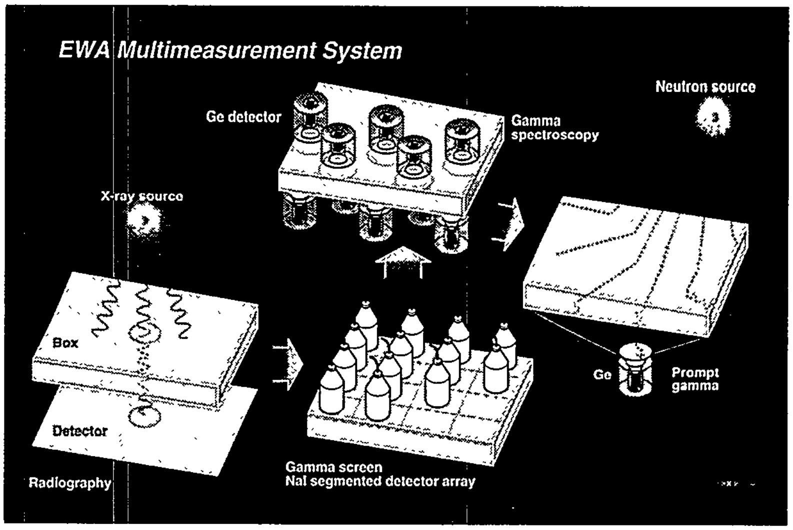

Figure 1.12. Isometric View of Passive Gamma-Ray Detectors and Collimators with a Sample Box.

ACCOMPLISHMENTS

None at this time.

TECHNOLOGY NEEDS

Retrieved waste will be assayed and packaged prior to shipment to an interim storage or treatment facility. Prior to treatment and at post-treatment prior to disposal, another assay will be performed. This system will be applied to quantify the presence of TRU wastes and confirm that the clean stream output of treated wastes meets radiological requirements for disposal.

This technology allows for the evaluation of the waste stream from a digface. It will determine whether storage or disposal is required. This technology will also help segregate TRU material so all material removed from the digface does not require storage or treatment. It can also be used on the output of a treatment facility to determine the level of activity of the material treated in the process.

BENEFITS

The principal attributes offered by this technology are improved accuracy, confidence in estimates, and assay of entire pre-treated (sifted or ground) waste streams. This technology also allows for the waste being evaluated to be treated appropriately, not spending more time or money on waste treatment and handling than is necessary. If this assay is not performed, all waste removed from a digface would have to be considered waste that required treatment.

A cost saving has not been calculated at this time. Savings will be realized when the assay system can reduce the volume of wastes classified as transuranic, thereby reducing waste handling, treatment, and disposal costs.

Collaboration/Technology Transfer

This technology is planned for implementation by INEL Environmental Restoration. Opportunities exist for private-sector involvement in both development and commercialization of this technology. Other nuclear institutions that may aid in further research or be interested in testing systems particularly for their waste stream monitoring are nuclear power plants, DOE sites, isotopic production laboratories, and medical establishments. Disclosure of this research through professional journals and presentations at technical conferences will enhance opportunities for transfer of this technology to private-sector industries.

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Bibliography of Key Publication

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1.13 WASTE ASSAY MEASUREMENT INTEGRATION SYSTEM

TASK DESCRIPTION

The Waste Assay Measurement Integration System (WAMIS) will consist of software that performs several functions from a single workstation, including access to all relevant data on a drum, visualization of the data, and several modes of simultaneous processing to enhance drum characterization. Displays of results will be available to a variety of possible end-users, including operators, physicists, regulators, and receiving personnel at disposal sites. Data-processing methods will include a combination of conventional approaches, expert systems, and artificial intelligence processing.

As a test case in FY95, data from real drums at RWMC will be used to demonstrate the capabilities of the system. The measurement capability at RWMC includes real-time radiography, gamma spectroscopy, and an active and passive neutron measurement. When WAMIS is demonstrated in FY96, it will integrate data from three other NDE/NDA systems: Digital Radiography and Computed Tomography, Combined Thermal and Epithermal Neutron, and Active and Passive Computer Tomography.

The primary objectives are to develop and demonstrate improved waste assay capability through the integration of multiple information sources (e.g., multiple measurements and prior knowledge); incorporate intelligent processing methods with expert systems and conventional analysis techniques, and to develop the methods to access and visualize all relevant data supporting an individual container. FY95 objectives are to demonstrate a prototype data visualization workstation using real NDE/NDA data from drums stored at the INEL RWMC and confirm the benefits of using neural networks for data processing.

TECHNOLOGY NEEDS

The WAMIS technology would directly apply to the remediation of buried waste sites where the waste is containerized. Retrieved waste would need to be assayed and packaged for shipment to an interim storage or treatment facility meeting shipping limitations and various criteria. Prior to treatment, another assay would likely be performed and at post-treatment, an assay would also be performed.

ACCOMPLISHMENTS

This project is an outgrowth of an older project known as the Radiological and Hazardous Material Measurement System (RHMMS). In prior years, several measurement systems were tested and determined to be critical to the multiple measurement process. These methods included gamma ray spectroscopy and passive and active neutron. The project was redirected in FY94 and renamed WAMIS in FY95. The redirection was to develop the software needed for integration and to develop the plan for the FY96 demonstration that will bring DRCT, CTEN, and A&PCT together. Both of these processes were initiated in FY94. The initial software demonstration will be done with existing data from existing systems. A proof-of-principle experiment using neural networks to process real neutron assay data was also successfully performed.

BENEFITS

The key attribute of WAMIS will be the ability to optimize use of all available data on a subject container. Data processing methods successful in other applications will be transformed and improved for the waste assay application. Cost savings also are important. DOE has estimated that if all of the waste drums had to be opened for characterization and certification, an immense cost would be incurred. With the number of drums being in the millions, the savings may be billions of dollars. This is in addition to the worker safety issue and any associated dollars for preventing excess exposure.

COLLABORATION/TECHNOLOGY TRANSFER

The completed system is planned for implementation by the INEL Waste Management Program. Disclosure of this research through professional journals and presentations at technical conferences will ensure transfer of this technology to private-sector contractors that may be performing waste site remediations. Several expressions of interest from industry with regard to CRADAs are being evaluated.

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BIBLIOGRAPHY OF KEY PUBLICATIONS

None at this time.

1.14 HIGH-SPEED DIGITAL RADIOGRAPHY AND COMPUTED TOMOGRAPHY OF WASTE DRUMS

TASK DESCRIPTION

A used, commercial digital radiography and computed tomography (DRCT) scanner (circa 1987) has been acquired through government excess. The scanner uses X-rays to measure density and non-destructively view the contents of waste drums. A higher throughput can be achieved by further enhancing the detection system to an area-type detector versus a linear array. A high-energy X-ray source will be installed for interrogation of high-density drums.

The primary objective is to:

Demonstrate the capabilities and applications of a commercial scanner for high-throughput DRCT of waste packages, with emphasis on 55-gallon waste disposal drums. The FY95 objective is to characterize the scanner's linear and area detection arrays for drum inspection, develop a high-energy source for use on high-density drums, and demonstrate the system on a small number of low-level waste drums.

TECHNOLOGY NEEDS

DRCT applies directly to the remediation of buried waste sites when the option of retrieve and treat is implemented. Assay and characterization are needed at pre-treatment, post-treatment, and disposal. Retrieved, intact containers and containers filled with retrieved wastes must be characterized prior to any further treatment and shipment to either an interim storage or treatment facility.

ACCOMPLISHMENTS

The X-ray scanner refurbishment has been completed and the scanner has been installed at Idaho State University. The new area detector is completed and is undergoing testing. The upgraded DRCT's performance, particularly the high throughput for the DRCT system, is being demonstrated at INEL.

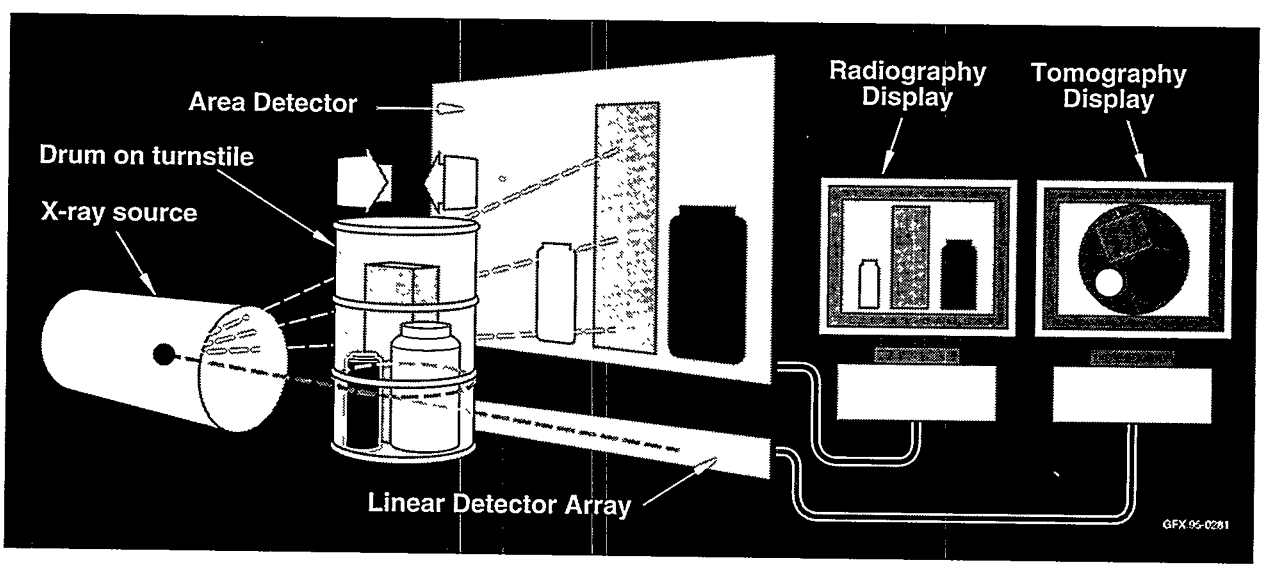

Figure 1.14. Schematic of High-Speed Digital Radiograph and Computed Tomography Scanner.

BENEFITS

DRCT offers a unique capability to spatially characterize containers of waste as part of the assay process and provides quantitative information where only qualitative information has been previously available. DRCT can evaluate waste drums to allow for certification to meet DOT shipping limitations and various receiving facilities' Waste Acceptance Criteria. The technology supports visual drum inspection like the present real-time radiography in use at certification facilities but with greater accuracy and speed.

DOE has estimated that if all of the waste drums were required to be opened, the cost would be in the billions of dollars, with the number of drums being in the millions. When DRCT is combined with other nondestructive systems, cost savings in the millions of dollars is estimated, in addition to the worker safety issue and any associated dollars for preventing excess exposure.

COLLABORATION/TECHNOLOGY TRANSFER

Technology development and demonstration activities are being conducted with both government (INEL) and private sector (Scientific Measurement Systems, Inc.) involvement. Industry involvement in the development and demonstration phases will enhance commercial applicability of this scanner.

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BIBLIOGRAPHY OF KEY PUBLICATIONS

None at this time.

1.15 Combined Thermal and Epithermal Neutron Assay

Task Description

The widely used differential-dieaway technique (DDT) uses thermal neutrons to interrogate for fissile isotopes in waste drums. The resulting fast fission neutrons are detected in cadmium-shielded helium detectors that are insensitive to the interrogating thermal flux. See Figure 1.15.

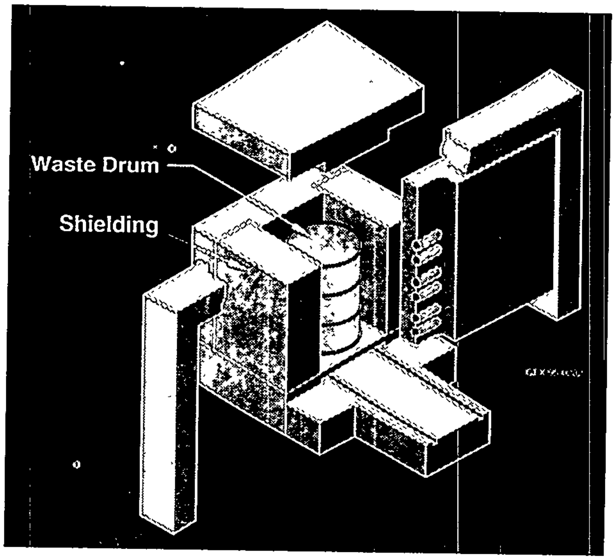

Figure 1.15. Schematic of a Combined Thermal/ Epithermal Neutron Instrument.

The combined thermal/epithermal neutron (CTEN) method is similar to the DDT method, but interrogates the sample with thermal and epithermal neutrons. This integration is achieved partly by the addition of 4He detectors, which have a faster response than 3H and can detect fast fission neutrons in the presence of the epithermal interrogating flux, and by a redesign of the moderating cavity so that thermalization occurs more slowly. Because epithermal neutrons are more penetrating in fissile material than thermal neutrons, the differential response can be analyzed to detect the occurrence of self-shielding by fissile material and measure the size of the effect. Self-shielding occurs when lumps of fissile material are present, and can result in assay errors of several hundred percent. A fully operational CTEN device would be expected to perform all the functions of existing DDT/passive-active neutron devices with the added capability of identifying and assaying lumps of material.

The primary objective is to develop a system to assay transuranic (TRU)/fissile contents of waste drums using both epithermal and thermal neutron interrogation to reduce inaccuracies caused by self-shielding.

Technology Needs

This technology will support the assay requirements of the retrieve and treat remediation option for buried waste. Specifically, it would apply to assay of the packages of retrieved waste prior to interim storage or treatment and posttreatment assay of the final packaged waste.

The technology of CTEN focuses on using thermal and epithermal neutrons to evaluate the contents of waste drums. It would directly evaluate waste drums to allow for certification to meet DOT shipping limitations and various receiving facilities Waste Acceptance Criteria.

Accomplishments

In FY94, the CTEN Instrument was physically completed. FY95 activities will focus on completing algorithm development, data analysis, and system evaluation. The basic fabrication of the CTEN instrument is complete. The Monte Carlo studies, design drawings, and first version of the system software are complete. Current work focuses on completing algorithm development, data analysis, and system evaluation to begin system characterization and calibration.

BENEFITS

The technology minimizes the effects of self-shielding by lumps of fissile material to provide more accurate and repeatable assay of waste drums. This system will incorporate techniques to determine if the waste matrix and fissile material are uniformly distributed.

The CTEN will match the capabilities of present commercial neutron assay systems. Additionally, it will be able to evaluate for larger pieces of transuranic material. Transuranics absorb their own radiation, so this absorption causes an error when evaluating waste drums that contain large quantities of Pu, etc. CTEN will allow for the assay to be much closer to the actual amount residing in the drum.

DOE has calculated that if all of the waste drums were required to be opened, there would be a significant cost. With the number of drums being in the millions, the cost saved is perhaps in the billions of dollars. This is in addition to the worker safety issue and any associated dollars for preventing excess exposure.

COLLABORATION/TECHNOLOGY TRANSFER

Primary applications are in the waste field. Use by fuel fabricators, international safeguard agencies, and DoD special nuclear material monitoring or organizations, may result in additional partners and provide incentive for joint testing, deployment. The research will be disclosed through professional journals and presentations at technical conferences to assist transfer of this technology to both private-sector contractors and other government agencies.

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BIBLIOGRAPHY OF KEY PUBLICATIONS

None at this time.

1.16 ACTIVE AND PASSIVE COMPUTED TOMOGRAPHY OF TRANSURANIC WASTE

TASK DESCRIPTION

Active and passive computed tomography (A&P CT) uses a high purity germanium (HPGe) detector for non-destructive assay (NDA) of gamma-emitting nuclides in sludge, combustibles, and metal matrices within a 55-gal drum. See Figure 1.16. Assay is necessary for determining radiological content for below regulatory concern (BRC) LLW, and TRU waste disposition of stored wastes; pre-assay and post-assay of retrieved treated waste and residues; meeting shipping requirements; and meeting RCRA low-level mixed waste (LLMW) disposal regulations.

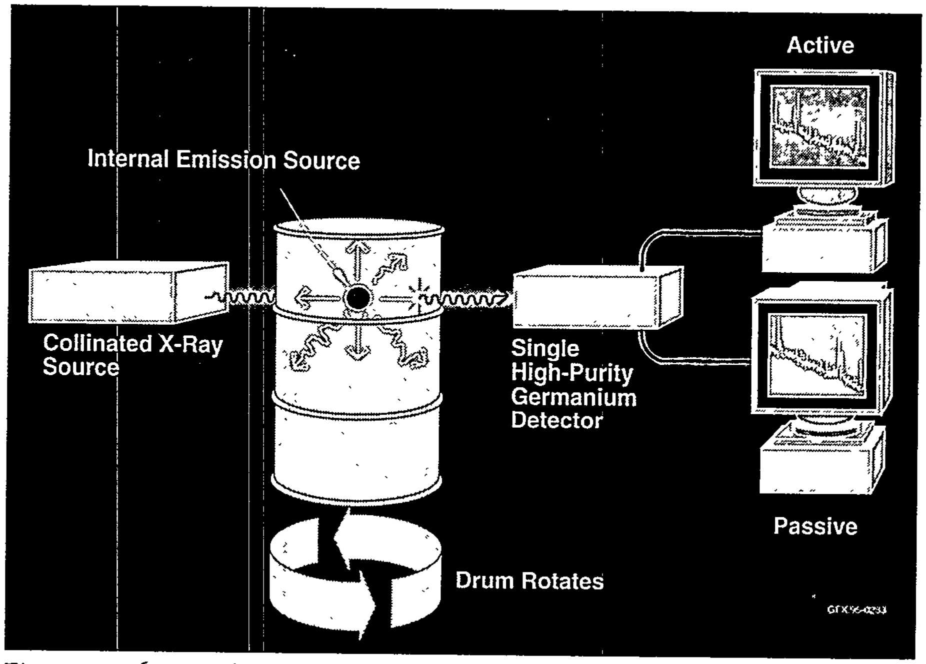

Figure 1.16. Coupling Multi-Energy A&P CT Data Yields More Accurate Waste Data Characterization (356-keV and 150-sec-ray-sum data).

The measurement of fissile U-235 and Pu-239 is the most important feature of the system. The system must optimize four other critical features: spatial resolution, energy resolution, contrast sensitivity, and total data acquisition time. These parameters are governed by optimum transmission source strengths as a function of density, proper transmission source, proper detector collimation sizes and lengths, and proper balancing of waste assay speed, accuracy, and cost.

The primary objective is to evaluate an A&P CT system on LLW and TRU waste contained in 55-gal drums.

TECHNOLOGY NEEDS

This technology will support the assay requirements of retrieved packaged waste prior to interim storage or treatment and post-treatment assay of the final packaged waste. Assay for pre-treatment and post-treatment scenarios is possible.

ACCOMPLISHMENTS

The A&P CT scanner has been developed to the state of system checkout and performance optimization. This work has been accelerated due to the interface with the DOE sponsored Waste Inspection Tomograph (WIT) system.

BENEFITS

A 1-HPGe-detector A&P CT drum scanner will:

- Differentiate TRU from LLW, decreasing substantially shipments to the Waste Isolation Pilot Plant.
- Differentiate LLW from BRC, substantially decreasing substantially shipments to the few LLW repositories that exist.
- Enable DOE to meet potential stringent transportation regulations for LLW and LLMW.
- Give 10 to 100 times lower Method Detection Limit for NDA drum waste assay than currently available segmented gamma spectrometry (10 mg MDL for Pu-239 compared to 1000 mg).
- Decrease assay time with the higher detection limits with multiple detector from 50 minutes to 30 minutes per drum.

DOE has calculated that if all of the waste drums were required to be opened, there would be a significant cost. With the number of drums being in the millions, the cost saved is perhaps in the billions of dollars. This is in addition to the worker safety issue and any associated dollars for preventing excess exposure.

COLLABORATION/TECHNOLOGY TRANSFER

Technology transfer is under way with the private partner, Bio-Imaging Research, through development of WIT and the training, use, and data interpretation at DOE Sites. The University of California San Francisco Medical School has medical expertise that is helping with this development while seeking advanced applications to medical diagnostics. Demonstration at numerous DOE sites will interest a variety of private environmental and waste assaying firms. Applications in the power industry and throughout the fuel cycle, particularly in fuel fabrication, are numerous. Safeguards monitoring and international use are also possibilities.

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None at this time.

1.17 ELECTROTHERMAL HOLLOW CATHODE DISCHARGE SPECTROMETRY

TASK DESCRIPTION

Highly selective determinations of actinides and RCRA metals can be made by combining the diode laser-based absorption, fluorescence, and optogalvanic methods used at Ames Laboratory with Furnace Atomization Non-thermal Excitation Spectrometric (FANES) systems. FANES is a versatile technique for elemental analysis and, when combined with diode laser-based optical spectrometric techniques, can be used for isotopic analysis of actinides.

The primary objective is to develop and test a prototype of an electrothermal hollow cathode discharge spectrometry system. See Figure 1.17.

TECHNOLOGY NEEDS

This technology will complement the radiation measurement techniques used by the Rapid Transuranic Monitoring Laboratory to provide an on-site capability for quickly assessing radioactive or hazardous contamination problems associated with buried waste remediation.

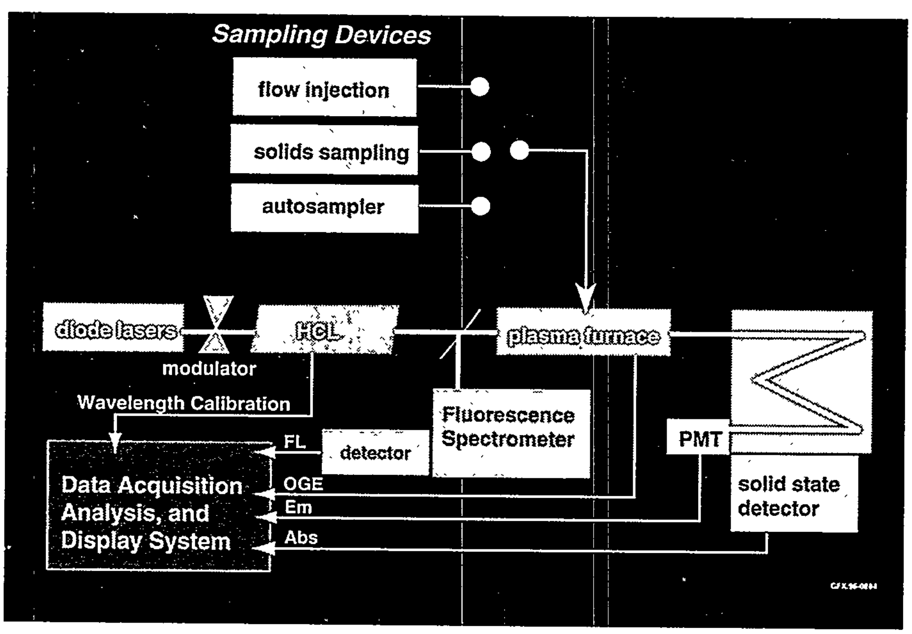

Figure 1.17. Instrumental Block Diagram of the Electrothermal Hollow Cathode Discharge Spectrometery System.

ACCOMPLISHMENTS

The system has been tested in laboratory setting.

BENEFITS

This technology can provide highly sensitive qualitative measurements of samples of hazardous contamination. It can be mobilized in an on-site laboratory to provide rapid response times. The instrumentation being developed is sufficiently compact to be housed in a site-based laboratory. The technique requires minimal sample sizes and half hour analysis. Minimum detectable quantities are in the picogram range.

Fixed laboratory analysis can cost up to $300 per sample and take up to one week. The goal of this technology is to produce sample analysis for $30 per sample and analyze 100 samples per day at or near the fixed laboratory quality.

COLLABORATION/ TECHNOLOGY TRANSFER

Disclosure of this research through professional journals and presentations at technical conferences will ensure transfer of this technology to private-sector contractors that may be performing waste site remediations. This system could be used during retrieval actions to verify the presence of hazardous materials and actinides in soils prior to return of the treated soils.

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BIBLIOGRAPHY OF KEY PUBLICATIONS

None at this time.

1.18 LANDFILL ASSESSMENT AND MONITORING SYSTEM

TASK DESCRIPTION

The Landfill Assessment and Monitoring System (LAMS) is a method to characterize metal and mixed waste contaminants, sources, and their migration beneath landfills. The emphasis of the system is on minimally intrusive technologies and downhole sensors when possible. The system focuses on using the best of available and emerging technologies with minimal development work.

The LAMS is envisioned to be a start-to-finish system for landfill assessment, using compatible, complementary, and integrated technologies. The result is a savings in cost and time. The LAMS consists of five separate subsystems: screening and sampling optimization techniques, innovative drilling technologies, on-site analysis and in-situ sensors, subsurface monitoring technologies, and data evaluation and risk analysis techniques. In some instances, technologies may be combined to produce hybrid systems, such as directional boring and downhole sensing. The LAMS approach employs minimally or nonintrusive assessment, safer directionally drilled access, measurement while drilling, sample optimization strategy, membrane liners, insitu sensors, and an on-site laboratory. As long-term monitoring needs become more important, the monitoring aspects of the LAMS are becoming increasingly emphasized.

Primary goals of the LAMS are rapid transfer and commercialization of these technologies throughout the DOE Complex and to the private sector.

TECHNOLOGY NEEDS

The system being developed includes all of the technologies for characterizing, monitoring, and remediating metal and mixed-waste contamination beneath landfill sites. More than one technology is usually required for adequate assessment and monitoring of hazardous and mixed waste sites. Often, these technologies are used in sequential fashion with little thought given to the synergy and savings in cost and time that can be gained by using an integrated system with compatible and complimentary technologies. Several components are necessary to implement a systems approach to site assessment and monitoring. These include using technologies that are appropriate and suited for the site-specific conditions and needs of the project, ensuring that the technologies are compatible and complementary so that they support each other, and selecting and integrating the optimum suite of technologies to adequately perform a job. The goal of the LAMS is to ensure that the technologies developed are adequate and appropriate for their intended use and that a systems approach is used whenever possible to maximize data gathered and minimize costs, worker exposure, and time expended for assessment and monitoring.

ACCOMPLISHMENTS

In FY94, the LAMS provided and participated in a wide variety of support and technical activities:

- The LAMS is providing assessment and monitoring oversite. The emphasis of the LAMS shifted toward the monitoring arena. In addition, remediation and barrier monitoring demonstrations were begun. Practical guidance and support were provided to eleven assessment and monitoring principal investigators within the LSFA, including field and laboratory demonstrations of the technologies. A 100-foot-deep vertical boring at the 60s Pits was drilled to provide a demonstration site for several of the PIs. In addition, the samples from the drilling also provided site assessment and remediation assessment information to the environmental restoration task leaders.

- Two milestone reports were completed and the FY94 Test Plan was written. The test plan directly supported four on-going field demonstrations of innovative technologies, created two new innovative opportunities for LAMS demonstrations, provided new site assessment data to two environmental restoration projects, provided research opportunities to over 20 university students, and will support a FY95/96 remediation demonstration for chromium reduction.
- The LAMS project began a monitoring initiative at a new environmental restoration site through the calibration and verification of the targets project at Sandia's Tech Area-2. This activity involved the target validation and calibration of various geophysical data at Tech Area 2. Several of the targets are to be excavated during the fall of 1994 to validate and calibrate the target identification algorithms developed during this work.
- An innovative monitoring project was initiated to assess the effects of a remediation process. This activity involves the use of tracer gases to assess remediation demonstration(s) at the Chemical Waste Landfill and began in the fall of 1994.
- LAMS also initiated interactions with EPA Technology Innovation Office personnel at two regional headquarters to increase the awareness and acceptability of emerging LAMS technologies.
- The first OTD Commercialization Workshop was attended, and a technology transfer plan for the LAMS was created and written.

COLLABORATION

Since PI oversight and direction are important elements of the LAMS, the project essentially includes all of the individual LSFA assessment and monitoring PIs and their partners. These include SNL, ANL, PNL, INEL, GeoCenters, Inc., Charles Machine Works, Inc., ConSolve, Inc., Scitek Corp., Radiometer America Corp., Science & Engineering Associates, Inc., Hydrogeochem, Inc., and New Mexico State University.

The LAMS has produced numerous successful technology transfers through partnerships, commercializations, demonstrations, implementation at environmental restoration sites, and reports and presentations. Technology transfer plans for the upcoming year include participation in a market analysis, a verification and monitoring options study, continued interactions with environmental restoration personnel and regulators, presentations, participation in a workshop or shortcourse, and site tours.

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1.19 OPTIMIZATION OF SAMPLING STRATEGIES

TASK DESCRIPTION

The primary objective of this project is to provide an approach for guiding sample placement for contaminant delineation. This approach must be capable of assisting in siting vertical soil bores and directionally drilled bores, as well as sampling locations along such bores. It should include an easy-to-use data management system that allows integration of the existing data and should visually display useful graphics on computer screens. Such graphics could include maps of contaminant extent, subsurface cross-sections that show contamination location relative to important geological features, bore logs, etc. It must be able to measure the volume of contaminated soil and water and be able to estimate errors associated with these measurements. The measures can determine when enough samples have been taken to accurately delineate contamination.

This project adopts a dual approach to the sampling strategy design problem. First, it uses a state-of-the-art object-oriented database system that was specifically designed for site assessment work to integrate, manage, and display site characterization data as it is being generated. This package (Site Planner) was developed by ConSolve, Inc. Site Planner provides technical staff with an understanding of their site data as quickly as possible. Coupled with Site Planner is PLUME, an interactive software package developed at ANL. PLUME merges historical site data with field sample results to form images of contamination location. It also provides quantitative measures of the potential benefits to be gained from additional sampling and indicates the best location sampling sites. PLUME uses advanced statistical procedures to complete these tasks.

TECHNOLOGY NEEDS

DOE facilities can contain hundreds, or even thousands of individual locations with soils, water, or structures contaminated through usage or disposal activities. Characterization of each of these potentially threatening locations using traditional approaches of pre-planned sampling programs and off-site sample analyses is prohibitively expensive and time consuming. There is an immediate need to apply emerging field screening technologies and smart sampling strategies in sampling programs adaptive to site characterization demands. This project targets the development and demonstration of smart sampling strategies for site characterization, in particular contaminant definition and delineation.

ACCOMPLISHMENTS

- Enhancement of Site Planner to meet the demands of adaptive sampling programs.
- Demonstration of Site Planner and PLUME for delineating subsurface chromium at the unlined chromic acid pit, and the 60s pit area of the Chemical Waste Landfill, SNL. Conclusion: significant cost savings could have been realized if these technologies had been used originally for characterizing the site.
- Demonstration of Site Planner and PLUME integrated with human health risk analysis at RB-11, a mixed-waste site belonging to Kirtland Air Force Base (KAFB).
- Demonstration of Site Planner, PLUME, human health risk analysis, and fate and transport modeling as interim action screening tools at the Mixed Waste Landfill, SNL. Conclusion: smart sampling design coupled with human health risk analyses can be used to effectively screen for interim remedial action needs at mixed waste facilities.
- Commercialization of enhanced Site Planner version, through Consolve, Inc.
- CRADA started and completed which commercialized PLUME.

BENEFITS

This approach has several advantages over traditional methodologies. In terms of data management and display, Site Planner provides specialized graphics that are dynamically tied to underlying data. As new data are generated and included in the database, graphics change to reflect the new information. In contrast, traditional geographic information systems (GIS) systems are limited in the types of graphics they can produce. Traditional GIS and Relational Database Management Systems (RDBMS) also require specialized computer experts to be effective and are usually not available to technical staff actually involved with site characterization work. However, Site Planner was designed as a mouse- and menu-driven system that is relatively easy to learn and apply.

In terms of data analysis, PLUME readily uses historical data along with field information to guide sampling strategy selection. This is particularly important for sites in the initial phase of characterization, when the amount of historical information available typically overwhelms any existing field sampling results. This capability makes it uniquely different from past sampling strategy selection methodologies. PLUME was designed to address the total sampling strategy problem, including measures of contaminant extent, measures of benefits to be expected from additional sampling, and recommendations about additional sampling locations. Most past approaches only addressed one or two of these issues. PLUME has been designed to work simultaneously with Site Planner using a mouse and menu interface. This also makes it readily accessible to site characterization technical staff.

The end results are sampling programs designed to save money and time when delineating contamination events. In a retrospective study of subsurface chromium contamination at the Chemical Waste Landfill at SNL, it was estimated that the use of these technologies for determining the extent of chromium contamination would have resulted in characterization costs that were less than half of what was actually spent, and would have provided significantly better contamination location resolution. In a side-by-side comparison of these technologies with traditional techniques at KAFB, these technologies resulted in a sampling program that reduced drilling costs by 25 percent and sample collection and analysis costs by more than 50 Percent.

COLLABORATION/TECHNOLOGY TRANSFER

Consolve, Inc., a U.S. small business, was the industrial partner in this project. The company's involvement was self-funded. Consolve, Inc. has commercialized both software packages. Site Planner has been commercially available since January 1992. PLUME has been commercially available since June 1994. Consolve, Inc. owns the copyright and trademark for Site Planner. The University of Chicago holds the copyright for PLUME.

DOE users of the Site Planner and PLUME include ANL, SNL, and Weldon Springs. DOE users of Site Planner include LANL and PNL. Other federal users of Site Planner and PLUME include the EPA, Los Angeles Air Force Base, Joliet Army Ammunition Plant, and Aberdeen Proving Grounds. Private sector users of both software packages include ARA, Inc., Woodward Clyde Consultants, Battelle, and SiteWorks, Inc. In addition to use in the United States, international inquiries about these two technologies have been received from companies and organizations in South Korea, Japan, Great Britain, and Argentina.

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Johnson, R., "A Bayesian Approach to Contamination Delineation," Proceedings of the Groundwater Modeling Conference, Golden, CO. P87-P95, June 1993.

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1.20 STRIPPING ANALYSIS

TASK DESCRIPTION

The objective of this task is to develop and test the effectiveness of using stripping analysis (SA) to determine the concentrations of leachable chromium, uranium, lead, cadmium, copper, and zinc on soils/sediments. The task will also identify underground source terms and plumes underlying SNL Chemical Waste and Mixed Waste Landfills.

Sediment samples are dried and digested in a microwave digestion system. Nitric acid solution is used as the leaching agent in the digestion process. Leachate (or digestate solutions) are diluted to 100 ml with distilled or deionized water. It is analyzed by adsorptive stripping voltammetry for chromium and uranium, and/or potentiometric or anodic stripping analysis for lead, cadmium, copper, and/or zinc. Results are reported as ppm of dry weight for the metals of interest.

TECHNOLOGY NEEDS

Stripping analysis is well suited for field screening. The system is compact, requiring minimal electricity (10 amp. at 120 volts-AC), and producing high-quality data in a short period of time. In fact, for trace metals, SA is an even more sensitive technique than lab analysis. Significant cost savings are anticipated using SA to support characterization and remediation activities. The cost savings arise from the ability to screen sediment samples concurrent with sampling activities. In addition, field screening efforts during removal actions can help delineate when a cleanup level has been achieved for a contaminant of concern.

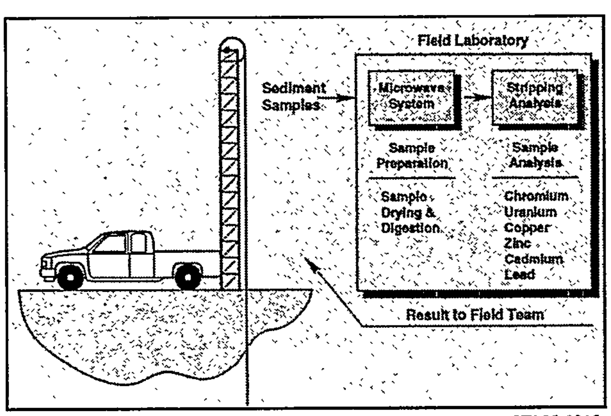

Figure 1.20. Stripping analysis.

ACCOMPLISHMENTS

- Developed and field tested the effectiveness of using SA to determine the concentrations of leachable chromium, uranium, lead, cadmium, copper, and zinc in soils/sediments underlying SNL's Chemical Waste Landfill.

- Developed commercial partnership with Radiometer America, Inc., to expedite transfer of methods developed under this task to the industrial and private sectors.

- Transferred this technology to field screening activities on the Hanford Site.

- Transferred this technology to field screening activities for lead in groundwater at Eielson Air Force Base in Fairbanks, AK.

BENEFITS

During site characterization activities at hazardous waste sites, the capability to determine the extent of contamination within hours from sample collection can decrease characterization and analytical costs. For example, drilling costs can be reduced by having near real-time knowledge when levels of contaminants of concern decrease to background levels to optimize depths of borehole. Laboratory analytical costs can also be decreased since 20 percent or less of samples need to be sent for confirmatory analysis using EPA approved methods. In addition, during the remediation phase of a site investigation, field analytical capabilities can be utilized to delineate the areal extent of contaminated material requiring removal without requiring off-site analytical services. Rapid on-site analysis can significantly decrease stand-by time for cleanup personnel waiting for off-site laboratory results, thus increasing the cost effectiveness of site cleanup.

COLLABORATION/TECHNOLOGY TRANSFER

Activities under this task supported a collaborative effort with New Mexico State University for the development and testing of several SA systems during field characterization activities at SNL.

Radiometer was identified as an industrial partner and procedures developed under this task were transferred to the company for evaluation in their development laboratory.

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Wang, J., R. Setiadji, L. Chen, J. Lu, and S. Morton, "Automated System for On-Line Monitoring of Uranium," Electroanalysis 4: 161, 1992.

1.21 Cross Borehole Electromagnetic Imaging

Task Description

Electrical properties such as resistivity, determined by electromagnetic methods, are unique among geophysical measurements, since the electrical property is directly related to chemical composition of the fluid passing through the geologic medium.

Fiber-optic cables lower the tool, which is 2" in diameter and 6-12' in length, into boreholes to determine properties such as permeability, saturation, and water chemistry. Based on the attenuation and phase shift of radio frequency signals propagated between boreholes, mapping of electrical conductivity or permittivity between boreholes can be accomplished. See Figure 1.21.

Technology Needs

In landfills containing metallic waste forms, the contrasts in electrical properties enhance the effectiveness of several electrical and electromagnetic methods. For the problem of source and plume detection at these landfill sites, the continuous wave and pulsed radar systems image the subsurface for targets that may be uniquely suited for the method.

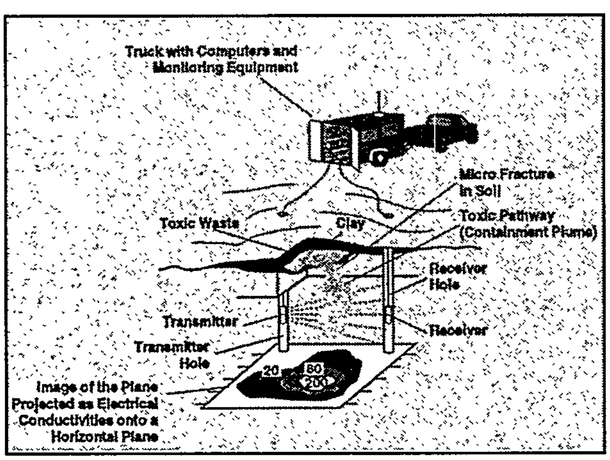

Figure 1.21. Cross Borehole Electromagnetic Imaging.

Accomplishments

- Rocky Flats has requested that RIMtech, Inc. design a trial radio imaging survey of selected sites.
- Presented and published a paper on radio imaging of the unlined chromic acid pits at the April 1993 Symposium on the Application of Geophysics to Engineering and Environmental Problems in San Diego, CA.
- Presented a paper on electromagnetic imaging of mixed waste landfills to Environmental Geology Section, Geological Society of America Annual Meeting, Boston, MA, October 1993.
- Completed three-dimensional surveys of the 60s pits at the SNL Chemical Waste Landfill. This survey utilized the two slant drill holes with the transmitter in the borehole and the receiver roving on the surface. These surveys delineated the covered trenches and possible plumes associated with them.
- Completed borehole-to-borehole images using the three Unlined Chromic Acid Pit (UNCAP) boreholes. These images delineated the major soil units that influence contaminant transport under the pit. The images also detected high-concentration portions of the plume beneath the pit. This survey was reproduced in 1993 with data agreement within 5 percent.
- Completed borehole-to-borehole images utilizing the pulsed radar system for treaty verification work. This survey was completed in October 1993 and correlated to the radio frequency-based images from the same boreholes.
- Geophysics Department—6116 and RIMtech completed a borehole-to-surface tomographic survey of the Kirtland Air Force Base radioactive burial site, RB-11.

- RIMtech, in addition to Raytheon Nevada Services, has been selected by EG&G Idaho at INEL to monitor infiltration through fractured basalt using the crosshole radio imaging method demonstrated in this project.
- DOE's Chicago Operations Office asked the electromagnetic imaging program to participate in a feasibility study on the uses of geophysics to characterize a Superfund Site at Brookhaven National Laboratories.
- A commercialization plan was developed and the technology was commercialized.

BENEFITS

There is a market for electromagnetic imaging anywhere high-resolution subsurface information is needed. Other important environmental applications are in remediation process monitoring and post-closure monitoring of landfills. The electromagnetic methods, in addition to qualitative mapping of units and processes, can provide information on porosity, saturation, permeability, and changes in fluid chemistry.

Outside the environmental market, there is a market for high resolution subsurface information in the mining, oil, and construction/engineering industries.

COLLABORATION/TECHNOLOGY TRANSFER

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Borns, D.J., Cross Borehole Electromagnetic Imaging of Chemical and Mixed Waste Landfills, Geological Society of America, Abstracts with Programs, 25, 1993.

1.22 MAGNETOMETER TOWED ARRAY

TASK DESCRIPTION

The magnetometer towed array, also called Surface Towed Ordnance Locator System (STOLS™)was built by the U.S. Navy as a proof-of-principal, non-intrusive characterization system to locate and identify buried ordnance. SNL, in conjunction with the U.S. Naval Research Laboratory and GEO-CENTERS, has adapted the system for use in landfill characterization.

Current technology is based on walkover magnetometer surveys that provide low-resolution data at the rate of an acre or two per day. STOLS™ has been commercialized by GEO-CENTERS, Inc. This vehicle-based system deploys a non-intrusive sensor platform containing seven total-field magnetometers with precise satellite positioning for locating the magnetic data. The acquired data sets are processed to produce high-resolution magnetic maps of the surveyed area (on the order of 0.5-meter resolution).

The vehicle that tows the sensor platform is rugged for handling the terrain variations in diverse field conditions. It enables the system to rapidly cover the survey area at a rate of at least 15 acres per day. The vehicle has been designed to exhibit a low magnetic signature in order to minimize interference with the magnetometers. In addition, the sensor platform, itself composed of low-magnetic materials, has been designed to keep the sensors at a sufficient distance from any spurious magnetic sources. An on-board computer accepts directional information from an electronic compass, and position coordinate information is now updated once per second by the dynamic global positioning system. The on-board computer also provides real-time information to the driver.

The sensor platform contains the array of 7 cesium-vapor magnetometers spaced at 0.5 meter intervals perpendicular to the direction of travel. Each of these magnetometers measures the total field strength at a rate of 20 points per second. This rate yields a total data-point density of 100,000 data points per acre.

The field strength at any point is determined by the sum of the Earth's field plus any local variations caused by the presence of ferrous materials. Data from a nearby reference station is used to remove the effects of the Earth's field from the sensor platform data. This step leaves behind only the variations due to local ferrous objects.

Precise positioning data is acquired simultaneously with the magnetic data. Based on a global positioning system, the location of the sensors is calculated at every instant to provide positions for every magnetic data point. After interpolating the positioned magnetic data to a regularly-spaced grid, magnetic maps of the survey area are readily produced and are repeatable from survey to survey. On these maps, the magnetic variations due to local ferrous objects are readily located through the use of appropriate color scales. In addition, areas that the system has yet to survey are clearly seen, and can be subsequently located and surveyed. Local landmarks and locations significant to a given survey can also be indicated.

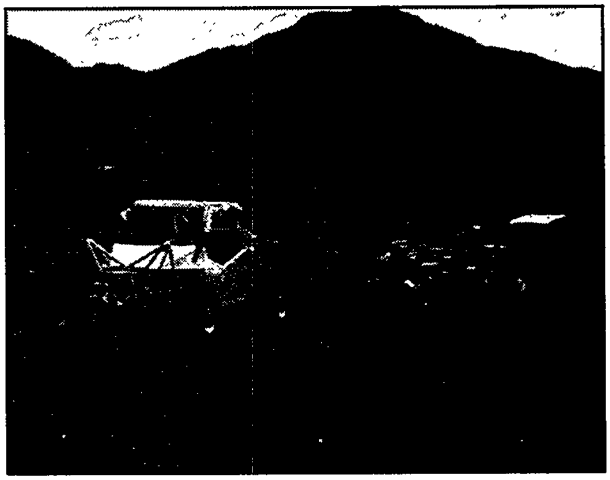

Figure 1.22. Magnetometer Towed Array.

Displayed on a video monitor, the magnetic map of a surveyed area provides the user interface to the semi-automated target analysis for small isolated targets. Using a mouse, the user selects an anomaly due to a given ferrous target. The target analysis then performs an iterative least-squares model match to determine the best fit of magnetic moment and depth to the selected anomaly for small isolated targets. Detection ranges include small pieces of ordnance (containing a few pounds of iron) down to a maximum depth of 6.5 meters.

TECHNOLOGY NEEDS

The STOLS™ technology represents a capability to perform environmental cleanup competently and efficiently. With rapid and repeatable surveying capability, coverage of broad survey areas can be performed in a cost-efficient manner that can be reliably documented. Additionally, target analysis can begin the remediation procedure by providing estimates of the location and quantities on the subsurface targets. Guidance for the total environmental cleanup procedure is also included in the target analysis.

ACCOMPLISHMENTS

- Eight vendors of locator systems demonstrated their ability to locate targets on the test track while driving at 5 MPH. Some vendors demonstrated real-time 100 percent accuracy at ≤ meter error, and 100 percent accuracy at ≤ 0.5 meter error in post processing. Other vendors were less than 10 percent accurate. A report documenting the performance of the eight navigation systems and the test setup was written and distributed.

- Based on the field test results, a GPS system was selected and purchased for incorporation into the towed array. The $100K Trimble Navigation 4000 SSE dynamic GPS system was purchased with both LSFA and Navy funds.

- Two trial surveys were conducted at the RB-11 landfill to make sure the actual field demonstration would be successful. In April, a trial survey was conducted with hand-held magnetometers. In May, a trial survey was conducted using dynamic GPS navigation systems.

- During the week of September 7, 1993, the Magnetometer Towed Array was successfully demonstrated at the RB-11 landfill. Less than two hours were required to survey the test site.

BENEFITS

MTA represents a characterization technology that enhances the speed and thoroughness of environmental cleanup. It provides an order of magnitude greater resolution than conventional technology which allows better horizontal resolution, and provides data redundancy and quantitative interpretation using computer algorithms. It also provides rapid and repeatable surveying facilitating surveys that cover a large area and can be reliably documented. MTA provides near real-time data display and analysis as opposed to data compilation and presentation a few days later in the office. It is approximately 10 to 30 times faster than standard walkover surveys. Independent of these advantages, the MTA is cheaper than conventional magnetometer surveys. When compared to a two-foot conventional grid, the MTA is cheaper at sites of three acres or larger, and when compared to a five-foot conventional grid, it is cheaper at sites of 50 acres or larger.

COLLABORATION/TECHNOLOGY TRANSFER

This technology involves collaboration with the following commercial industries:

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BIBLIOGRAPHY OF KEY PUBLICATIONS

None at this time.

1.23 POST-CLOSURE MONITORING

TASK DESCRIPTION

The objective of this task is to design, construct, install, field test, and evaluate an automated state-of-the-art soil moisture monitoring system for measuring the hydrologic performance of migration barriers and advanced surface covers for remediating landfills. The test will involve a comparison of automated state-of-the-art Time Domain Reflectometry (TDR) technology with the conventional neutron moisture gauge. Three brands of TDR will be evaluated, including one manufactured in Germany, one by Campbell Scientific, and one manufactured in Logan, UT. Performance, reliability, and cost of each of the technologies will be compared and documented. Radiation, VOCs, or other chemical detectors may also be evaluated as possible components of an integrated monitoring system.

The concept behind TDR is used commercially to locate open or short circuits in long cables. A very short pulse is sent down the cable by a signal (pulse) generator and the reflected pulse is measured by the device. A short circuit produces one type of signal on the display and an open circuit produces the mirror image signal on the display. When this principle is used for moisture measurements, a probe is attached to the end of a cable with well known electrical properties. The probe consists of two parallel stainless steel "spikes," a holder to keep them approximately three inches apart, and a connector to the rest of the cable. The spikes are inserted (or buried) in the soil to be measured and data are collected. If the soil between the probe spikes is very dry, the TDR device will "see" an open circuit. If the soil between the probe spikes is very moist, the TDR device will "see" a short circuit (since water conducts electricity). By using special interpretation software, these measurements can be directly related to soil moisture levels. If these probes are installed beneath and around a landfill, a sharp increase in soil moisture in a certain location might indicate that water (possibly carrying contaminants) has seeped (or leached) out of the landfill, requiring corrective action.

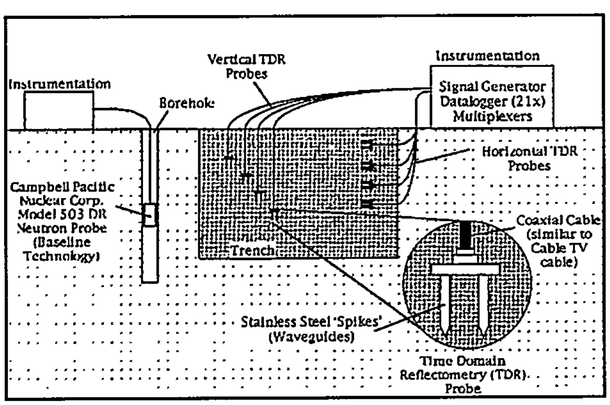

Figure 1.23. Post Closure Monitoring.

TECHNOLOGY NEEDS

TDR is not yet a "push button" technology, and performance characteristics in a range of climate and soil (frozen, extremely dry or wet, etc.) environments, and over extended time (years) is not well understood. Also, there are some discrepancies between neutron probe measurements (the baseline) and TDR measurements, especially in extreme environments, that must be resolved. This will need to be done in a laboratory on a sample of soil from the test area. Corrosion of the probes over the long-term is an issue that is being addressed by the manufacturer. Probes must be buried in the soil since installation in boreholes may be difficult.

ACCOMPLISHMENTS

- Prepared draft evaluation of one brand of TDR soil moisture system.
- Lab and field comparisons of neutron probe data to TDR data show a strong correlation under most climate and soil conditions.

BENEFITS

Screening technologies are essential for compliance with increasingly stringent effluent requirements and for cost reductions in site operations. TDR is a passive (no moving parts) technique that relies on simple probes that can be installed with new landfills or added to old landfills. It can fill landfill monitoring needs by providing a real-time representation of moisture levels around and under a landfill. TDR systems can potentially run for weeks at a time without intervention and do not use any radioactive or hazardous materials. Probes can be installed in configurations that provide redundant operation to verify measurements or to provide a backup in case of probe failure. Reliable monitoring systems are a key ingredient in gaining regulator and public support for in-place containment of waste.

COLLABORATION/TECHNOLOGY TRANSFER

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BIBLIOGRAPHY OF KEY PUBLICATIONS

None at this time.

1.24 SANDIA ENVIRONMENTAL DECISION SUPPORT SYSTEM

TASK DESCRIPTION

The primary purpose of this project is to develop a decision support methodology and automated decision support tool for aiding environmental decision makers in selecting appropriate characterization and remediation schemes. See Figure 1.24.

Sandia Environmental Decision Support System (SEDSS) is designed to extend the application of risk based performance assessment methodologies to environmental restoration and waste management activities. This problem solving approach explicitly accommodates uncertainty while integrating risk analysis with data collection. Consequently, it has begun to have broader application within the arena of environmental restoration, siting of low-level nuclear waste facilities, and may be extended to D&D activities.

The primary measures used to define good decisions within this framework are risks to human health and the environment coupled with cost. Some examples of decisions to which SEDSS would apply include: How should resources (cost and time) be prioritized based on estimates of risk? Is a site safe? If the site is unsafe, what remedial action or containment is necessary and optimal? When is the remediation complete, and how can it be defended as adequate? Is a potential new waste facility design safe (i.e., can a permit application be defended)? Is a monitoring network adequate?

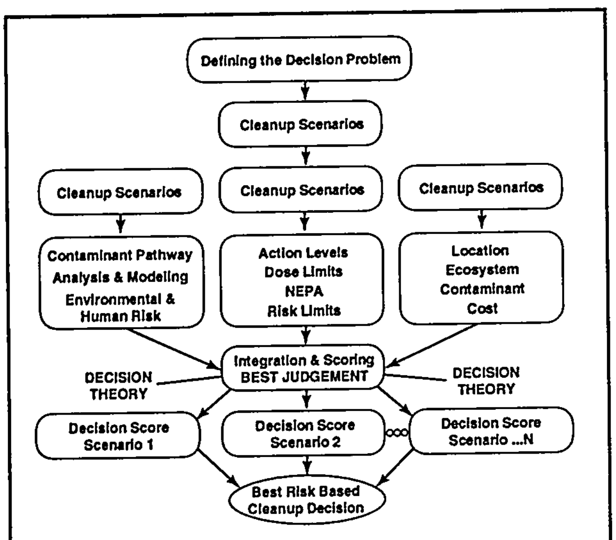

Figure 1.24. Decision Support System Methodology.

TECHNOLOGY NEEDS

An early prototype developed to handle contaminant transport through ground water pathways in limited geologic settings is currently operational. This system modeled the thick unsaturated zone conditions found at the Mixed Waste Landfill and provided a basis for some of the current system development.

The current SEDSS prototype is being developed to link numerous probability-based analysis tools in a user-friendly computer-based environment. Eventually, the system will provide the user a mechanism for making and substantiating decisions based on a level of confidence in the environmental restoration or waste management path that should be taken or on the feasibility of the associated costs of the various options.

The prototype will be developed into an operational version in FY95. This version will have 1) robust computer architecture (one that is suited for future development of both the risk and site characterization tools), 2) a set of analytical hydrological simulation codes to accommodate a variety of geological/ hydrological conditions for the ground water pathway, all within a probabilistic framework, and 3) the ability to trace hazardous constituents through the ground water pathway and determine their resulting human health risks as defined in the EPA risk assessment guidance.

The system requires a mid-level Sun workstation running the Soloris 2.3 UNIX operation system. In addition, there are direct links to Arcviews, PLUME, Site Planner, and graphics/data management packages.

ACCOMPLISHMENTS

- A prototype of SEDSS has been developed that is able to link numerous probability-based analysis tools in a user-friendly computer-based environment.
- Requirements for the first version of SEDSS are nearly complete. The version will be able to determine risk from hazardous and radionuclide contaminants moving via the groundwater pathway.

BENEFITS

There are two primary benefits resulting from the SEDSS project. First, the methodology is concise with a widely applicable process or framework for formulating, addressing, and solving environmental problems. The process can be viewed as an integrating framework that ties together in a logical fashion activities such as regulatory analysis, data acquisition and maintenance, development of the conceptual understanding of the contaminant source, human exposure, and consequent risk evaluation; sensitivity analysis to identify new data needs and establish data quality objectives; and cost benefit analysis to evaluate the value of new data or potential cost differences between radiation schemes. Second, a foundation for a computer-based decision-support tool is being created. Automation of the approach listed above via a computer system (SEDSS) allows rapid and consistent application of the approach for both broad and localized evaluation of risk, cost, and consequently defensible decisions.

In general, the system will reduce the time required for characterization and remediation operations and thereby reduce cleanup costs. SEDSS will also automate much of the integration between analysis techniques and put the entire decision analysis framework at the decision-maker's fingertips.

COLLABORATION/TECHNOLOGY TRANSFER

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1.25 PASSIVE ALPHA TRACK DETECTOR AND ELECTRET IONIZATION CHAMBER TECHNOLOGIES

TASK DESCRIPTION

The focus of this project was to determine the feasibility of using the passive Alpha Track Detector (ATD) and the Electret Ionization Chamber (EIC) Technologies as a means of making inexpensive, simple, and accurate surface and near-surface soil measurements for detection of uranium contamination.

Alter and Fleisher (Health Physics 40:693-702, 1981) described the application of ATDs to the measurement of indoor airborne alpha activity. The underlying principles of the measurement are: (1) damage tracks in the plastic material are induced by the passage of alpha particles through the material, (2) damage tracks can be subsequently enlarged by exposure to potassium hydroxide solution, (3) enlarged tracts can be counted with a microscope, and (4) density (per unit area) of tracks is proportional to the alpha activity.

Kotrappa and coworkers (Health Physics 41:35-46, 1981; Health Physics 54:47-56, 1988) have described the application of EICs to the measurement of indoor alpha activity. The underlying principle of the measurement is that ionizing particles passing through the air in the sensitive volume of the detector create electron showers that are attracted to the positively charged face of the electret, neutralizing the charge.

TECHNOLOGY NEEDS

The current state of development of the EIC technology allows on-site implementation, including deployment and retrieval by general site personnel with on-site reading of exposed EICs. Continuing development efforts focus on reducing or compensating for interferences from radon and moisture in the soil. The ATDs are also deployed and retrieved by general site personnel, but analysis of exposed ATDs occurs in off-site laboratories. Future efforts will include development of on-site analysis capability that will achieve a turn-around time of about one day between end of exposure and final reported results.

ACCOMPLISHMENTS

Preliminary results showed that generally there was a linear relationship between ATD or EIC response and bulk soil activity (expressed in pci/g) when the devices are exposed to contaminated soil. It was found that substantial variation existed among ATD and EIC responses to soils from different sites. Therefore, a required element for data analysis is the collection of a set of soil samples from the measure site. The set of samples should reflect a range of activity concentrations so that after radiochemical analysis is complete, site-specific calibration exposures can be performed in the laboratory.

BENEFITS

During the remediation of uranium-contaminated sites, decision makers frequently have a need to know the size (i.e., geographic extent) of a contaminated area and would like to get that information quickly and inexpensively. The use of ATDs or EICs can satisfy this objective. Both devices register alpha activity without being strongly affected by beta or gamma activity. Both techniques have been fully commercialized for the detection of airborne alpha activity in indoor environments. Adaptation of the presently available infrastructure to these added measurement tasks is expected to result in substantial cost savings to DOE and other users of passive alpha detectors. Total cost per measurement is likely to be under $10, exclusive of labor costs incurred in the placement and retrieval of detectors by general site personnel.

Collaboration/Technology Transfer

The principal vendor of the ATD technology (Landauer, Inc.) in the indoor radon monitoring market and the principal vendor of EIC technology have signed CRADAs with Martin Marietta Energy Systems, Inc., the contractor operating ORNL. As part of these agreements, both vendors are pursuing the development of new markets for their respective technologies. They anticipate demand for these technologies from site managers who are charged with environmental restoration, decontamination, or decommissioning responsibilities.

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1.26 REGULATORY DATABASE SYSTEM FOR EVALUATING ALTERNATIVE TECHNOLOGIES

TASK DESCRIPTION

This task was to develop a means by which regulatory requirements could be identified and more effectively used in technology development planning and design. The Regulatory Database System (RDS), a database and associated data management software, was so developed to identify and report linkages between federal/state regulations and programmatic DOE guidance to remedial activities and interim response actions. The database can be utilized to identify remedial activities that are governed by a specific regulatory requirement or to identify the set of regulatory requirements associated with a specific activity. This linkage is established through the precoding of the nearly 1,200 requirements in the database according to the remedial activities that may be governed or affected by them. These requirements include EPA, NRC and DOT regulations, DOE Orders, federal laws, Executive Orders, and State of Ohio regulations.

A predefined set of "building block" activities that encompass the basic components of a broad range of response activities and remedial process operations are built into the RDS, but additional project-specific activities also can be defined. For each requirement, the database contains 16 fields of information that were selected to be of particular value to remediation or process engineers needing to perform compliance evaluations for various technological options. The fields of information include regulatory citation, Applicable or Relevant and Appropriate Requirements (ARAR) category, effective date of the requirement or guidance, enforcement agency, title, brief synopsis, quantitative or qualitative compliance standard, and criteria to determine applicability. The associated data management software facilitates viewing the regulatory records, filtering the database according to one or more of its various fields, searching by keyword(s), editing records, and printing prestyled or customized tables of selected requirements.

TECHNOLOGY NEEDS

There is a continuing need to identify what regulatory requirements and programmatic guidance must be considered in compliance evaluations of remedial options or competing technologies. These requirements must be identified quickly and in a cost-effective manner, since remedial options or treatment processes can be changed and modified several times during the critical decision-making period. A tool was needed to quickly develop initial sets of requirements relative to a technological alternative for design and implementation planning or in side-by-side comparisons of competing technological alternatives. In addition, information about these requirements must be presented in a format that conveys meaning to a broad set of users, including remediation engineers and project managers not intimately familiar with regulatory jargon.

ACCOMPLISHMENTS

The RDS has been used as an integral tool in the development of ARARs and to be considered technologies for an Operable Unit at DOE's Fernald Facility and for a soil washing demonstration project under DOE's uranium soils demonstration project.

The written report format developed for the uranium soils demonstration project ARAR document includes: (1) presentation of requirements by project activity or phase, (2) characterizing the activity or phase in clear, descriptive terms, (3) grouping related requirements by topic for prioritization and discussion, and (4) identifying the requirements in both tabular and text formats. In addition, the written reports were extensively indexed according to common engineering and remediation terminology.

BENEFITS

The Regulatory Database System and associated software can streamline the initial steps of the process in identifying ARARs and to be considered technologies for a specific response action or remediation scenario. It facilitates the maintenance of a centralized collection of pertinent regulations for a facility, combining federal and state requirements and DOE Orders and guidance in one database. The RDS facilitates comparisons of technologies on a regulatory basis. It is a component of the development of an ARARs document geared toward providing engineers and project managers with early regulatory input to technology evaluation and design projects.

COLLABORATION/TECHNOLOGY TRANSFER

None at the present time.

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1.27 CHARACTERIZATION OF CONTAMINATED SOILS AND RESIDUES USING ELECTRON AND ION BEAM METHODS

TASK DESCRIPTION

Remediation technologies are being developed to clean up heavy metal and radionuclide contaminated sites throughout the United States. The effectiveness of these technologies is highly dependent upon the form of contamination in soils and residues from incinerator waste. At ANL methods are being developed for characterizing waste components in contaminated soils, building upon work from the uranium in soils demonstration program at Fernald.

Following a protocol based on EPA guidelines for determining the nature of radionuclide contamination in soils, characterization information is used to assist remediation technology development and optimization. This characterization method involves a combination of electron and ion beam methods: (1) scanning electron microscopy with backscattered imaging and x-ray energy dispersive spectroscopy (EDS) capabilities, (2) analytical transmission electron microscopy for characterization of sub-micron radionuclide phases with electron diffraction, EDS, and electron energy loss spectroscopy (EELS), and (3) a secondary ion mass spectrometer (SIMS) for trace radionuclide detection. Optical microscopy and x-ray diffraction are also used in characterization studies for representative analysis.

Facilities dedicated to the study of radioactive materials also include elemental analysis using inductively coupled plasma mass spectroscopy (ICP-MS) and gamma and alpha spectroscopy for radiochemical characterization of soils. These instrumental techniques are all available within the Radioactive Waste Microscopy Group at ANL, and are being utilized to characterize contaminated soils from various sites.

TECHNOLOGY NEEDS

Present regulatory, environmental, and social demands require that a remarkably large number of sites undergo decontamination of local soils that have been fouled by a wide variety of human activities. Effective remediation of contaminated soil demands that unnatural waste products be removed with minimal processing or alteration of the natural chemistry and morphology of the environment. Such remediation is possible only with detailed knowledge of the chemical and structural composition of both the waste constituent and the native soil.

Soil around the Fernald site in Ohio has become contaminated with uranium due to operations conducted there from the early 1950s until 1986. The form of the uranium contamination was not known. Thus, proper selection of the appropriate cleanup technology was impossible. Characterization has helped the selection of suitable remediation methods.

Other DOE sites, including Portsmouth, OH, and Rocky Flats, CO, also have significant volumes of radionuclide contaminated soils. Unless the form of the contaminant is understood, and its chemical and physical characteristics determined, the remediation techniques will operate by trial and error. The large amount of plutonium contained in incinerator ash is a national resource and needs to be recovered. By determining the form of the plutonium using Analytical Electron Microscopy (AEM), methods can be developed to leach this element from the host material.

Accomplishments

- Identification of the major uranium-bearing phase in Fernald soils as meta-autunite (calcium uranyl phosphate), a U(VI) phase. Determination of the major uranium phase allows prediction of its fate in the local environment.
- Determination of U(IV) phases that have not been removed by soil washing at Fernald as uranium metaphosphate [$U(PO_3)_4$] and uraninite.
- Based on AEM characterization observations, remediation groups were advised within the Uranium in Soils program to use a chemical carbonate extraction followed by physical separation.
- Investigated the form of plutonium and uranium "hot particle" contamination on Johnston Island.
- Determined the form of plutonium in incinerator waste from Rocky Flats and LANL, as a reduced plutonium oxide with some Pu incorporated into silica glass phases.
- Determination of the distribution of thorium oxide particles in contaminated soils for Ecotech, Inc.

Benefits

This methodology is being offered as a service to the private sector for characterizing contaminated sites, evaluating remediation approaches, and selecting remediation technologies. To proceed with a cleanup procedure without clear knowledge of the nature of the contamination can result in an even larger volume of contaminated material. Knowledge of the nature of heavy metals in soils and the other phases present will allow for complete evaluation of the most suitable technologies to clean up a contaminated site. The benefit for such a study as proposed is that, in the long run, it will reduce remediation costs and the total time required to cleanup the site.

Collaboration/Technology Transfer

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1.28 COST/RISK PERFORMANCE ASSESSMENT OF SOIL CHARACTERIZATION TECHNOLOGIES

TASK DESCRIPTION

Technical tools are being developed to evaluate and compare dissimilar field-screening technologies for detection of uranium contamination in surface and near-surface soils. With the use of these tools, a cost/benefit comparison is being performed for five field screening and four industrial standard technologies demonstrated under the Uranium in Soils demonstration that were designed to meet the need for real-time detection and measurement of radionuclides in soil.

The five field screening technologies include: (1) in situ gamma-ray spectroscopy (GAM), (2) the Long Range Alpha Detector (LRAD), (3) the beta scintillator counting (BETA), (4) laser ablation-inductively coupled plasma-atomic emission spectroscopy (LA-ICP-AES), and (5) passive radon monitoring Alpha Track Detector (ATD). The industrial standards are: (1) sodium-iodide detector (NaI), (2) low energy scintillation detector (FIDLER), (3) x-ray fluorescence detector (XRF), and (4) soil sampling/laboratory analysis.

The technologies are compared on the basis of estimated cost of site scale application, degree of accuracy, and reliability under operating conditions. Each technology is compared with the baseline alternative of closely spaced sample collection with subsequent laboratory analysis. Additionally, a program is implemented that guarantees successful transfer of the technology developed in this task. Rapid dissemination of university and laboratory research to industry and the federal community is also included under this program.

TECHNOLOGY NEEDS

The framework of the technology is based on a risk-based philosophy of engineering design that couples the uncertainty of the geologic information with a decision model seeking to optimize a cost-risk-benefit objective function.

ACCOMPLISHMENTS

- Analyzed the four technologies' results from the August and September 1992 demonstration and produced concentration and probability maps of the uranium concentrations.
- Developed an automated data management and geostatistical process to transmit data from Fernald to SNL.
- Received, entered, and analyzed data and provided new locations for the next day's sampling within a four-hour window.
- Provided data sample format controls to maintain integrity and quality of sample data.
- Analyzed the sample data from five field screening and four industrial standard technologies demonstrated during May-July 1994.
- Produced concentration and probability maps of the analyzed data.

BENEFITS

Direct benefit to the Uranium in Soils demonstration at Fernald is the evaluation of alternative characterization technologies within a framework that provides the program manager with the costs, risks, and benefits of alternative strategies. Direct benefit to DOE is the generic nature of the approach and its applicability to any site investigation. The approach is expected to decrease the time required for the input and interpretation of technical data to the decision-making process, provide a better estimate of the risks and costs involved with alternative decision strategies, and limit site characterization activities to the collection of data that has value with respect to the specific problems at each individual site.

It is clear from preliminary analyses conducted so far that the information generated by the analytical process could also be used to optimize the design of any additional characterization activities, the design of batch treatment plants, and the design of soil scraping to minimize the spread of contamination. The analytical approach and the technology to apply it are just as applicable to many problems facing industry.

In 1991, the environmental protection industry constituted a $185 billion market (Berg, 1992). Published literature (Massmann et. al., 1991) suggests that the analytical approach and technology being developed under this proposal is capable of reducing the costs of remediation and design by at least 6 percent and possibly much more. If only half the 1991 expenditures are reduced by 6 percent, a cost savings of $5 billion a year, to the industry as a whole, would not seem unreasonable. The potential could be substantially greater.

COLLABORATION/TECHNOLOGY TRANSFER

The Western Governors' Association and four federal agencies—the DoD, DOI, DOE, and the EPA—are collaborating in this project.

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1.29 INTEGRATED METHODOLOGY FOR DETERMINING CLEANUP LIMITS FOR URANIUM IN TREATED SOILS

TASK DESCRIPTION

The objective of this task is to devise a state-of-the-art methodology for developing cleanup limits for uranium in treated soils. The assessment methodology incorporates the latest dose and dose-response information on uranium using a series of transport and exposure models that link uranium concentrations in treated soils with human contacts and associated radiation doses. In addition, the methodology will deal with monitoring equipment and techniques for cleanup compliance with limits. Uncertainties associated with the quantification of soil-remediation limits will be characterized. The methodology addresses the need for determining cleanup limits for uranium in soils that have been treated by various remediation technologies. The on-going work is a joint effort between ORNL and LLNL with additional technical support provided by the University of Cincinnati.

TECHNOLOGY NEEDS

The remediation of uranium–contaminated soils is mainly controlled by the target cleanup levels for uranium in soil. Generic assessment models for determining cleanup levels often lack the flexibility to deal with a given site. Unduly conservative models will tend to give soil cleanup levels that are very low—perhaps even lower than background levels of a contaminant in indigenous soils. It is very desirable, therefore, to have a realistic assessment methodology that is based on techniques that are technically sound, clearly communicated, and that can be verified independently by others. This type of methodology will greatly facilitate (1) the dialogues and negotiations with regulatory agencies charged with the responsibility of overseeing cleanups of uranium–contaminated soils at DOE facilities, and (2) communication with the concerned public regarding the basis of remediation actions.

ACCOMPLISHMENTS

- Reviewed regulatory guidelines for uranium-contaminated media and associated daughter products;
- Examined methodological issues pertaining to the development of techniques for quantifying cleanup limits for treated soils;
- Prepared analyses of key biokinetic parameters involving the uptake, distribution, and dosimetry of uranium in humans; and
- Analyzed the current basis for limits on the ingestion of uranium by workers and members of the public.

BENEFITS

At least three sets of benefits are associated with development of an improved assessment methodology. First, a realistic, risk-based determination of cleanup limits for uranium will help establish the technical credibility needed to convince regulatory agencies that cleanup limits are indeed health protective. Second, a methodology that can be easily communicated to regulators and the concerned public will enhance the acceptability of alternative cleanup limits. Finally, an improved methodology for determining cleanup limits will minimize the possibility that chosen levels are unrealistically low.

COLLABORATION/TECHNOLOGY TRANSFER

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1.30 Removal and Recovery of Uranium and Toxic Metals From Contaminated Soil by BNL Citric Acid Process

Task Description

The presence of radionuclides and toxic metals in soils and wastes at many of the DOE facilities is a major environmental concern. The first step in the cleanup and restoration of these contaminated sites is the development of practical techniques for the removal of contaminants. Specifically, this study is aimed at testing the applicability of the patented Brookhaven National Laboratory (BNL) Citric Acid Process to treat effluents containing uranium and other toxic metals generated from citric acid extractions of Fernald storage pad soils.

The BNL process consists of three steps: extraction, biodegradation, and photodegradation. Citric acid, a naturally occurring organic complexing agent, is used to extract metals and radionuclides from contaminated soils and wastes through the formation of water-soluble metal citrate complexes. The citric acid extract containing radionuclides and metals is then subjected to microbial degradation followed by photodegradation. Most of the metal citrate complexes, with the exception of uranium, undergo biodegradation and are recovered in a concentrated form with the bacterial biomass. Hence, uranium is easily separated from the rest of the metals. On subsequent exposure of the uranium-containing effluent to light, the uranyl citrate complex undergoes rapid photodegradation and uranium precipitates out as a stable oxide that is recovered for recycling or disposal.

Laboratory scale treatment studies of citric acid extracts of Fernald storage pad soils have been completed. Further, the possibility of using the BNL process for treating uranium and toxic metal contaminated sludges from the Y-12 site, Oak Ridge, TN, has also been demonstrated. Currently, the biodegradation and photodegradation steps are being optimized to improve rates and efficiencies of metal removal.

Technology Needs

Recent estimates indicate that there are 2,000,000 yd^3 of uranium contaminated soil at the Fernald site in Ohio. Besides this, eight other DOE sites have similar soil contamination problems. Uranium containing sludges are also present at the Y-12 site in Oak Ridge, TN, and other DOE facilities. Moreover, decontamination and decommissioning of nuclear facilities, and retrieval and processing of stored radioactive wastes are bound to increase the need for uranium remediation technologies.

Although the feasibility of the BNL technology for remediation of uranium contaminated soils and sludges has been demonstrated, additional R&D work is necessary for scale up of the process. Currently, 87 percent and 94 percent uranium has been removed from contaminated sludge and soil, respectively. The sludge contained 2410 ppm and the soil 449 ppm of uranium. There is a need to test a wide variety of soils and improve the removal or extraction efficiency by pretreatment. Additionally, it is necessary to design a supplementary process for recovery and recycle of citric acid to reduce overall cost.

Accomplishments

- Confirmed applicability of BNL Citric Acid Process for treatment of Fernald storage pad soils.
- Demonstrated feasibility of using BNL Citric Acid Process for treating Y-12 sludge.
- Accomplished selective removal of uranium from other metals.
- Achieved greater than 99 percent barium, strontium, thorium, and zinc, greater than 90 percent lead, and greater than 50 percent

chromium and nickel removal via biodegradation.

- Achieved greater than 99 percent removal of uranium during photodegradation.
- Initiated bench scale optimization studies.

BENEFITS

The BNL Citric Acid Process is versatile and applicable to various materials and waste forms.

COLLABORATION/TECHNOLOGY TRANSFER

A CRADA with Forrester Environmental Services, Inc., to remove and recover lead, cadmium, and other metals from incinerator ash is underway. Bench-scale studies have been completed and pilot-scale tests in a full production facility are under consideration.

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RETRIEVAL

Section 2.0

2.1 REMOTE EXCAVATION SYSTEM

TASK DESCRIPTION

A previously developed remote excavation system (RES) will excavate the Hill Cut Test Facility at ORNL. During the field tests, the vehicle will be equipped with dosimeters to assess the operator exposure risks during overburden removal and cask handling. A grappling end effector must be developed and integrated with the existing RES and control station.

A standard military vehicle, the Small Emplacement Excavator, was modified by ORNL for remote operation and computer-assisted control. The excavator contains automated dig and dump functions, multiple video cameras, joint encoders, and other sensor feedback. See Figure 2.1. Video and control data are transmitted to the control station via radio frequency links or fiber optics. A joystick controller and a graphical computer interface were developed to provide a remote control station that is easy to use and does not require line-of-sight operation.

The RES will remove the overburden and manipulate the disposal casks so rigging can be attached. The majority of the casks will be transported to the Interim Waste Management Facility (IWMF) staging area where they will be placed in the standard IWMF concrete casks prior to disposal in tumulus units. The approach will provide a pre-commercialization field test of remote excavation technology that could have widespread application to buried waste site remediation. Dosimetry measurements during excavation will provide worker exposure data for future risk analyses. The grappling end effector and controller will integrate manipulation technology with heavy equipment technology.

The primary objective is to test and demonstrate remotely operated excavation technology for applicability to a specific class of buried waste remediation.

ACCOMPLISHMENTS

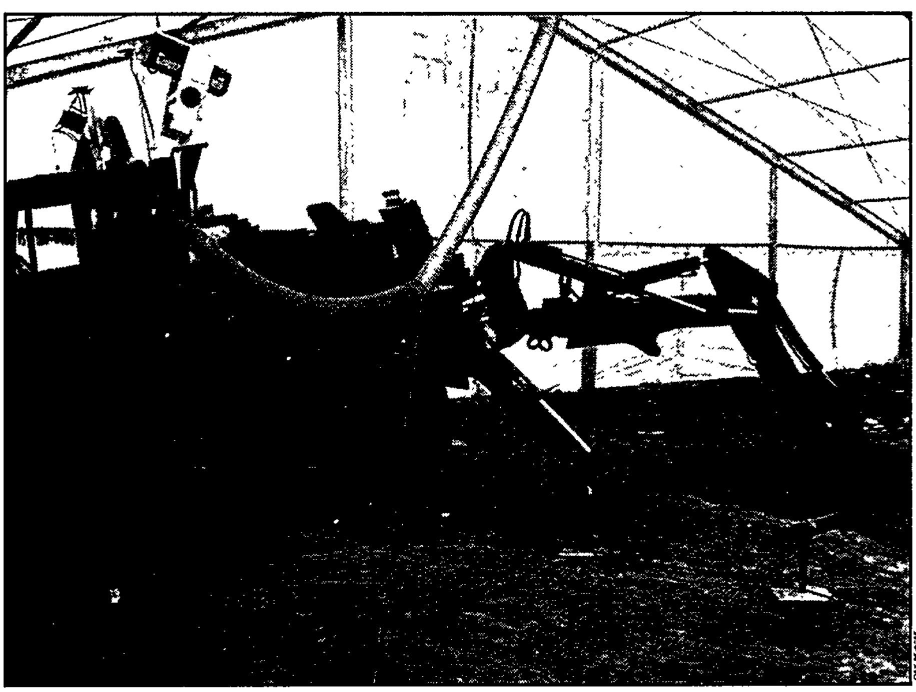

Figure 2.1. Remote Excavation Operations at INEL Cold Test Pit During LSFA Summer Demonstration.

The RES was demonstrated in 1993 at the INEL Cold Test Pit and the U.S. Army Redstone Arsenal to evaluate the feasibility of excavating buried waste and unexploded ordnance with a remotely operated vehicle. At each of these demonstrations, the relative performance benefits of teleoperation and telerobotic excavation were evaluated and documented. The demonstration showed that the system can be operated remotely to effectively excavate buried waste. The advanced control technology and computer-assisted operations made excavation relatively easy for both inexperienced and experienced operators.

TECHNOLOGY NEEDS

The RES can be used for remote excavation of radioactive and hazardous sites and for retrieval of unexploded ordnance. The controls technology developed for this project was implemented in a modular fashion that permits rapid transfer of the technology to other excavator platforms. High surface dose rate waste, likely to be encountered in many buried waste sites, will require remote techniques for excavation. At other sites, remote retrieval may be desired due to safety concerns, such as potential for explosion and fire. The concrete casks in the Hill Cut Test Facility provide an attractive test because the potential for contamination spread is minimal.

BENEFITS

With the RES, materials can be excavated and retrieved in a hazardous environment without endangering operator personnel. The RES is designed for relatively small excavations. Remote operation of the system demonstrated a retrieval rate of approximately 2.4 ft^3/min, while manual operation under test conditions achieved rates 50 percent higher.

COLLABORATION/TECHNOLOGY TRANSFER

Disclosure of this research through professional journals and presentations at technical conferences will ensure transfer of this technology to private-sector contractors that may be performing waste site remediations. Many companies have expressed interest in the control technology and the operator interface technology developed by ORNL, and several are pursuing CRADA scope negotiations. Mechanisms will be sought to transfer the technology to interested parties.

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BIBLIOGRAPHY OF KEY PUBLICATIONS

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2.2 REMOTE RETRIEVAL INTEGRATION

TASK DESCRIPTION

The buried waste program has centered investigation of the excavation of waste on three primary system components: a remotely operated excavator, an autonomous waste conveyance vehicle, and a telerobotic gantry crane. The telerobotic gantry crane is equipped with two manipulators attached to independent trolleys to deploy other technology for characterizing waste, controlling dust and contamination spread, cutting large objects, and performing archaeological excavations.

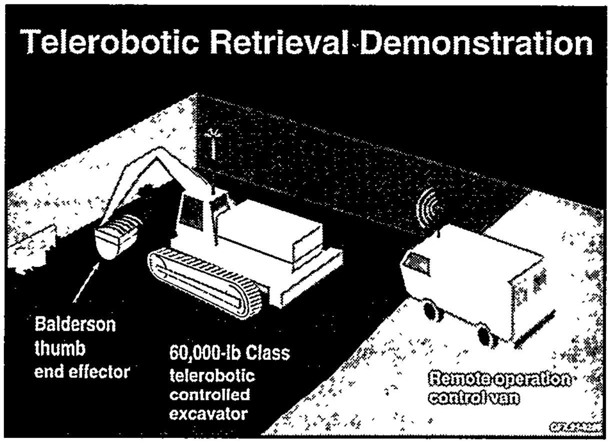

Figure 2.2. Conceptual drawing of a Telerobotic Retrieval Demonstration using a 60,000 lb-Class Remotely-Operated Excavator.

TECHNOLOGY NEEDS

Based on safety analyses done in the past, the retrieval of buried waste will be required to be performed remotely. DOE's desire to remotely retrieve buried waste and DoD's interest in remote retrieval of unexploded ordnance share similar technology needs. One need of both programs is the development of a remotely operated excavator to perform the retrieval tasks. Radioactive contamination is a concern, but larger concerns identified in the safety analyses include explosion and fire potentials. The development of remotely operated equipment such as the remote excavator will allow the remediation operations to be performed in a manner that provides worker safety. Effective and efficient remote operations are dependent on the development of human-machine interfaces and proper system integration.

ACCOMPLISHMENTS

Conceptual design of a Human Engineered Control Station (HECS) was completed to provide controls and displays for the retrieval equipment. The design addressed controls, displays, workspace, work arrangement, and work environment.

The HECS includes a Supervisory Control System (SCS) to aid in collision avoidance and allow for data transfer between the systems. The SCS provides a broadband data highway with network capacity to carry all the data between the control trailer and the retrieval enclosure. The network makes data from each system available for use by other systems that require the information.

A Caterpillar 325L excavator was fitted with a commercially available open loop control system modification package to allow simple operations to be performed remotely. The system was tested at Jefferson Proving Grounds and operated satisfactorily.

Functional and operational requirements for the SCS were developed. Each platform was to provide system-specific data from appropriate resolvers to allow the SCS to determine platform configuration. Additionally, the SCS would have a subsystem to identify each platform's position and orientation. With each platform located and configured via the SCS, a graphical model of all the platforms and exclusion zones surrounding the platform can be generated and maintained. This modeling information would then be used to perform collision avoidance chores.

The control system for an excavator and the system vision systems were mounted on the excavator to simplify remote operations. Additional operator aids that may simplify remote operations are being investigated.

BENEFITS

This technology aids in remotely operating excavation equipment. The HECS provides an integrated remote control mechanism that integrates human capabilities, limitations, and expectations into the design of the retrieval system to reduce potential for human error, provide an easy system to learn and operate, and reduce the ultimate investment in training.

COLLABORATION/TECHNOLOGY TRANSFER

Much of the technology development performed as part of this activity was done by industry. DoD has funded Wright Laboratories, based at Tyndall Air Force Base, to perform research and development on remote excavators. The buried waste program teamed with Wright Laboratories to leverage government funding in this development effort. Caterpillar was involved in specially fitting equipment to allow simple operations to be performed remotely. Testing was done at Jefferson Proving Grounds, a DoD facility.

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BIBLIOGRAPHY OF KEY PUBLICATIONS

None at this time.

2.3 Three-Dimensional Dynamic Graphic Simulation of Retrieval Options

Task Description

The three-Dimensional Dynamic Simulation Tool (3DDST) consists of a collection of computer hardware and software components that have been integrated to create three dimensional (3-D) graphical displays featuring proposed LSFA telerobotic retrieval technologies. During FY95, the 3DDST will be further enhanced to integrate with and illustrate FY95 LSFA characterization/retrieval demonstration/ex situ treatment configuration options. Software equipment models will have the ability to display soil removal performed by LSFA technologies.

The primary objective is to modify existing commercially available software packages to provide a graphical 3DDST for LSFA systems analysis.

A software model library will also be developed, consisting of the proposed LSFA technologies to be deployed for the FY95 demonstration. The data base will facilitate timely development of work site scenarios involving those technologies.

Technology Needs

The system will be developed with flexibility to allow OTD to carefully plan retrieval efforts in various waste scenarios.

The system will test the technologies for various data parameters in a safe setting, without extensive resource commitments. The system may also be used as a training tool. The 3DDST can easily be modified to illustrate site-specific retrieval needs, scenarios, and technologies.

Accomplishments

Prior year progress involved a technology survey. Hardware and software components have been procured to develop preliminary graphical display presentations. This work will be augmented by developing software equipment models, displaying representative soil removal.

Benefits

This graphical tool:

- Visually defines the relative merits of proposed technical development activities of LSFA characterization/retrieval/ex situ treatment configurations.
- Identifies crosscutting technologies, compares existing and emerging technologies and technology gaps, and illustrates how these components fit into the overall system.
- Provides communication for presenting possible system scenarios.
- Forms three-dimensional images of different configuration options at various DOE sites.

The 3DDST will allow researchers to simulate testing of technology designs and test scenarios for feasibility of success and job safety. Such data may be utilized in the decision-making process related to technology development, retrieval feasibility studies, and/or personnel training.

Cost savings cannot be quantified at this time. However, this tool will enhance planning for remedial design and operations, thereby increasing production efficiency.

Collaboration/Technology Transfer

The product from this TTP will be software and associated hardware. Development of the 3DDST will involve integrating and modifying numerous commercial software products. Transfer of this technology may require involvement of each software contributor. However, there is potential for commercial application of the tool as a service to various industries for technology testing, training aids, etc. This may be accomplished through a CRADA with interested parties, if the market exists.

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2.4 COOPERATIVE TELEROBOTIC RETRIEVAL

TASK DESCRIPTION

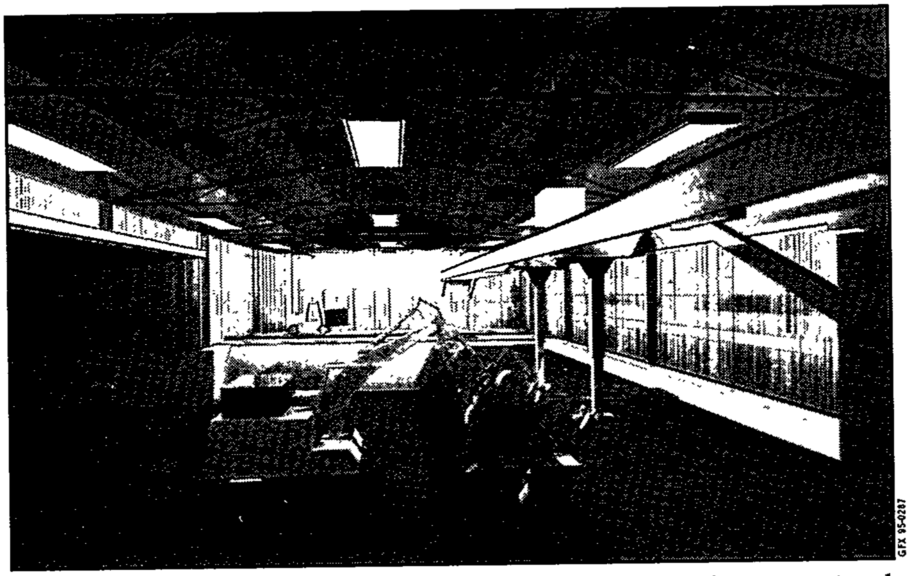

Figure 2.4. Conceptual Drawing of a Cooperative Telerobotic Retrieval System.

A study has determined the type of delivery system required to transport dual manipulation capability to the digface. The delivery system, a gantry crane, will transport the manipulators and deploy a sonic digging/vacuum system, digface characterization equipment, and other equipment to the digface as required.

The remotely operated vacuum system will remove soil and debris from around objects. See Figure 2.4. End-effectors for the vacuum system will be designed to break up hard soil, carefully clean around buried objects, and ensure that large sheets of plastic and other objects do not plug the system. The vacuumed debris will be placed in a transport container for subsequent removal and treatment. The system will be developed to control the required number of motions, including control of the delivery system, manipulator freedom, and vacuum system.

As a common platform (gantry crane) for LSFA deployment during the FY95 demonstration, the gantry crane will be equipped with two cooperative telerobotic manipulators [multi- manipulator capability (MMC)]: a telescoping mast, and a hoist for ancillary tools. The crane system will support: (1) archeological excavations (soil vacuum and sundering equipment), (2) digface characterization [INEL radiation, magnetics, VOC sensors, Pacific Northwest Laboratories (PNL) radar], (3) waste retrieval from the excavation, and (4) delivery of waste to the proposed transport system.

The primary objective is to develop the capability to perform selective retrieval at a buried waste site. Two robotic manipulators will be installed on the delivery system. In tandem, the manipulators will selectively remove debris from around an article and retrieve the article.

TECHNOLOGY NEEDS

Current buried waste retrieval scenarios indicate a need to selectively retrieve objects uncovered at the digface. This technology will remove and process intact drums, machining tools, potentially explosive objects, and other hazardous articles removed at the site.

ACCOMPLISHMENTS

Prior year progress has included the purchase of the gantry crane, associated deployment mechanisms, the MMC and hydraulic drive unit, and components of the systems control unit. Technologies developed under separate previous years, LSFA TTPs and/or research efforts (digface characterization, soil vacuum/sundering tool) will be integrated for use in FY95.

BENEFITS

The system has been developed to demonstrate that available technology can be deployed in a realistic waste remediation scenario by a cooperative telerobotic platform.

Since cost savings associated with this technology are dependent on the application and operation scenario, quantitative cost analyses have not been performed. The primary driver for the technology is improved worker safety. Cost savings are expected through removing human workers from hazardous environments. Additional cost savings will be realized by reducing the need for personal protective equipment in hazardous environments.

COLLABORATION/TECHNOLOGY TRANSFER

Industry participation is anticipated in the development of a delivery system for this project. Advances made in the expansion of a control system will be transferred to the control system manufacturer partnered in these activities. Capabilities developed at ORNL in the area of coordinated, dual manipulation will be used in current development efforts.

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None at this time.

2.5 WASTE CONVEYANCE AND INNOVATIVE END-EFFECTOR

TASK DESCRIPTION

The conveyance system will consist of an automatically guided vehicle (AGV) or gantry crane-mounted device to transport retrieved buried waste. This will be integrated with an innovative end-effector for digging and dumping. See Figure 2.5.

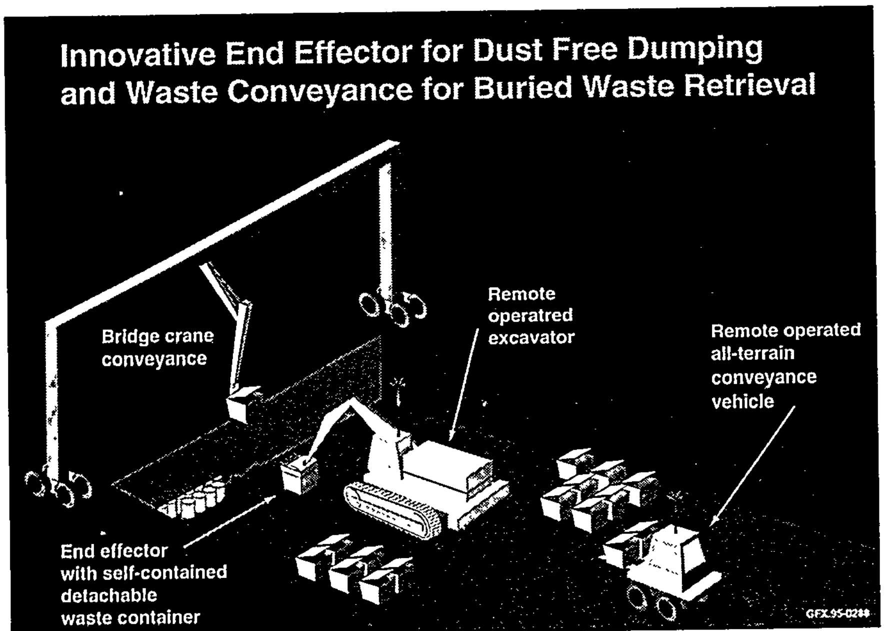

Figure 2.5. Conceptual Design of an Innovative End-Effector for Dust-Free Dumping and Waste Conveyance.

The AGV or gantry crane will be developed and tested to remotely convey a variety of wastes from retrieval areas to processing or packaging areas. This driver must be able to transverse a variety of terrains, operate in a hazardous environment, and be easily maintainable and easy to decontaminate.

The end-effectors consist of detachable buckets, specialized excavator buckets, integral dumping apparatus, or any other mechanism that might facilitate dust-free transfer and dumping of waste. A formal evaluation of forklift/dumpster concepts, gantry crane, and AGV designs will lead to procurement or fabrication of apparatus and conveyance mechanisms to be tested.

The primary objective is to develop a remotely controlled conveyance system and an innovative end-effector to allow for digging and transfer of retrieved waste from the digface to the processing or packaging area with virtually no dust generation.

TECHNOLOGY NEEDS

The end-effector and AGV development are designed to reduce contamination during waste remediation digging, conveyance, and dumping. These operations have the maximum potential for dust spread. Previous problems with dust emissions during funnel dumping operations and in transporting dumpsters over rough terrain will be addressed.

ACCOMPLISHMENTS

Test alternatives for digging and dumping retrieved buried transuranic waste were determined. Dumping improvements such as sealing the dumpster to the bucket prior to dumping were tested to eliminate the soil/waste matrix from falling through a distance and displacing a volume of air. An alternative digging end-effector or a detachable excavator bucket to avoid dumping in the retrieval area was tested. The end-effector, gantry crane, and AGV testing will be combined into a unified demonstration at the Cold Test Pit. Testing will involve putting the bucket/dumpster and AGV through a set of digging and dumping operations for containers spiked with rare earth tracers.

Benefits

Advanced conveyance systems testing will:

- Minimize contamination spread during waste remediation;
- Minimize personnel exposure and health risks;
- Maximize waste retrieval and transfer rates;
- Verify sampling and monitoring;
- Assist CERCLA and Pit 9 retrieval option assessment; and
- Examine low dust dumping techniques in a cold environment on an engineering scale.

Collaboration/Technology Transfer

Industry participation will be sought for the end-effector and waste-conveyance systems. The systems developed by INEL scientists and engineers can be transferred to the private sector.

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2.6 Contaminated Material Excavation Handling and Retrieval System

Task Description

The Contaminated Material Excavation Handling and Retrieval System (CMEHRS) is a large movable building that can be placed over a portion of a buried waste site to retrieve and handle buried objects. See Figure 2.6. The unit may include manipulators such as: (1) an industrial-grade, high-capacity blower and vacuum pickup system for contamination and dust control, (2) several large overhead cranes for removing buried objects of all sizes and shapes, (3) master slave manipulators, (4) robotic arms for specialized handling, (5) drum venting station for potentially pressurized sealed drums, (6) shielded work area for in-place glovebox analysis or separations, and (7) airlock for entry and exit to equipment and work area.

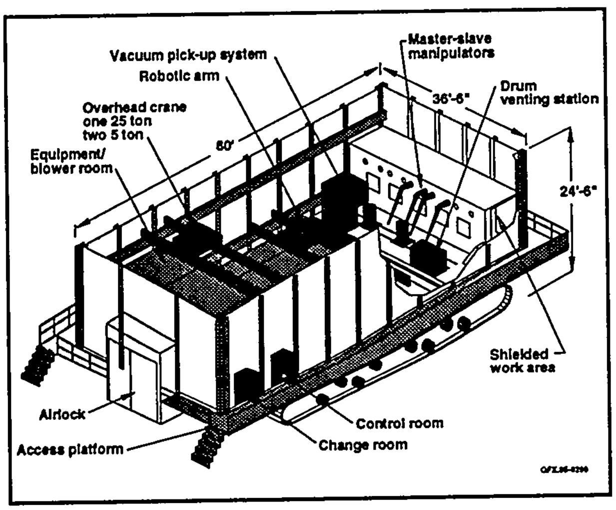

Figure 2.6. Conceptual Design of the Contaminated Material Excavation Handling and Retrieval System.

The primary objective is to design a movable, track-mounted, remote, full-scale, retrieval gantry system that can be placed over a waste trench to retrieve waste packages with containment provided by a localized seal.

Technology Needs

The system will have immediate application for buried radioactive waste retrieval of the Hanford cribs, trenches, hot spots, and repackaging for contact-handled transuranic waste. Buried hazardous and radioactive waste at any site can be remediated with this system. Remediation and retrieval of localized hot spots are especially suited for this equipment.

Accomplishments

Completed preparation of conceptual design of containment facility and packaging and handling equipment.

Benefits

This system will:

- Incorporate other technologies developed by LSFA.
- Integrate equipment and technologies developed by other DOE laboratories and the private sector.
- Be transferable to the private sector when complete.
- Provide a viable hot spot retrieval device.

Collaboration/Technology Transfer

The retrieval technology is directly applicable to most of the buried waste at DOE sites. The equipment is ideal for private-sector cleanup of hazardous waste, especially acute hazards at Superfund sites.

The unit could be placed into service at completion of the field demonstration as a large-scale operation unit on other DOE sites or in the private sector. The design will be documented in open literature and PNL documents. Private-sector participation for developing a prototype system exists.

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BIBLIOGRAPHY OF KEY PUBLICATIONS

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2.7 MACHINE HEALTH MONITORING

TASK DESCRIPTION

This monitoring system will provide equipment status information for remote operators. Information gathered by the use of sensors and computer algorithm technology will be the basis for estimating time to failure and overall health of the machine. The system will use data to limit operator actions that may cause damage and provide emergency override mechanisms.

Selected parameters of hydraulic, electrical, thermal, mechanical, and other functions of field retrieval equipment will be monitored with appropriately designed sensors. The remote sensor capability demonstrated in the remote area vehicle and excavator will be extended to failure mode data. Available sensors will be linked to developed algorithms contained in software modules. The algorithms will analyze real-time trend data to predict failures on specified LSFA equipment.

The primary objective is to develop a health monitoring prediction system for hydraulic, mechanical, and electrical functions of field demonstration equipment.

TECHNOLOGY NEEDS

System monitoring will assist the remediation of any type of waste. The sensors will protect personnel while expediting retrieval. This reduces exposure and lowers operating costs. Monitoring will mitigate equipment failure and reduce contaminant releases associated with equipment repair.

ACCOMPLISHMENTS

During FY94, three hydraulic test benches were fabricated to monitor real-time operating parameters, including flow rates, inlet and outlet pressures, temperatures, and vibrations. Operational and failure data were collected for four different failure modes on a fixed displacement gear pump. Based on the data collected, development of a failure algorithm was initiated.

BENEFITS

Monitoring the performance of retrieval equipment has several advantages:

- Decrease of equipment downtime and improved retrieval rates.
- Decrease of exposure to personnel for invasive equipment repair.
- Decrease of exposure, costs, and damage from incorrect operating equipment, such as overloading, overheating, and overstressing components.
- Optimization of remote operations where onsite observation of the equipment and potential failure is not possible.

At this time, a significant amount of work has been completed in the area of machine monitoring. That work is directed mainly towards stationary plant equipment. The Machine Health Monitoring (MHM) system, on the other hand, will monitor remotely operated equipment in real-time and will provide diagnostic information about that equipment. This technology is beneficial to many different types of equipment, particularly for hazardous waste retrieval and cleanup. One of the primary benefits of MHM is reduced exposure to personnel.

Since this technology is still in a research phase, cost benefits cannot yet be determined. However, this technology will reduce unscheduled downtime and worker exposure to hazardous environments. Case studies indicate that predictive monitoring programs can achieve cost savings from 35 percent to 80 percent over preventive type maintenance programs.

Collaboration/Technology Transfer

There are numerous public and private applications across the DOE Complex for remote operations, including remote retrieval, decontamination and decommissioning, and nuclear fuel cycle systems. Outside DOE there are applications to Superfund retrieval, DoD ordnance remediation, mining, and special hazardous production activities. Private-sector involvement is being sought for CRADA participants.

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TREATMENT

Section 3.0

3.1 CRYOGENIC CUTTING

TASK DESCRIPTION

The system will use high-pressure liquid nitrogen and solid carbon dioxide to perform cutting and abrading without introducing a secondary waste stream from the cutting media. An adaptation of the highly effective waterjet techniques is used to cut surface abrading, eliminating secondary waste-streams. The cryogenic cutting technology will enhance existing fluid systems to deliver high-pressure liquid nitrogen and solid carbon dioxide to a sophisticated nozzle. The system will be evaluated by cutting select materials. See Figure 3.1.

Figure 3.1. Cryogenic Cutting System.

The primary objective is to perform sizing of large objects during retrieval operations, using cryogenic cutting technology.

TECHNOLOGY NEEDS

Large objects unearthed during buried waste retrieval operations will need to be made smaller prior to treatment. Current methods for size reduction include shearing, plasma arc cutting, waterjet cutting, and other similar techniques. Shearing can be used for materials that are not too large or too strong for the shears. Plasma arc cutting adds risk to operations due to the flame inherent in the operations and the high temperature. Waterjet cutting adds an undesirable secondary waste stream to the process. Cryogenic cutting is a widely applicable technique and produces no secondary waste stream.

ACCOMPLISHMENTS

During FY94, the existing Cryogenic Cutting System underwent extensive upgrades to improve cutting effectiveness. The nozzle was attached to a gantry crane to allow it be operated in an 18" x 18" x 18" space, which gave sufficient movement to establish cutting rates with various materials. A plywood box was opened in 15 minutes at a scan rate of 0.5 in/s. A steel drum was opened by directing the jet around the periphery of the drum. For one revolution the travel speed was 0.012 in/s, giving a 0.007 in depth of cut. At this rate, eight passes were required to perforate the drum wall, which would take approximately seven hours.

BENEFITS

This technology will be used to (a) reduce multiple material types in size and (b) eliminate the secondary waste stream inherent in waterjet cutting. This project is still in a research phase and the cost benefits are not quantified. Cost savings will be dependent on the specific application; however, savings will be driven primarily by reducing secondary waste stream handling and disposal costs.

COLLABORATION/TECHNOLOGY TRANSFER

Several companies have expressed interest in collaborating in the development of this technology. Interested parties include cutting service companies, high pressure pump companies, control system companies, and cryogenic companies. Cryogenic cutting may have wide applicability to site decommissioning where secondary waste streams are of concern.

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BIBLIOGRAPHY OF KEY PUBLICATIONS

None at this time.

3.2 GRAPHITE DC ARC AND IN SITU REAL-TIME MEASUREMENTS

TASK DESCRIPTION

The primary objective is to demonstrate and evaluate a graphite-electrode, direct-current (DC) arc furnace for processing radioactive waste (both low-level and transuranic), mixed waste, and soil. Innovative diagnostic tools for monitoring the treatment process will be used.

The Mark II furnace is a refractory-lined, carbon steel vessel measuring 23-ft high and 7-ft in diameter, with four soft patch panels around the circumference to provide access for waste feed, glass discharge, and diagnostic equipment. The furnace is designed for semi-remote operation, alpha containment, and ability to process at 1-MVA power giving up to a 1.5 ton/hr processing rate. See Figure 3.2.

The electrode assembly has a unique coaxial arrangement. The outer graphite electrode is 14-inch outer diameter and 10-inch inner diameter. The inner electrode is a solid 6-inch piece of graphite. The electrode assembly can be operated in the transferred arc mode or the non-transferred arc mode.

The real-time measurement systems include analytical equipment for measuring furnace and glass temperatures and exhaust emission in the furnace chamber and off-gas line. There is less interference on the millimeter wave radiometer from the furnace environment for measuring furnace and glass temperatures than on the infrared pyrometers. Specially deconfigured plasma sources will be tested for in situ measurement and analysis of gaseous and particulate emission in real time. Molecular emission analysis and particle size and velocity determination monitor composition of solid material at various stages of processing.

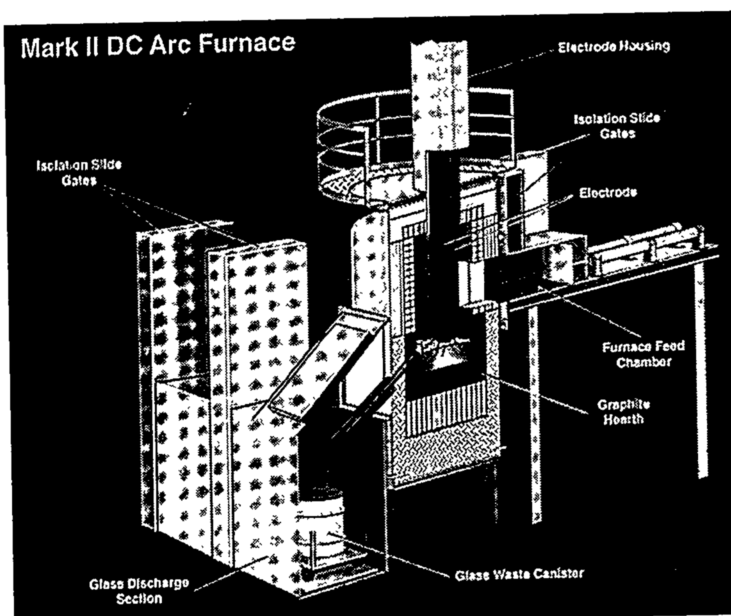

Figure 3.2. Schematic Drawing of the Mark II DC Arc Furnace.

TECHNOLOGY NEEDS

The plasma arc technology can treat any type of buried waste—hazardous, low level, and TRU, along with any contaminated soils and containers. The technology destroys organics and stabilizes metals (both radioactive and hazardous) in a suitable final waste form. Ash, secondary waste, and soil can be treated.

ACCOMPLISHMENTS

An engineering-scale furnace, the Mark I, has been built and demonstrated. Design improvements are ongoing, including development of improved diagnostics. Surrogate waste has been treated with this furnace. A large pilot-scale unit, the Mark II, has been built incorporating off-gas treatment, higher power, and throughput. Improved diagnostics include analytical instruments for spatially resolved measurements of furnace and glass temperatures. Gas concentration measurements in the furnace and off-gas exhaust line are also included. A self-calibrating millimeter wave radiometer, plasma sources, and analytical instruments have been developed for use in Mark II testing.

BENEFITS

The Mark II can handle objects as large as a 35-gallon drum, test limited quantities of hazardous materials, and can be used for a full-scale production furnace. The plasma arc can treat any type of buried waste—hazardous, low level, and TRU—along with any contaminated soils and containers. The final waste form (slag, solidified residue) is extremely durable and is similar to long-life natural analogues.

Competing technologies include other arc-melter designs and joule-heated melters. Other arc melters, or plasma furnaces, are designed with single metal electrodes. The arc melter at the U.S. Bureau of Mines uses three graphite electrodes. The single graphite electrode design may require less maintenance than multiple electrode designs. The use of graphite increases metal electrode lifetime. In general, arc melters have higher throughput capabilities than joule-heated melters. Arc melters are well suited for contaminated soils and containers, as they require high melting points.

The DC Arc technology can process solid waste at 1 kilowatt hour per pound of material processed. This value is better than any reported value for the plasma torch systems and is equal to that for joule-heated melters and the ISV process. The difference between the joule-heated melters and the ISV is the relative rates at which material can be processed. The DC Arc is capable of processing material at a much faster rate due to the high temperature arc zone. The submerged arc operating regime can efficiently transfer energy into the melt.

COLLABORATION/TECHNOLOGY TRANSFER

Other commercial entities have expressed interest in both the melter and diagnostic technology. Technology transfer is occurring with the Massachusetts Institute of Technology (MIT) and Electro-Pyrolysis is a partner on the project. Technical progress reports and design data will be transferred to other projects.

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3.3 ARC MELTER VITRIFICATION

TASK DESCRIPTION

A plasma arc furnace pyrolyzes, combusts organic materials, and melts residual inorganic materials with an electric arc. The American Society of Mechanical Engineers/United States Bureau of Mines (ASME/USBOM) plasma furnace—a 1.5 MVA, 1.5 ton/hr (nominal) electric arc furnace—features three carbon electrodes, continuous feed system, off-gas treatment system, and slag and metals tapping capability. See Figure 3.3a. The side wall is cooled from a slag layer on the lining of the refractory. This further protects the refractory from degradation. The resulting molten slag, upon cooling, produces a durable vitrified cast form that may be safely disposed of.

The primary objective is to demonstrate, in a currently operational commercial-scale plasma arc melter, the applicability and feasibility of existing plasma arc melter technology for high temperature treatment of TRU and mixed hazardous wastes and buried or stored soils.

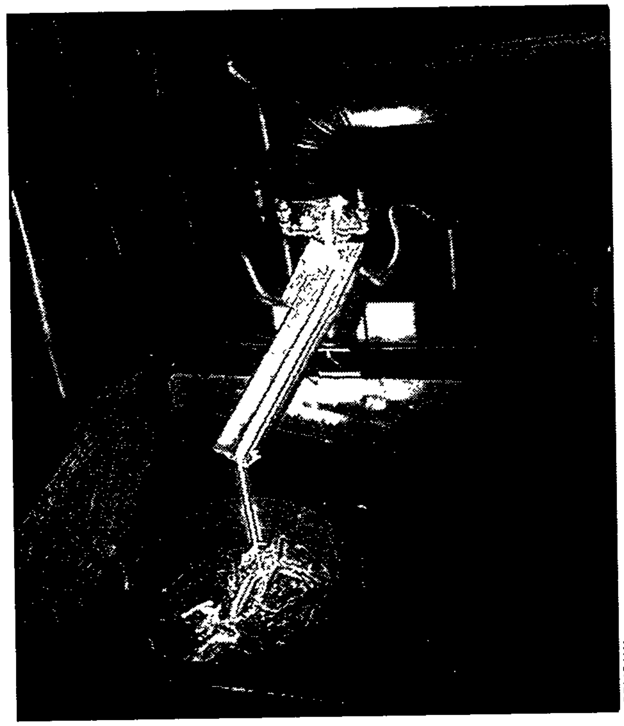

Figure 3.3a. Continuous Tapping of Slag.

TECHNOLOGY NEEDS

The arc melter could be used to treat a variety of waste containers and matrices containing both hazardous and radioactive substances. See Figure 3.3b. It is especially useful whenever high-efficiency destruction of organics is required. It permanently encapsulates heavy metals and radionuclides in a non-leachable final product.

ACCOMPLISHMENTS

The existing off-gas system components can be modified for TRU surrogates and heavy metals containment. Approximately 20 to 30 metric tons of simulated waste will be processed in each melt campaign, or about 4 to 6 metric tons per day. Surrogate wastes, including soils, metals combustibles, and sludges will be prepared and separately incinerated, as appropriate, in preparation for melter processing.

BENEFITS

The advantages over conventional thermal-processing methods include high temperatures, high enthalpies, choice of inert or chemically active torch gases, and operation with low gas volumes. Additional attributes of this research include:

- Optimal configuration of plasma arc,
- Operating characteristics,
- Time needed for mixing,
- Migration of plutonium and cesium,
- Electrical field patterns of plasma arc,
- Energy balances throughout system,

- Distribution of waste,
- AC versus DC melter comparison,
- Non-equilibrium chemistry,
- Extent of immobilization of radioactive and hazardous waste, and
- Recovery of valuable metals.

Cost savings have not been quantified. The key advantage of arc melter technologies is their ability to process a wide variety of heterogeneous waste into a durable glass ceramic waste form that is more leach resistant at less volume than other waste forms, such as compacted or cemented incinerator ash. Savings will be realized during ultimate disposition of the waste form (reduced volume, less stringent requirements).

Collaboration/Technology Transfer

University, industry, and other laboratory participants are being solicited. Since many private-sector companies are members of the present ASME test consortium, CRADAs with industrial partners are being sought to speed completion of the demonstration project and accelerate technology transfer to the private sector. Test wastes were used in the first melt campaign. Test data were reduced and reported. FY95 test plans are being prepared to disseminate information.

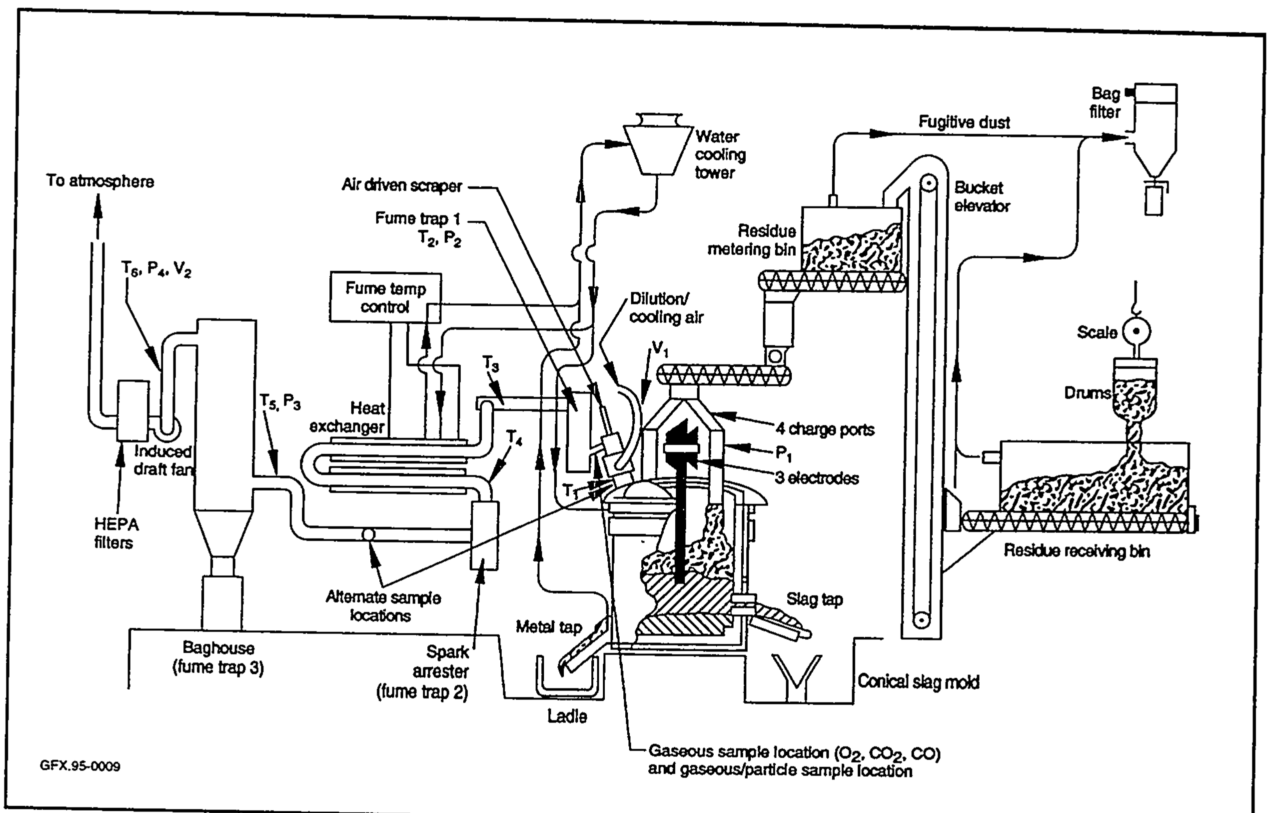

Figure 3.3b. U.S. Bureau of Mines Three-Phase Arc Melter Furnace at the Albany Research Center, Oregon.

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3.4 MODELING OF THERMAL PLASMA ARC TECHNOLOGY

TASK DESCRIPTION

The computer model of the plasma arc treatment will simulate a variety of plasma arc waste treatment facilities. See Figure 3.4. It will determine the migration of particulate and gaseous contaminants to the off-gas by composition and into the equipment. The contaminants encapsulated within the final waste slag and the effects of molten metal pooling on the chemistry and heat transfer of the arc plasma will also be modeled. Further data for modeling the chemical aspects of the plasma arc process not in the current databases and model limitations will be provided.

The primary objective is to develop a computer model of the plasma arc treatment process, that gives information on the most likely composition of final waste slag and off-gas, location of heavy metals, and size and distribution of slag and metal pool.

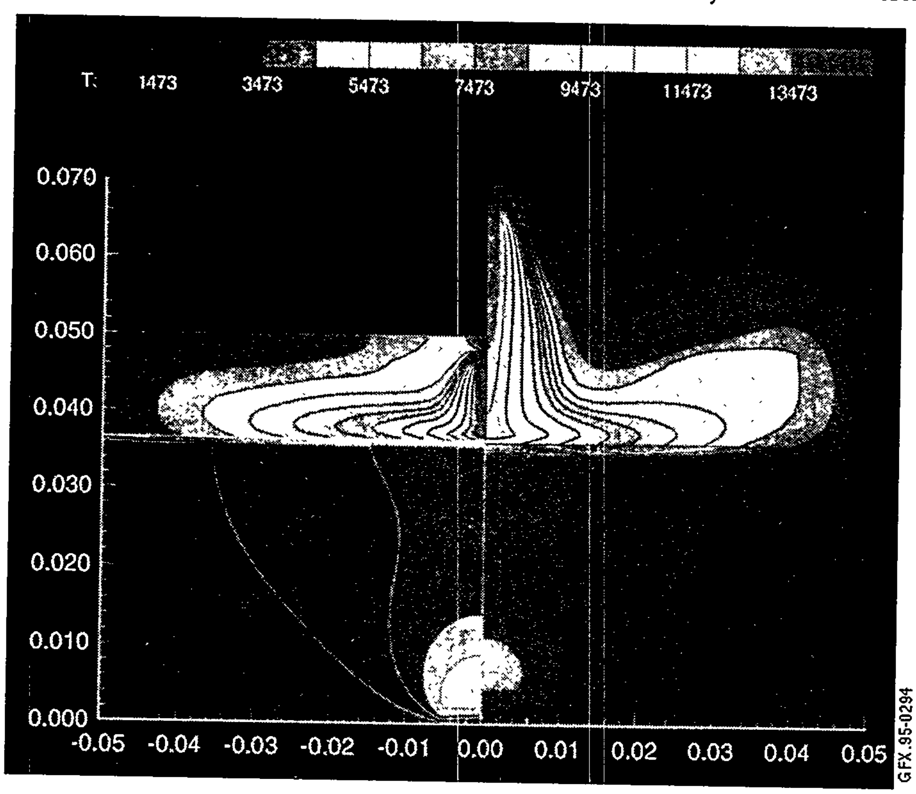

Figure 3.4. Modeling of Thermal Plasma Arc.

TECHNOLOGY NEEDS

Plasma arc modeling will have short-term and long-term advantages in analyzing and improving thermal waste treatment technologies. Knowledge of effects of convection within the molten slag and melts and the thicknesses of the different layers can help maximize waste loadings and minimize metal off-gassing. Lower processing costs can be achieved in understanding the effects of the power input to the plasma arc on the temperature field and heat transfer within the facility.

Expedited experimental tests can be achieved, lowering costs and achieving technology use sooner.

ACCOMPLISHMENTS

During FY94, a model of a two-dimensional axisymmetric transferred plasma arc was developed and validated. This model includes the growth of a slag pool. The thermo-fluid model is used to predict the temperature and pressure field within a plasma arc furnace. A robust and accurate model for the chemical equilibrium calculations has been implemented to determine chemical composition of the final waste form and off-gas based on the temperatures and pressures within the plasma arc furnace.

Benefits

The model can be used to:

- Develop, optimize, and understand plasma arc technology.
- Reduce the operation costs of current arc melters.
- Determine the migration of the contaminants during the process and the location of the contaminants after the process.
- Develop designs that are more efficient (i.e., capture more waste within the vitrified product).
- Determine areas in which experiments may benefit the advancement of the technology.
- Understand the cause and effects of the physical processes occurring within the plasma arc facilities.

Collaboration/Technology Transfer

The model can be transferred for use at other public and private facilities, including specific application at PNL, MIT, and the USBOM. The experimental work from these labs and furnace manufacturing organizations can aid in validating the code. The intermediate and final codes will be transferred to plasma arc developers and end users.

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None at this time.

3.5 SECONDARY TREATMENT OF OFF-GAS USING NON-THERMAL PLASMA

TASK DESCRIPTION

Non-thermal electrical discharge plasma can promote favorable chemistry to destroy hazardous chemicals. See Figure 3.5. Electrical energy directed into the process chemistry creates highly reactive free radicals that oxidize/reduce pollutants, fragment pollutants directly, or promote excited-state chemistry.

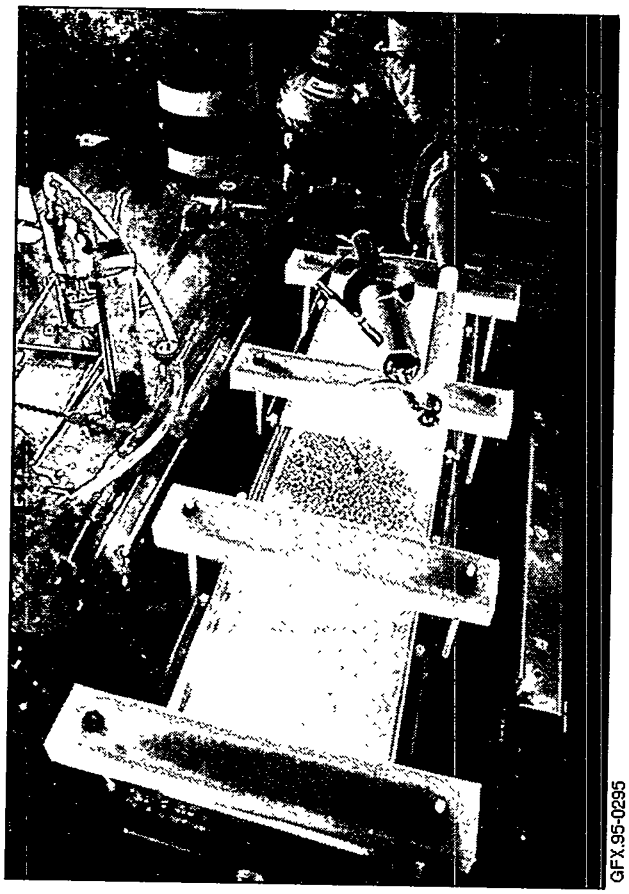

Figure 3.5. Secondary Treatment of Off-gas Using Non-thermal Plasma.

Silent discharge plasmas consist of two parallel metal electrodes with a dielectric barrier between and adjacent to one electrode. High voltage is applied between the electrodes, creating a microdischarge on gases flowing between them. The electrical energy is channeled into free radical production. This creates an active environment for destruction of gaseous hazardous organics.

The primary objective is to evaluate the non-thermal plasma (NTP) process for removal of VOCs SOx/NOx, hazardous compounds, and high vapor pressure metals (HVPMs) in melter off-gases.

TECHNOLOGY NEEDS

This technology is an alternative non-incineration treatment for volatile organic destruction and metal oxidation to remediate contaminated soil and direct mixed waste treatment. It also treats secondary waste gases from commonly used treatment processes for mixed waste such as vitrification, incineration, and thermal stripping.

ACCOMPLISHMENTS

During FY94, considerable effort was made to define a surrogate off-gas mixture to represent generally-expected LSFA arc melter outputs. This work involved examining large data sets from arc melter tests and off-gas simulation calculations. Interfacing with LSFA and USBOM personnel, projections of off-gas outputs based upon a wide variety of expected feed material were developed. A surrogate mixture composed of SO_2, NO, a chlorocarbon, and a chlorofluorocarbon was specified, and bottles of gas were ordered from a specialty vendor. Conceptual designs were formulated for laboratory-scale evaluation tests at LANL and demonstration testing on a bench-scale arc melter. Laboratory-scale apparatus for low-temperature (<300 C°) testing was designed, assembled, and evaluated.

BENEFITS

NTPs have two major applications for hazardous waste treatment:

- Primary Stage–Treating gaseous-based wastes such as VOCs in stack gas and as stand-alone plasma devices.
- Secondary Stage–Treating the offgas stream of incompletely destroyed waste from primary stage units and incinerators or furnaces.

Competing technologies for VOC treatment include thermal catalytic incineration and activated carbon treatments. Selective catalytic reduction (SCR) techniques compete in the treatment of sulfur and nitrogen oxides. Non-thermal plasma technology has the advantage of potentially being able to treat each of these waste gases as well as HVPMs simultaneously. This technology does not compete well on cost, at first, because electrical processes are generally more expensive than thermal processes. Nonetheless, it may compete well on a more global scale, because of its ability to treat several waste gases simultaneously, and because the process produces less greenhouse gas than thermal treatments.

This is an emerging technology, so little data is available for this category. One baseline comparison is for VOC abatement, where it is projected that NTP is 2 to 4 times cheaper per kg than activated carbon.

COLLABORATION/TECHNOLOGY TRANSFER

DOE sites such as SRS, Hanford, and Mound and participants in the industrial sector such as the chemical, electrical production, and paper and wood products industry support technology transfer. The Electric Power Research Institute intends to cooperate with DOE on an air-toxics effort through a CRADA and technology commercialization with the private sector.

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3.6 MINIMUM ADDITIVE WASTE STABILIZATION PROGRAM

TASK DESCRIPTION

Minimum Additive Waste Stabilization (MAWS) provides an environmentally sound cleanup alternative for large amounts of hazardous, low-level radioactive and mixed wastes that exist across the DOE Complex. A wide variety of waste streams often contain the basic chemical components from which a glass waste form can be made. The MAWS approach combines these resources to minimize the use of non-waste additives, and produces an environmentally safe and acceptable final waste form. The final waste volume is minimized because little or no additives are used. Vitrification results in volume reduction through 1) evaporation of water, 2) destruction of organics, and 3) consolidation of the RCRA metals and radioactive material into a non-porous amorphous glass. Disposal costs are reduced and future environmental risks/costs are minimized, since the glass is both durable and leach resistant.

Integrated systems are used to apply the MAWS concept and to maximize benefits. Vitrification incorporates both primary and secondary waste streams into glassy waste forms. Supporting technologies may include thermal treatment, soil washing, biodegradation, gas scrubbing/filtration, and ion exchange waste water treatment. Efforts are made to recycle any secondary waste streams from these supporting technologies back into the vitrification system. The particular suite of technologies chosen will depend on the waste streams available for treatment.

The MAWS Program is proceeding in five major areas. These include: 1) materials science, 2) waste form durability/characterization, 3) technology process development and systems integration, 4) system demonstration at DOE sites, and 5) life-cycle cost savings/benefits.

Compositional envelope development is the main focus for the materials science efforts. This involves investigating a variety of glass and vitreous ceramic compositions to determine processing properties and phase separation tendencies. Initial studies have focused on surrogates. Present efforts are directed to studies with actual waste streams from the various sites so that interesting combinations of wastes can be screened as potential candidates for MAWS implementation. Through development of the compositional envelope, future candidate waste streams can be more quickly screened based on the known limits.

Closely tied to compositional envelope development is characterization of waste form durability. Glass compositions may vary widely and result in a broad range of durabilities defined by the tendency to dissolve or leach under various conditions. This effort is providing a database of durability information as measured by Toxicity Characteristic Leach Procedure and Product Consistency Test (PCT) results, which can be used to optimize the waste forms. An effort is also planned to investigate appropriate tests and models to calculate long-term performance given a set of assumptions. This effort will develop new or verify existing test methods and models that prove to be the best approach for making such projections.

Since vitrification is at the heart of the MAWS approach to treatment of wastes, a major effort is to develop higher temperature melting systems. See Figure 3.6. Such systems will provide the flexibility to address a broader range of waste streams and generally produce more stable and durable waste forms. Systems under study include unique variations of plasma, microwave, and joule-heated melters that can potentially minimize off-gas generation so as to better trap the contaminants in the vitrified waste form. These technologies are being developed at the bench scale and will progress through various stages of scale-up and cold to hot testing as warranted.

An initial demonstration of joule-heated vitrification in combination with soil washing and ion exchange water treatment has concluded at Fernald,

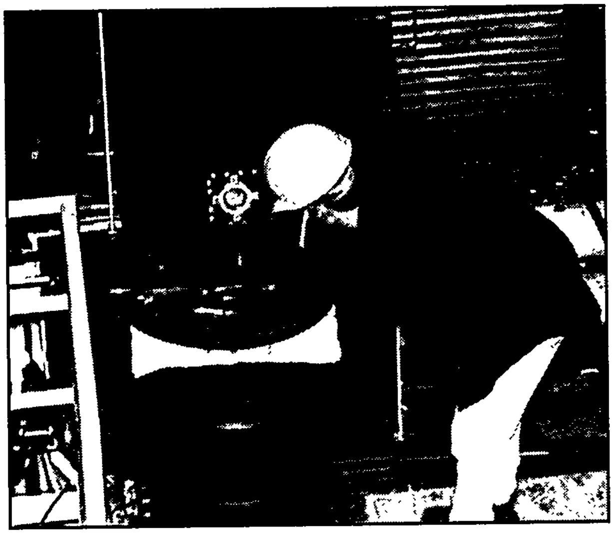

Figure 3.6. 1,000kg/day Joule Heated Ceramic Melter.

OH. That demonstration successfully washed 57 cubic yards of contaminated soils to less than 35 pCi/g and produced several thousand kilograms of glass from site high fluoride sludges and soils contaminated with uranium, thorium, and technetium. Negotiations and plans are proceeding for a second demonstration of the MAWS concepts at INEL.

Life cycle cost analyses provide the required information to determine the best use of limited funds. For the MAWS program, these models are being developed to estimate full implementation costs in comparison to cementation or other appropriate baseline technologies. An initial model has been developed based on the information available from the Fernald demonstration. This model will be modified, as appropriate, to project cost savings for waste streams from other sites. Uncertainties are being quantified and the sensitivities of the various parameters determined through mathematical Monte Carlo analysis.

Technology Needs

The MAWS program is aimed specifically at treating low-level and mixed wastes with vitrification. In order to achieve workable formulations for acceptable waste forms requiring minimum additives, innovative ways of combining wastes need to be investigated along with appropriate integrating technologies. The strategy is to use, where possible, actual waste streams during evaluations and commercially mature technologies to be able to quickly tailor systems of interest to the DOE Offices of Waste Management and Environmental Restoration in meeting their compliance agreements.

Glass compositional effects must be understood to screen waste streams for necessary components and to combine them in optimal proportions to achieve a processable and durable waste form for disposal. Contaminated soils may provide one of the building blocks for making a vitrified waste form. Finding a composition that is both processable and durable, and combining wastes in an integrated system can be quite challenging. A systems approach is needed to minimize additives and secondary waste generation. Individual supporting technologies are optimized to provide a better feed to the vitrifier. The ultimate goal is to produce a glass or vitreous ceramic that can be released to the environment. Flexibility is needed in the systems chosen so as not to limit applicability and to deal with the largely heterogeneous nature of many mixed wastes.

Of particular concern in many vitrification systems is the off-gas system and potential release of contaminants to the air. Although vitrification is different from incineration, some organics may be part of the waste streams to be treated. Also, the high temperatures can cause some problem contaminants to volatilize. Real-time monitoring equipment is needed to ensure that no releases occur. Also, consideration will be given to closed loop type systems and strategies to minimize volatilization or entrainment of contaminants in the off-gas. Effective ways to deal with mercury are needed.

Emphasis will be given to technologies and integrated systems directed toward specific DOE waste problems with abilities to test actual waste streams and for which no other baseline treatment has been defined.

Accomplishments

- Acceptable glass and vitreous ceramic waste forms have been developed spanning a spectrum of compositions for candidate wastes.

Good glass formulations have been developed from several Hanford, ORNL, and INEL waste streams.

- Volume reductions of 25 percent and more have been achieved with many DOE wastes such as soils, sludges, and sediments during the vitrification step.

- Metal loadings of up to 70 percent with soils have been oxidized into a stable basalt like ceramic using plasma melting technology. The process and waste form quality has scaled well from bench through pilot tests.

- Stable vitrified glass and vitreous ceramic waste forms have been developed that are able to meet EPA toxic characteristics leaching procedure (TCLP) criteria and surpass product consistency testing (PCT) standards developed for high-level waste glasses.

- Waste loadings up to 94 percent have been achieved with actual Fernald sludges and soils. In other laboratory tests, waste loadings of 100 percent have been demonstrated through careful choice of wastes.

- An integrated treatment system which contains a 300 kg/day melter, 0.25 cubic yard/hour soil washing unit, and a 100 GPM ion exchange unit has been demonstrated at Fernald.

- Laboratory-scale soil washing tests have reduced uranium concentrations to less than 35 pCi/g and achieved a volume reduction of greater than 80 percent with Fernald clay-type soils. The pilot-scale unit has successfully processed 57 cubic yards of contaminated site soils with a volume reduction of 70 percent for use in the pilot-scale vitrifier.

- Tests with actual Fernald site radioactive sludges and soils have successfully been completed in both the 10 kg/day and 100 kg/day melters at the Catholic University of America (CUA), providing high quality waste forms and needed operational data for the 300 kg/day melter at Fernald. To date, the Fernald melter has produced several thousand kilograms of glass with actual radioactive sludges and soil concentrates.

- The Fernald off-gas system on the 300 kg/day melter has effectively captured the high levels of hydrogen fluoride volatilized from the melt and recycled it as sodium fluoride sludge back into the melter. Emissions were within prescribed limits.

- A preliminary life-cycle cost analysis for vitrification of the OU-1 sludges and soils using the MAWS system concept indicates a minimum savings of $100 million, as compared to cementation.

BENEFITS

The MAWS technology approach provides a lower cost vitrification alternative for the vast quantities of low-level and mixed wastes that exist across the DOE Complex. This is possible because of the minimum use of additives and the high waste loadings achieved (often greater than 90 percent). Cost savings result from reduced processing costs and disposal costs, since with vitrification the waste tends to be concentrated rather than diluted. Volume reductions of 25 percent to 75 percent are common, whereas, generally volume increases during other treatment options like grout or encapsulation. Therefore in treating a combination of waste streams, a larger fraction of the time is spent actually processing waste, and disposing of only waste rather than a lot of additives. The additives required for ease of vitrification are provided through optimum combination of the available wastes on site, and therefore additive purchase costs are minimized.

In most cases, this allows vitrification to be cost competitive with other waste treatment technologies such as cementation while providing a nonporous superior waste form in terms of durability and leach resistance (lowest leach index of all waste forms). This is the reason that glass has been chosen as the waste form of choice for disposal of high-level wastes.

Vitrification is a preferred treatment approach for many inorganic waste streams such as soils, sludges, asbestos, ashes, ion exchange resins, D&D debris, etc. The wastes actually become a part of the glass matrix rather than merely encapsulating the waste in cement/grout, polymer, or asphalt. Through use of a systems approach, MAWS is able to recycle most secondary waste streams back into the melter to ultimately become glass. Implementation of a MAWS approach on a site-wide basis to treat multiple waste streams may avoid the need to build multiple smaller treatment facilities based on other technologies, thereby providing economies of scale.

COLLABORATION/TECHNOLOGY TRANSFER

There are a number of industry/university partners that have been instrumental in developing technologies for use in the MAWS treatment approach. The initial demonstration of the MAWS concepts at Fernald were made possible through a collaborative effort between GTS Duratek Corporation and CUA to develop the vitrification and waste water treatment technologies, and Lockheed Environmental Services Corporation to develop the soil washing technology. ANL provided project management and long-term glass performance testing.

GTS Duratek teamed with the Vitreous State Laboratory (VSL) at CUA to develop a compositional envelope of glasses from Fernald wastes that are both durable and processable in the joule-heated melter developed by GTS Duratek. Together, they proceeded to develop and scale up a process from the bench (10 and 100 kg/day units) to pilot-scale units (300 kg/day) demonstrated at Fernald. GTS Duratek and CUA hold several patents on this unique melter design.

The experience gained by GTS Duratek in designing, installing, and operating the joule-heated melter during the Fernald demonstration has helped the company in bidding for other contracts to treat DOE wastes such as 700,000 gallons of M-area sludges at SRS, and to demonstrate applicability for Hanford low-level wastes. In addition, GTS Duratek/Chem-Nuclear have formed a joint venture and signed an agreement to build a commercial low-level waste vitrification plant at Barnwell, SC, leveraging off their experience gained from the Fernald demonstration melter.

For further development of suitable compositional envelopes for glass and vitreous ceramic waste forms, there is a three-pronged effort underway. CUA is continuing to develop the glass waste forms area utilizing a variety of actual waste streams from several DOE sites including Hanford, ORNL, and INEL. Both ANL and PNL are conducting similar studies on wastes and surrogates more appropriate to a vitreous ceramic (natural basalt like) waste form. These studies are providing phase compositional, processing, and long-term performance data that will ultimately be part of an overall database and modeling effort initiated by CUA. This model and database should facilitate the initial screening of wastes appropriate for treatment into a vitrified waste form, and suggest likely formulations to be bench-tested utilizing a MAWS approach. This should allow more rapid transfer of this technology approach to the other sites across the DOE Complex and ultimately to private industry problems.

To enhance the capability to vitrify a greater variety of wastes requiring higher melting temperatures and thereby minimize the use of additives, there were several efforts underway. The first was a three-way effort where a series of tests on high metal content feeds utilized a high-temperature centrifugal plasma melter to produce glassy slag waste forms. This work initially involved a collaborative effort between Retech, Inc. and MSE, Inc. to test this concept out in both a bench scale and pilot sized unit at each facility. In addition, ANL was involved in the design of the feed formulation matrix and evaluation of the glassy slags produced.

The most recent scale up and duration tests on these high metals feeds in the pilot scale unit at MSE, Inc., were funded by the Army Corps of Engineers through DoD's Construction Engineering Research Laboratory (CERL). Mississippi State University's Diagnostic Instrumentation and Analysis Laboratory provided capabilities to monitor enhanced real-time off-gas. There is great interest in this plasma technology because it potentially minimizes the pretreatment and separation needs for many wastes, thereby resulting in a much simplified process flow scheme. In addition, the slag-like waste form has been shown to be comparable and often better than the glasses developed to contain high-level wastes in many respects.

Additional efforts are funded through CUA's VSL to develop other high-temperature technologies. Both the VSL and PNL are working on improved electrodes for high-temperature joule-heated melting. VSL is working on testing of new materials, while PNL is investigating unique coatings and electrode biasing techniques to increase the electrode life.

Another collaborative effort has just concluded between the Air Force Institute of Technology and FERMCO to provide a life-cycle cost model for MAWS vitrification processes. This funding involves an Interagency Agreement. This provides a very general model and allows waste data from other sites to be easily input for rapid assessment of MAWS vitrification potential compared to other treatment technologies.

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TTP Numbers: CH231007, CH231008, ID751004, RL351005, ID751010, OH151001, ID141003,.PE021105, RL351011, HQ051008

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3.7 Aqueous Biphasic Separation Systems for Treating Uranium-Contaminated Soils

Task Description

Aqueous biphasic separation (ABS) systems have been developed to treat solid and liquid waste and to recover uranium from contaminated soil. The extraction process involves the selective partitioning of solutes or fine particulates between two immiscible aqueous phases. The biphasic systems consist of immiscible polyethylene glycol (PEG) and salt solutions. Each phase contains at least 70 to 80 weight percentage water. Some inorganic salts that promote biphase formation with PEG solutions include the sodium/potassium salts of sulfate, carbonate, phosphate, and hydroxide.

The ABS system used in the soil treatment studies contains PEG-1500/Na_2CO_3. The carbonate/PEG biphase system provides rapid phase separation at solids concentrations of 30-35 weight percentage.

Laboratory work is currently devoted toward optimizing the countercurrent extraction system using a 1-inch diameter Karr column. Significant improvements in soil throughput and particle size handling capability have already been achieved. Methods are being examined to improve solid/liquid separation capabilities. A detailed flowsheet is being prepared to include cost estimating for full-scale implementation of the technology.

Technology Needs

The former Feed Materials Production Center, now the Fernald Environmental Management Project (FEMP), at Fernald, OH, produced uranium metal for defense needs until production was halted in 1989. The soil at the site became contaminated with uranium from a variety of sources, including deposition of airborne uranium particles and spills of solvents and process effluents. There are an estimated 2,000,000 yd^3 (1.6×10^6 m^3) of uranium-contaminated soil that needs to be treated. Soil cleanup levels have not yet been set.

The major constituents of the soil at the FEMP site are quartz, calcite, dolomite, and clay. Due to high levels (>80 weight percentage) of silt (<53 to 2µm) and clay (<2µm), this soil is not directly amenable to treatment by conventional soil washing techniques. A number of uranium (VI)-bearing phases have been identified in the soil. These include uranium silicates, uranium phosphates (e.g., autonites), and uranium oxides (UO_3). In addition, a number of uranium (IV)-bearing phases, such as uranium silicide, uranium oxide (UO_2), and uranium phosphite [$U(PO_3)_4$] have also been identified. While the uranyl species are easily leached with aqueous carbonate solutions, some of the uranium phases, like uranium phosphite, are extremely refractory and do not readily dissolve in carbonate solutions even in the presence of an oxidizing agent. The more refractory uranium phases are present as discrete particles with sizes in the micron and submicron range.

New physical separation technologies are needed to selectively recover micron-sized particulate contaminants from soils to help reduce the costs of environmental remediation efforts. The ABS technology directly addresses this need.

Accomplishments

A continuous, countercurrent process is being tested in a 1-inch diameter, pilot-scale Karr column.

- Demonstrated ability to handle soil slurries containing 30-35 wt. percent solids with particle sizes ranging from 150µm to below 1 micron.
- Demonstrated uranium removal efficiency of 89-95 percent.
- Demonstrated clean soil recoveries of 98-99 percent.

- Identified effective flocculating agents for enhanced solid-liquid separation of process streams.

BENEFITS

The main advantages in using aqueous biphasic separation technology to decontaminate soils is the ability to achieve high decontamination factors, together with high selectivity. The solid contaminants are concentrated in only 1-2 percent of the feed volume. Aqueous biphasic extraction is applicable to the treatment of soils containing a high clay content. The process works best with ultra-fine refractory contaminant species that are difficult to remove by chemical dissolution. The ABS process could be used as a stand-alone technique, or as a polishing step to remove the remaining uranium particles that are resistant to chemical leaching.

COLLABORATION/TECHNOLOGY TRANSFER

U.S. and foreign patent coverage of this technology has been applied for. The technology is available for license.

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3.8 BIOSORPTION FOR REMOVAL OF URANIUM FROM CONTAMINATED SOIL-WASHING MEDIA

TASK DESCRIPTION

Low-level contamination by radionuclides and heavy metals in soils is a serious problem at many sites in the United States and throughout the world. The current technology for removing the contamination is soil washing, which creates enormous volumes of spent washing media contaminated with the metals and/or radionuclides initially present within the treated soils as well as with the lixiviant or extractant material(s) used to effect the release of those contaminants from the soil. This spent media may be disposed of directly as hazardous, radioactive, or mixed aqueous waste. However, selective removal of the contaminants through a gentle secondary treatment would allow regeneration and reuse of the washing media, thus minimizing the final volume of waste for disposal and decreasing overall cost of the washing process.

A technology currently under development at ORNL exploits both the negatively charged and/or sorptive nature of the surface of certain naturally-occurring microorganisms and the ability of specific microbial species to scavenge and transform dissolved metals, including radionuclides. Sorption of the dissolved metals results in their removal from solution via physical means, coupled with their concentration onto microbial biomass. This phenomenon is independent of cellular metabolism, permitting the design of a process based on killed biomass.

Transformation of the dissolved metals via chemical oxidation or reduction may result in their stable conversion to an insoluble form. Precipitated metal may remain associated with microbial biomass. Both biosorption and biotransformation technologies are most effective in the treatment of dilute wastes, i.e., those containing contaminants at the part-per-million level. In this respect, the biological technologies are superior to chemical precipitation or sorption for treatment of dilute wastes. Final contaminant concentrations in the biologically-treated media are usually at the part-per-million levels, allowing reuse or release.

In the case of either biosorption or biotransformation, the contaminated biomass may be easily separated from the spent media via filtration or centrifugation. Alternatively, the biomass may be employed within a continuous-flow process in immobilized form. Because the biological treatment occurs at ambient temperature and pressure in the absence of harsh or corrosive reagents, it is inexpensive and yields no noxious secondary wastes. This approach may be considered both cost-effective and environmentally acceptable.

TECHNOLOGY NEEDS

Soil around the Fernald site has become contaminated with uranium as a consequence of defense-related activities conducted at the Feed Materials Production Center. A number of aqueous soil washing media, containing various lixiviant materials, have been considered for use in soil contamination there. A current lead candidate is carbonate, which forms very stable, water-soluble complexes with hexavalent uranium. Improved technologies for the regeneration of the spent soil-washing media are needed.

This effort focuses on the identification of microbial biomass capable of competing with carbonate for uranium binding sites. This biomass will form the basis of a new technology for remediation of spent soil washing media. In practice, the biomass would be immobilized within a matrix that can be formed into small-diameter beads so that it may be deployed in a manner similar to that of currently available commercial ion-exchange resins or activated charcoal. The technology will be used within a large-scale process designed to accommodate large volumes of spent soil washing media.

ACCOMPLISHMENTS

Microbial biomass capable of binding dissolved hexavalent uranium has been identified. Preliminary evidence indicates that sorbed hexavalent uranium is converted to and precipitated as uraninite. Inexpensive, simple pretreatments of the soil washing medium under consideration for use at Fernald have been designed to enhance sorption and/or transformation of extracted uranium. An inexpensive, stable, resilient immobilization matrix for the biomass has been developed. Methods for large-scale production of immobilized biomass have been devised.

The technology development effort is ready to proceed from the bench-scale, batch stage of testing to a flow-through columnar arrangement in which kinetics and other important process characteristics may be precisely defined.

BENEFITS

Likely benefits of this technology to users who select it as their method of remediating and/or regenerating spent soil washing medium contaminated with dilute concentrations of uranium are cost savings relative to conventional regeneration technologies vis-a-vis ultimate waste storage, transportation, and/or disposal.

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None at this time.

3.9 HEAP LEACHING OF URANIUM FROM SOIL

TASK DESCRIPTION

The objective of this task is to determine the performance and economics of leaching uranium from soil by simulated heap leaching. Heap leaching is simulated in the laboratory using leaching columns. Initially, 1kg samples of soil were leached in 4-inch diameter 1-foot tall columns. The small size was chosen to minimize waste in the event of test failure. However, work has progressed to larger 10-inch diameter 12-foot tall columns holding 70kg of soil. The extraction reagent of choice is sodium carbonate/bicarbonate. The bicarbonate extracts uranium and humics from the soil, leaving other materials behind. Testing is being conducted at room temperature and pressure, using homogeneous soil sample from the FEMP incinerator site. The soil does not contain large rocks, leaves, or sod.

During leaching tests, aqueous solutions of bicarbonate are pumped from a dewar to the top of the columns. The solution is dripped into the column at a very low rate, e.g., .012 ml/cm^2/min (.005 gpm/ft^2/min). The solution flows through the column, solubilizing and mobilizing the uranium. The leachate from the bottom of the column is collected and analyzed for volume, electrical potential, pH, uranium content, and other materials.

Figure 3.9. Small vs. Large-Scale Leach Columns.

Pilot-scale tests are envisioned to excavate contaminated soil and place (heap) it on an impermeable pad on the surface of the ground. The pad will be sloped toward a sump at the bottom edge of the heap. Selected leaching reagent(s) will be pumped to and distributed on top of the heap with a drip irrigation system or aerial sprayers. The reagent will travel down through the soil, solubilizing and mobilizing the contaminants. The leachate will then be collected from the sump and pumped to a leachate treatment and regeneration system. This system will remove the contaminants from the leachate and regenerate the leaching reagent for return to the top of the heap. The process will be continued nonstop until the contaminants in the soil have been reduced to EPA standards, or as low as possible. If the EPA standards cannot be met, the residual uranium will be immobilized in the soil, so that it cannot be leached out by future rain, snow, or ground water.

TECHNOLOGY NEEDS

Economical, effective, and safe methods are needed to remove contamination, especially metals, from massive amounts of soil, so the soil may be returned to its original site and use. Heap leaching for soil cleanup is an adaptation of a proven mining method for removing precious and semiprecious metals from low-grade ore. In the mining industry, thousands of tons of ore are processed daily for less than \$100/yd^3. Metals remaining in the depleted ore are measured in parts per billion. The benefits of this form of soil remediation, when proven at field scale, include:

- On-site cleanup,
- Low-cost processing,
- Conservation of expensive repository space, and
- Elimination/reduction of long-term costs for monitoring, isolation, and habitat protection of disposal areas.

Additionally, the method would be used to examine, sort, treat, and verify the cleanliness of the soil. This methodology will provide a permanent solution to the soil contamination problem, not just a relocation of the soil and cost for future care.

ACCOMPLISHMENTS

- Demonstrated that carbonate/bicarbonate is highly selective for uranium. The latest results indicate only negligible quantities of other compounds (non-uranium bearing) were removed from the soil during leaching.
- Demonstrated that it is not necessary to separate the soil into its size fractions (i.e., gravel, sand, clay, and silt) before it can be leached.
- Demonstrated that the liquid-to-solid ratio can be kept quite low (1 to 2 liters per kg soil per 24-hour day) to minimize (or eliminate) the need for dewatering of the soil after treatment.
- Demonstrated that the electrical energy consumption is negligible.
- Demonstrated that uranium removal is a function of carbonate/bicarbonate concentration.
- Demonstrated that breakthrough time (time between start of leaching at the top of the column and appearance of leachate at the bottom) is proportional to column height.
- Demonstrated that total leaching time is generally not dependent on column height.
- Most of the uranium removal occurs in the first two weeks.
- In leaching soil contaminated with 387 mg of uranium/kg of soil using a .1M solution of $KHCO_3/K_2CO_3$ with leaching conducted 24 hr/day:
  - 58 percent of uranium was removed after 1 day; the liquid-to-solid ratio was 1:1.
  - 90 percent of uranium was removed after 10 days; the liquid-to-solid ratio was 10:1.
  - 97 percent of uranium was removed after 33 days; the liquid-to-solid ratio was 33:1.
- Remaining contamination levels in the soil were 164, 37, and 12 mg/kg, respectively.
- In leaching 13 columns of soil contaminated with 470 mg uranium/kg of soil with various solution concentrations and times:
  - 81 percent of uranium was removed after 8 days using a .1M solution of $NaHCO_3/Na_2CO_3$; the liquid-to-solid ratio was 8:1.
  - 82 percent of uranium was removed after 6 days using a .25M solution of $NaHCO_3/Na_2CO_3$; the liquid-to-solid ratio was 6:1.
  - 92 percent of uranium was removed after 6 days using a .5M solution of $NaHCO_3/Na_2CO_3$; the liquid-to-solid ratio was 6:1.

Remaining contamination levels in the soil were 90, 83, and 40 mg/kg, respectively.

BENEFITS

The technology is widely applicable to problems of uranium-contaminated soil at DOE sites and at commercial and military sites in the United States and around the globe. This approach may reduce implementation time because of the mining industry usage and benign nature of the major chemical involved baking soda (sodium bicarbonate).

The data generated so far suggests the process effectively removes at least 80 percent of the uranium contamination in the soil. By extending these studies to other soils the process improves its general applicability to soils with different characteristics. In addition, the issues of secondary waste stream size and treatment, ease of acceptance by the public, cost, equipment inventory, etc., are found to be favorable. Preliminary cost estimates suggest a treatment cost of \$227/ton for heap leach treatment, which compares favorably with the figure of \$334/ton for transporting and long-term storage.

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3.10 Chelator Approaches to Actinide Removal from Soil

Task Description

The objective of this project is to develop effective extraction processes for the removal of uranium from contaminated soils. Important requirements for the process are that it should not destroy the soil or generate secondary waste streams that are difficult to treat. This approach is focused on the use of siderophores (microbial iron chelators) and biomimetic analogs as mobilizing agents for uranium. Based on the use of these chelators, together with redox chemistry, chemical extraction of the uranium can be performed under mild conditions. This process will produce an aqueous leach solution that will be treated to remove and concentrate the solubilized uranium. The treated leach solution will be recycled in order to minimize costs and secondary wastes.

Inputs for the process are contaminated soil and a neutral aqueous solution containing chelators and mild redox agents. In some cases, it may be beneficial to pretreat the soil with a physical separation process or another chemical leaching process to either pre-concentrate the uranium or to remove a fraction of the uranium not amenable to this process.

The outputs of the process are soil from which the majority (90 - 99 percent) of the uranium contamination will have been removed, and an aqueous leach solution containing the solubilized uranium. The final uranium concentration in the decontaminated soil has yet to be determined. Results obtained to date demonstrate that for certain specific soils at Fernald (e.g., Plant 1 storage pad soil) chelator approaches to decontamination can reduce uranium levels in treated soils to close to background, (<10 ppm).

It is envisioned that this process will be used on soil that has been excavated from contaminated sites at Fernald. Both agitated vat leaching and heap leaching are under consideration for implementation. A leachate that is enriched with uranium will be collected from the heap leach or separated from the soil in vat leach for subsequent uranium recovery and/or chelator recycle by pH adjustment and ion exchange. The recovered uranium will be immobilized for disposal, and the decontaminated soil will be returned to the site.

To date, the best decontamination results in batch tests on soil treatability samples have been obtained using Tiron, a bio-mimetic chelator with extraordinary affinity for U4+ and dithionite as a reductant. Good decontamination effectiveness has been obtained with Tiron alone.

Technology Needs

Many DOE sites have radionuclide and/or toxic metal contamination in soils and ground waters. This project is primarily focused on the FEMP site where previous processing activities have resulted in uranium contamination. The precise extent of the contamination is unknown, but estimates suggest that 2,000,000 yd^3 of soil have unacceptable levels of uranium contamination.

Present technologies for remediation of radioactively contaminated soils involve immobilization of the radioactive metals in place, excavation of the site and transport of the contaminated soil to a secure repository, or separation (usually by density or size) of the more highly contaminated soil fractions. Immobilization approaches suffer from poor public acceptance and from high and continuous monitoring costs. Transport and storage of the entire volume of contaminated soil will be expensive and simply transports the problem to another site where it may have to be remediated later. Physical separation methods are quite effective for contaminated soils in which a large fraction of the contamination is concentrated in a small volume of soil that can be separated by density or size. However, at Fernald, the uranium contamination is associated with all size and density fractions of the soil. Consequently, it appears that traditional physical separation methods will not be applicable, and that any successful soil washing strategy will depend upon a chemical extraction process.

ACCOMPLISHMENTS

Fernald Site Soils:

Reductive dissolution of uranium (VI) phases in the presence of strong chelators was shown to be an effective strategy for uranium decontamination. Residual uranium concentrations in treated samples ranged from 10 to 60 ppm.

For Primary Waste Stream:

Effective treatment of leachate has been accomplished for chelator recycle and to remove uranium to less than 1 ppm.

BENEFITS

The chelator approach used here accomplishes moderately greater extraction of uranium as compared with the use of other chemicals. Additionally, the extraction occurs at a lower pH and results in less loss of organics from the soil during the leaching operation. Soil physical characteristics are retained well. Other attributes of the process are ease and effectiveness of secondary waste treatment and recyclability.

COLLABORATION/TECHNOLOGY TRANSFER

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3.11 Selective Extraction/ Leaching of Uranium from Soil

Task Description

Methods are being investigated to eliminate the need for collection and bulk disposal/isolation of large volumes of uranium-contaminated soils. The objective of this task is to design extraction media and procedures to remove uranium to concentrations less than 35 pCi/gm of soil (an activity level of natural uranium selected as a screening level to evaluate potential decontamination technologies) without adversely affecting the physicochemical or agronomic characteristics of the soils. Additionally, the extraction media and procedure(s) chosen should effectively remove the uranium without generating additional waste forms that are voluminous or difficult to dispose.

Selective extraction/leaching of uranium from soil is being accomplished in studies to evaluate the effectiveness of various leaching media (carbonate/bicarbonate, citrate, and carbonate dithionite citrate) and conditions of leaching (i.e., attrition, time, and temperature). Bench-scale studies have been completed and pilot-scale studies have begun. Methods for leachate treatment are being investigated to remove and concentrate uranium solubilized in the aqueous leaching media. Process engineering aspects of the total soil decontamination process (e.g., the necessary equipment, flow rates, method for screening and dewatering soil suspension, etc.) are being evaluated for pilot- and full-scale field operations. The pilot-scale treatability tests are being conducted at Fernald in the same facility used for Fernald's Operable Unit OU-5 Remedial Investigation/Feasibility Study (RI/FS) soil treatability test. The potential of the cleaned soil to grow plants is being evaluated. Cleaned soil generated from the bench-scale studies as well as that generated from the pilot-scale treatability tests has been used to evaluate soil phytotoxicity characteristics and any steps needed to improve plant growth.

Technology Needs

The Fernald site has significant volumes of soil (estimated at 2,000,000 yd^3) containing elevated levels of uranium. Uranium concentrations range to as high as 70,000 ppm in soils adjacent to processing plants within the production area. It is estimated that 50 percent of the surface soils (top 18 inches) within the production area contain uranium concentrations in excess of acceptable limits. At certain locations (e.g., within the waste pit areas), significant contamination is also present at soil depths greater than 15 ft.

Other DOE sites, including the Y-12 and K-25 plants at ORNL, also have significant volumes of uranium-contaminated soils. The potential exists for migration of contaminants to groundwater or aquifer systems. Thorough cleanup of those sites is a major public concern and a high priority for DOE. Selective extraction and leaching of contaminants have the potential to clean soil to acceptable levels and to significantly reduce the volume of disposable contaminants.

Accomplishments

- Laboratory/bench-scale treatability studies completed.
- Pilot-scale treatability studies have been completed.
- Pilot-scale studies using carbonate-based extractions lowered uranium concentrations in the Fernald storage pad soil from 2000 ppm to less than 150 ppm (removal efficiencies of greater than 90 percent).
- Pilot-scale studies using carbonate-based extractions lowered uranium concentrations in the Fernald incinerator soil from approximately 800 ppm to less than 150 ppm (removal efficiencies of approximately 80 percent).

- Phosphate amendments to carbonate-leached soils have shown a significant immobilization effect on uranium solubility (i.e., soil solution concentrations of uranium less than 0.1 ppm).

BENEFITS

- Carbonate extractions are highly selective for uranium
  - 100 to 1,000 times less secondary waste as compared to acid extractions;
- Removes 80 to 90 percent of uranium from soils
  - based on bench- and pilot-scale studies with Fernald soils;
- Initial costs estimates indicated costs less than $200/ton
- Uranium waste form is less than 0.1 percent of volume of treated soils
  - 1,000 pounds of uranium from 1,000 tons of contaminated soil;
- Disposal costs for off-site disposal are very low
  - less than $350 for uranium waste, compared to $700,000 for 1,000 tons of contaminated soil (assuming disposal costs of $700/ton for off-site disposal);
- An agronomic productive/aggregated soil product can be returned to site; and
- Residual uranium in treated soil is highly immobile
  - phosphate amendments greatly reduce potential for leaching of uranium to groundwater (ambient uranium concentration in soil water less than 1 ppm).

COLLABORATION/TECHNOLOGY TRANSFER

None at the present time.

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CONTAINMENT/STABILIZATION

Section 4.0

4.1 In Situ Encapsulation of Buried Waste

Task Description

In situ grouting involves the injection of phosphoric, iron oxide, or calcium carbonate precipitating solutions into buried waste streams, encapsulating them in a cemented block that is impervious to water migration. The technique can also be used as an intermediate stage to solidify waste to prevent future aerosolization of contaminants should retrieval be necessary.

The concept is an analogue of the natural processes that produce classic sedimentary rocks. Loose unconsolidated soil or sediment is converted into a hard, durable, impermeable rock by precipitation of minerals (cement) from ground water between the particles of unconsolidated materials. The most common natural cements are calcite, hematite, and apatite. The existence of such rocks in the natural environment for long periods of time requires that they be in chemical equilibrium with their surroundings. The success of using artificial analogues of natural cementing processes to encapsulate and isolate waste materials hinges on the ability of the aqueous cementing solutions to penetrate and permeate INEL soils.

The primary objective is to demonstrate encapsulation techniques using precipitating solutions and polymers injected into buried waste, resulting in a cemented block that is impervious to water migration.

Technology Needs

Stabilization of 2 million ft^3 of buried TRU waste mixed with up to 6 million ft^3 of soil at INEL and similar or greater quantities of low-level, TRU, and mixed waste buried at other DOE sites might be necessary to prevent potential health and environmental hazards.

Accomplishments

Laboratory scale tests were conducted at INEL using synthetic analogs of natural cementing agents to determine if these iron oxide materials (hematite) were suitable for a waste encapsulation material for application at the INEL Subsurface Disposal Area (SDA). The data indicated that the iron oxide waste encapsulation materials tested are appropriate choices for mixing with INEL soil to encapsulate waste. Field tests were recommended to determine the performance of the material under field conditions involving monitoring over an extended period.

Benefits

In situ remediation or stabilization technologies have the potential to significantly reduce worker exposure. In situ grout technology that is capable of isolating waste material from the natural environment has several unique features. The technology can stabilize a variety of DOE and Superfund sites, is compatible with complex mixtures of various contaminants, isolates and encapsulates buried materials containing hazardous waste, radioactive waste, and TRU element waste, is applicable to various waste forms and surrounding materials and isolation of buried structures such as waste storage tanks, and has a natural analogue both in formation and longevity in limestone, phosphoric ores, iron oxide beds, and the LeBrea Tar Pits.

The cost of retrieval/treatment/disposal for the INEL SDA has been estimated between \$2-\$10 billion. The cost of applying in situ encapsulation at the SDA is in the \$0.5 billion range.

Collaboration/Technology Transfer

The technology participants from the INEL, PNL, BNL, and a private vendor (Applied Geotechnical Engineering and Construction) will aid in technology transfer. Additional industrial and university participants will be involved in the program as requirements and needs become better defined. The data obtained from each of the activities will allow technical evaluation for remediation by private, DOE, and Environmental Restoration/Waste Management (ER/WM) concerns.

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Bibliography of Key Publications

Weidmer, Jerry, Peter Shaw, In Situ Encapsulation Bench Scale Demonstration Report, (INEL-95/0039), Idaho Falls, ID. 1995.

TASK DESCRIPTION

The primary objective is to demonstrate an innovative grouting concept for buried waste retrieval involving a three-step process in a field environment. The first step is to grout the waste, causing an agglomeration of fine soil particles that may have become contaminated. Next, the monolithic grouted block is fractured using a demolition grout. Finally, the debris is excavated in a relatively dust-free environment with remotely controlled equipment.

A secondary objective is to use the jet grouting procedure to create a grout wall around a hot spot in the waste. The material within the wall can then be excavated without the surrounding waste sloughing into the pit, and thus increasing excavated waste. The soil/waste matrix is grouted with a Casa Grande drill apparatus with special fittings at the surface for contamination control. The grout material is jet grouted with up to 6,000 psi pressure into the soil/waste matrix. The fine, silty clay interstitial soils will be intimately mixed with the grout. The grout will readily fill voids in the waste matrix. The exact grout formulation and compatibility with INEL soils was determined through FY94 field experiments. See Figure 4.2.

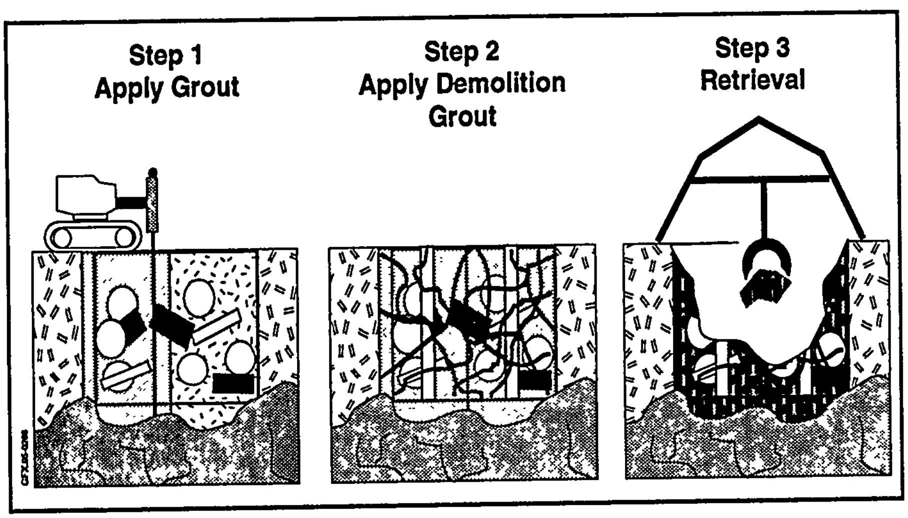

Figure 4.2. Grout Retrieval Project.

TECHNOLOGY NEEDS

ER/WM has expressed interest in examining technologies required for the safe removal of contamination point sources or hot spots from within a waste storage site. There are 2 million ft^3 of TRU waste commingled with up to 8-million ft^3 of soil in shallow land burial at INEL. Other sites such as Hanford also have this type of buried waste.

Using the grouting technique to create a monolith and then retrieving the waste provides an inherent contamination control advantage because the contaminants are locked up in the solidified blocks.

Prior to conventional hot spot excavation, grout walls can be created around the perimeter of the hot spot. The walls will serve as shoring to protect against cave-ins during removal which would result in cross contamination of potentially clean surface soils, less contaminated subsurface waste materials, and associated soils. The shoring will also provide stability at the surface to aid support of the required excavation equipment.

ACCOMPLISHMENTS

Prior year progress: demonstration and evaluation of jet grouting as a form of contamination control through amalgamation and encapsulation of waste have been conducted. The grout injection technology and chosen grout material will be utilized in the 1995 demonstration of the grout wall for hot spot removal.

BENEFITS

The innovative technology accomplishes buried TRU waste retrieval with less contamination spread. This grouting technique allows the waste to be confined prior to retrieval and treatment, contains the spread of contaminated soils by agglomeration of fine soil particles in the grout, and eliminates the need for elaborate contamination control strategies during retrieval and handling.

The innovative technology supports hot spot retrieval by:

- Providing support to the dig-face;
- Providing an effective and inexpensive means of placing shoring material; and
- Enabling walls to be left in place to hinder migration of certain waste products back into the vicinity of the dig.

Successful development of this system would enable remediation site contractors to reduce contamination control costs without jeopardizing worker safety during retrieval activities. The cost estimate of applying this technology for the retrieval of a one acre pit is $15M for retrieval and another $15M for repackaging and assay. This compares to the estimated cost of $200M for conventional retrieval (INEL Pit 9 estimate).

COLLABORATION/TECHNOLOGY TRANSFER

The concept can be transferred to the INEL Environmental Restoration Program for use by the private sector for remediation of TRU pits and trenches. The private sector could also use this technique on buried waste sites where contaminant spread is a problem.

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BIBLIOGRAPHY OF KEY PUBLICATIONS

Loomis, G.G., Innovative Grout/Retrieval Demonstration - Final Report, (LITCO-94/0001), 1995.

4.3 MONOLITHIC CONFINEMENT

TASK DESCRIPTION

The technique will use Casa Grande drill apparatus to drill into basaltic formations and apply, by pressure grouting, a material to fill the inner granular cracks in the basalt. This technique also simultaneously locks in contaminants that may have spread to regions below buried waste. See Figure 4.3.

The primary objective is to create a barrier to waste migration below buried waste sites in a basaltic field environment and verify success by examining the inner granular regions for penetration of grout by borehole drilling and permeation testing.

TECHNOLOGY NEEDS

There are 2 million ft^3 of TRU waste commingled with up to 8 million ft^3 of soil in shallow land burial at INEL. Underlying this buried waste are hundreds of feet of intermittently fractured basalt. Migration of volatile organics and other contaminants to the aquifer below the basalt must be minimized to maintain water quality.

ACCOMPLISHMENTS

During FY94, the monolithic confinement concept was tested at the Box Canyon site near INEL. It was demonstrated that hydraulic conductivity was reduced significantly by grouting the fractured basaltic matrix.

BENEFITS

The technology provides a positive barrier to further migration of buried waste contaminants to potential underlying aquifers.

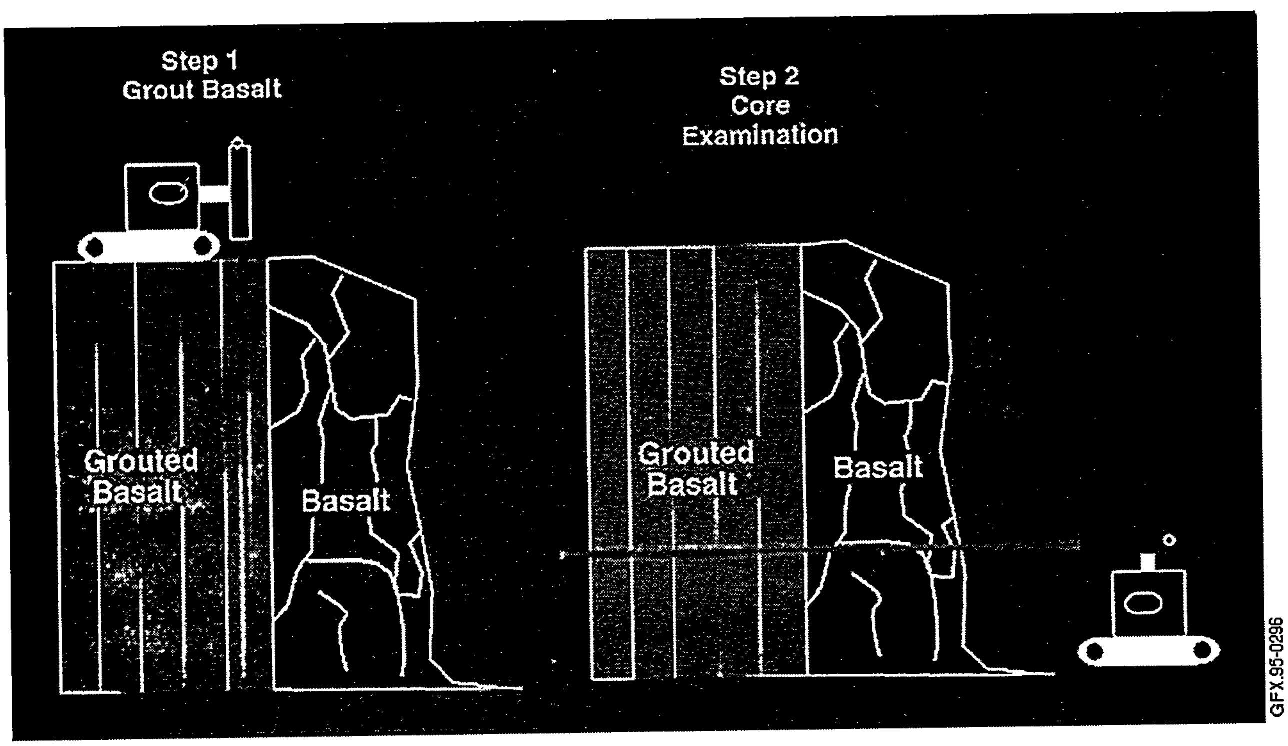

Figure 4.3. Monolithic Confinement Demonstration.

COLLABORATION/TECHNOLOGY TRANSFER

The technology will be provided to ER programs for private sector implementation for remediation of pits and trenches. This technique can be used on any buried waste site where contaminant spread is a problem.

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BIBLIOGRAPHY OF KEY PUBLICATIONS

Draft *FY94 Technology Report Monolithic Confinement*, Westinghouse Hanford Report.

4.4 Containment and Stabilization of Buried Waste

Task Description

This technology will develop, demonstrate, and implement advanced grouting materials for in situ stabilization of contaminated soils and the placement of impermeable, highly durable subsurface barriers. The effort focuses on cementitious and soil cement mixtures compatible with commercially available placement techniques. See Figure 4.4.

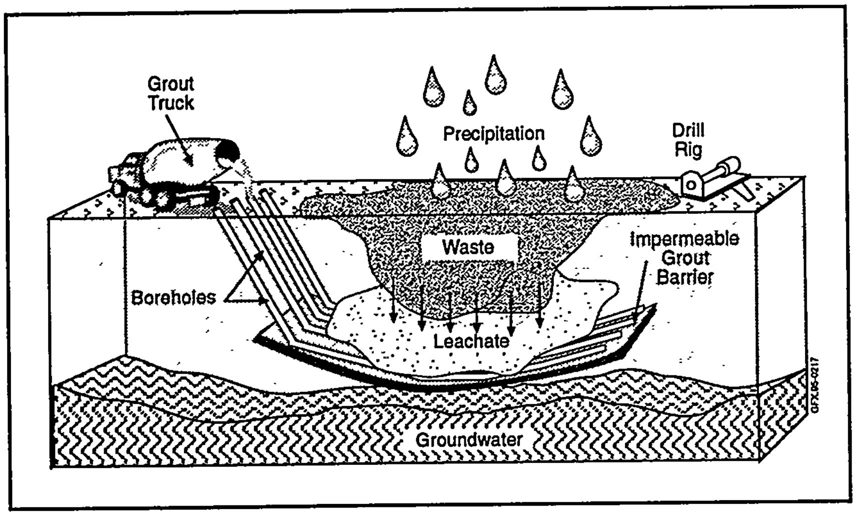

Figure 4.4. Containment and Stabilization of Buried Wastes.

Technology Needs

This effort is addressing two key needs for environmental restoration: 1) in situ containment technologies, and 2) in situ stabilization technologies. The magnitude of the soil contamination problem is illustrated by the 517 sites described on the National Priorities List, as well as the 7,313 DoD sites and 4,000 sites belonging to DOE. Without significant advances in barrier stabilization technologies, it is questionable whether restoration of these sites can be performed in a cost effective manner.

Accomplishments

Barrier formulations in an arid environment were optimized and characterized. The major placement techniques considered were jet grouting, soil mixing, and soil sawing. Cementitious grouts with permeabilities on the order of 10^{-10} to 10^{-11} cm/s suitable for monolithic grout subsurface barriers were developed. Permeability after accelerated leaching and repeated wet-dry cycles was on the order of 10^{-10} to 10^{-9} cm/s. The results compared favorably with the EPA permeability limit of 10^{-7} cm/s for landfills.

The developed super-plasticized grouts and soil cements have significantly superior mechanical, physical, and durability properties than those of conventional formulations. The permeabilities are two to five orders of magnitude less than for other materials frequently used as caps and barriers such as clay, soil-bentonite, and cement bentonite slurries. Therefore, the dimensions of the barriers can be reduced significantly.

When used for stabilization, blast furnace slag modified grouts—soil mixtures placed by jet grouting or soil mixing—can stabilize and solidify soils contaminated with trivalent or hexavalent chromium in a one stage process. The treated soils pass the EPA Toxicity Characteristic Leaching Procedure. They also have high strength, low permeability, and resistance to wet-dry cycles.

Benefits

The benefits from this work include: 1) reduction in costs compared to those of excavation, treatment, and disposal, 2) improved operations, thereby increasing regulatory agency and public acceptance, and 3) reduction of health and environmental risks as compared to those from the use of other remedial techniques.

COLLABORATION/TECHNOLOGY TRANSFER

Industrial interest in the technology has been expressed by major world-wide geotechnical construction firms.

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Allan, M.L., and L.E. Kukacka, "Grout Treated Soil for Low Permeability Barriers Around Waste Landfills," American Concrete Institute Materials Journal, 91: 4, 1994.

Allan, M.L., and L.E. Kukacka. "Permeability and Microstructure of Plain and Fibre Reinforced Grouts," Cement and Concrete Research, 24:4, pp 671-81, 1994.

Allan, M.L., and L.E. Kukacka. In-Situ Containment and Stabilization of Buried Waste, Annual Report for Mixed Waste Landfill Integrated Demonstration, FY 1993. BNL 49709, November 1993.

Allan, M.L., L.E. Kukacka, and J. Heiser. In-Situ Containment and Stabilization of Buried Waste, Annual Report for Mixed Waste Landfill Integrated Demonstration, FY 1992. BNL 48252, October 1992.

4.5 MIGRATION BARRIER COVERS FOR MIXED WASTE LANDFILLS

TASK DESCRIPTION

The objective of this project is to provide field-tested capping alternatives, including the EPA RCRA cap, and calibrated water balance models that can be used in the assessment phase of the remedial investigation and as a component of the corrective measures study for selecting remediation alternatives for landfills. The goal is to ensure that cost-effective capping technologies are available so that cap design can be selected based on the level of hydrologic control needed at the site.

Over the past eight years, parallel and collaborative research and development by LANL, PNL, INEL, U.S. Department of Agriculture-Agriculture Research Service (USDA-ARS), USGS, and the Uranium Mill Tailings Remedial Action (UMTRA) program have explored several alternative long-term migration barrier cover technologies for interim stabilization and final closure of radioactive waste landfills in arid sites. See Figure 4.5.

These barrier technologies have addressed erosion control, deep percolation, and biological intrusion using engineered covers constructed of synthetic and/or natural geologic materials. Underlying hydrological and biological phenomena were used to design barriers that control the fate of precipitation falling on the site. The spectrum of designs vary from simple soil barriers with optimum configurations of soil, plant cover, and surface slope to more complex multi-layered cover profiles incorporating engineered barriers that inhibit downward movement of soil moisture. The EPA's RCRA cap uses compacted clay as a hydraulic barrier, while others employ a capillary barrier to divert water laterally. Few of those designs, including EPA's RCRA cap, have been constructed in the field and monitored to allow complete evaluations of performance characteristics. Field-tested designs were evaluated under very specific climatic and environmental conditions.

LANL has conducted the basic research and has begun to field-test various landfill cover designs, with some success in reducing erosion and percolation of water into underlying waste under local climatic conditions. However, tests have just begun for some of these barrier concepts in other climatic conditions (e.g., at Hill Air Force Base in Utah) and for wastes other than radionuclides. Factors such as climate, soils, vegetation, and waste composition are important site attributes that affect both the design and the performance of migration barrier cover systems. Field testing will evaluate the performance levels of each cap to prevent water percolation into the waste and erosion.

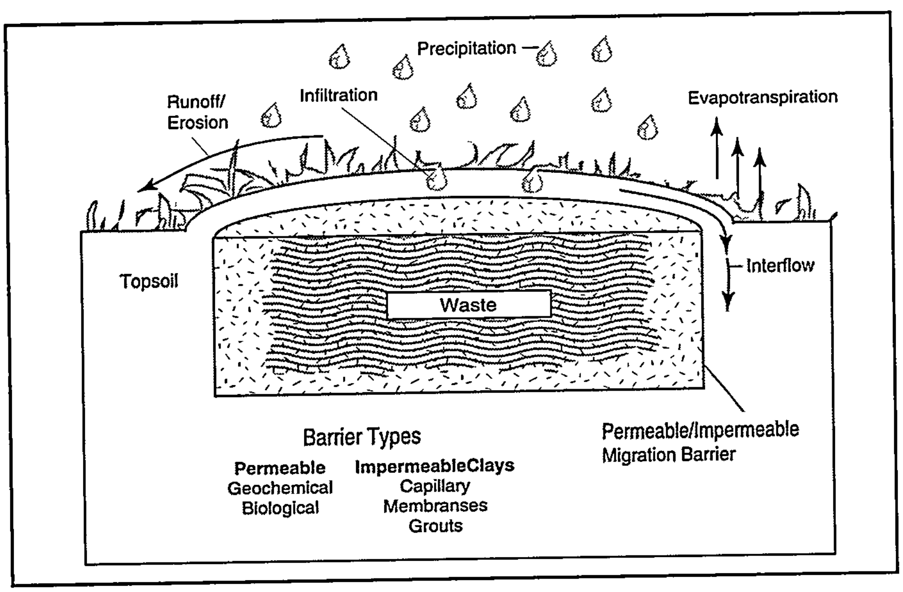

Figure 4.5. Integrated Migration Barrier System.

TECHNOLOGY NEEDS

Field-tested migration barrier cover designs, tailored to the climate, can serve as the sole containment technology or as a component of an integrated barrier system to contain wastes. In addition, the hydrologic control exerted by the cover can be used to establish optimum moisture conditions in the waste backfill to improve performance of other treatment technologies such as ISV, vapor extraction, and other in situ treatment technologies. Relative to the excavate and re-bury option, containment with field-tested migration barrier designs can reduce remediation costs 10-1000 times and still ensure regulatory compliance.

ACCOMPLISHMENTS

Selected and delivered a report on the best barrier design based on performance data, from a demonstration at Hill Air Force Base.

COLLABORATION/TECHNOLOGY TRANSFER

USDA-ARS

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BIBLIOGRAPHY OF KEY PUBLICATIONS

None at this time.

4.6 DECISION SUPPORT SYSTEM TO SELECT LANDFILL COVER SYSTEM

TASK DESCRIPTION

The objective of this technology is to provide risk managers with a defensible, objective way to select capping alternatives for remediating radioactive and mixed waste landfills. The objective will be achieved through a joint project between LANL and USDA-Agricultural Research Service (ARS) by developing a multi-objective decision-making software system (DSS), with embedded simulation models, to design and evaluate engineered surface barriers for mixed waste landfills. See Figure 4.6. The data collected from the Migration Barrier Covers for Mixed Waste Landfills project will be used to evaluate the DSS. The task includes testing the prototype DSS for remediation of waste disposal sites with migration barrier cover technology, using the designs and database from the existing cover barrier field demonstration at Hill Air Force Base in Utah. The objectives of the work include:

- Assembling the technical database to develop site-specific parameters for the knowledge-based system (KBS);
- Incorporating the multi-objective analysis tools into the existing DSS;
- Assembling the heuristic database and scoring functions for the DSS;
- Evaluating the DSS with monitoring data from Hill AFB, and selecting the best barrier cover design for meeting the regulatory requirements at a minimum cost;
- Using the DSS to design and evaluate migration barrier cover alternatives for mixed waste landfills; and
- Comparing DSS predicted performance with monitoring data from the planned LSFA barrier technology demonstrations at Hanford and SNL.

Applications of a DSS to natural resource management and to landfill cover remediation have been explored, and a prototype DSS has been partially developed by the USDA-ARS for water quality management. The DSS uses a computer model [a new version of the EPA's Hydrological Evaluation of Landfill Performance (HELP) model] to calculate water balance. The technical criteria include runoff erosion, percolation, interflow, and evapotranspiration, given the climate of the area. Other criteria are pertinent regulations and cost. All criteria go towards an overall score used to determine which cap is best for the site.

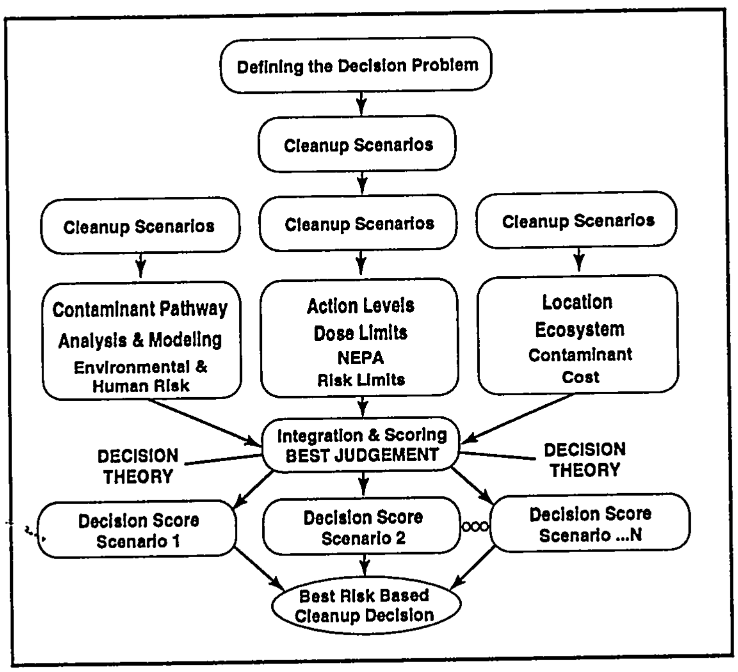

Figure 4.6. Decision Support System Methodology.

A PC-based prototype DSS software package, running with Microsoft Windows 3.1, is under development. It will be a user-friendly coupling between symbolic processing and numerical near-surface hydrologic modelling. The embedded KBS will integrate confidence limits and exceedance probabilities from stochastic conjectural analyses of hydrologic variables in space and time, and the symbolic objects that influence landfill technology. The integration will result in a DSS that should improve long-range predictability of migration barrier performance, by incorporating complex environmental processes, along with the management issues, into the decision-making process.

Interpreting the output of the KBS applied to landfill design and remediation problems, particularly when multiple and sometimes conflicting objectives exist, requires the aid of decision analysis tools to simplify the decision-making process. For example, the hydrologic analysis from the KBS might identify a particular barrier design as "better" in controlling runoff (and erosion) from the site, but at the expense of increasing water infiltration into the landfill. A method to decide whether the increased infiltration will significantly enhance the potential of deep percolation and concomitant migration of solutes toward ground water, and whether this enhanced migration has relevance in light of other factors, such as thickness of the unsaturated zone, potential use of the water, climate, etc. can be very useful.

The DSS will use dimensionless scoring or utility functions parameterized from the quantitative KBS output and expert judgment to convert the range of the decision variables to a unitless common range. This process allows the user to combine the decision variables and rank the alternative designs. A major task of this project is to integrate a new decision-making methodology into the existing DSS in order to eliminate much of the subjectivity in existing multi-objective methods.

TECHNOLOGY NEEDS

Containment technologies, including surface caps, are essential to reducing the potential for contaminant migration from a landfill by an alteration of the surface and/or subsurface soils. The process of selecting containment cover technologies for landfills requires consideration of many complex and interrelated technical, regulatory, and economic issues. A decision support system is needed to integrate the knowledge of experts from scientific, engineering, and management disciplines to help in selecting the "best" capping practice.

ACCOMPLISHMENTS

Developed a prototype decision support system and delivered a report on barrier cover demonstrations to evaluate alternatives using a KBS.

COLLABORATION/TECHNOLOGY TRANSFER

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BIBLIOGRAPHY OF KEY PUBLICATIONS

None at this time.

4.7 DRY BARRIER APPLICATIONS FOR LANDFILLS

TASK DESCRIPTION

The objective of this project is to develop and demonstrate an air-enhanced dry barrier for application to landfills in arid environments. See Figure 4.7. This technology is based on the well-founded capillary barrier concept: the contrast in unsaturated hydraulic conductivity of a coarse layer (barrier) and an overlying finer layer that limits downward water flow. The technique goes beyond the conventional capillary barrier because the coarse layer is dried with lateral air flow through the layer, preventing moisture accumulation in the layer and ensuring its unsaturated hydraulic conductivity remains low. The drying of the barrier by air can be accomplished by passive or active means, in order to ensure that the air flow is sufficient to load and transport any net recharge to the atmosphere. The dry barrier may also have application as a method for stripping gas-phase contaminants.

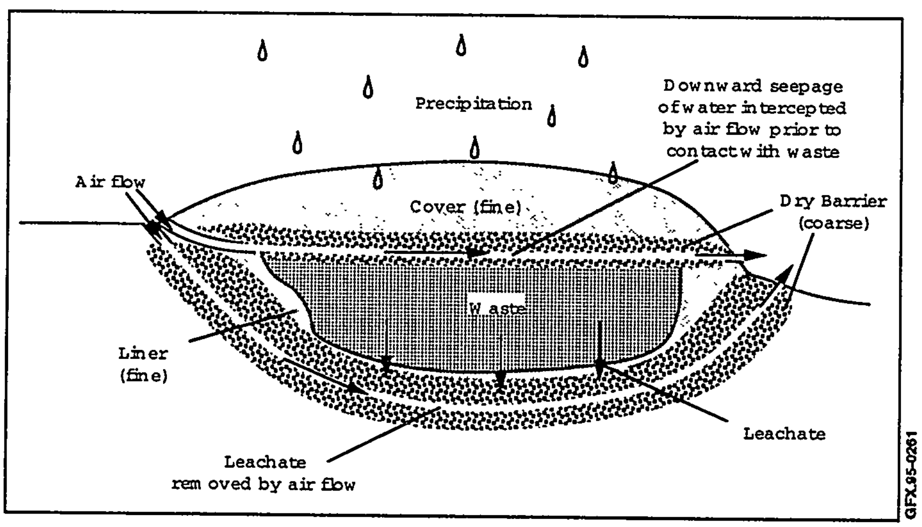

Figure 4.7. Dry Barriers.

The air-enhanced dry barrier could assume numerous forms and functions. Most simply, it can be a component of a cap or cover system. The barrier would principally be used to limit vertical infiltration through the cap. Another application would be in engineered liner systems. The air-dried layer can be used as a final barrier to prevent leachate movement beyond the landfill, and to strip denser-than-air gas-phase constituents (e.g., TCE) as they migrate downward. This application does not rely on an engineered liner, but rather utilizes the existing heterogeneous soil beneath most landfill sites. Air flow through a highly air-permeable layer beneath the landfill can be induced with vertical or directional holes to supply and remove air. These schemes may be able to utilize the prevailing westerly winds to induce sufficient air flow through the layer without relying on blowers or vacuum pumps. For applications underneath landfills, the contaminant concentration of the air is likely to be low enough as to not require treatment.

This project will evaluate the feasibility of the dry barrier concept for applications at landfills in arid environments by a combination of laboratory, design, and field efforts. First, a better understanding of unsaturated transport properties of both engineered and natural soils is needed to develop the dry barrier concept. A novel technique will be evaluated as a means of simultaneously obtaining gas permeability and unsaturated hydraulic conductivity. Small-scale testing of the dry barrier concept will utilize sandbox experiments as two-dimensional models of dry barriers. These experiments will evaluate the ability of lateral air flow to remove downward flowing water using soil types with various properties. Based on the laboratory studies, dry barriers for field demonstration will be designed. At this point, the feasibility of different applications of dry barriers will be assessed. This project will culminate with field demonstration of the dry-barrier concept at a local site.

Technology Needs

Most landfills require both above-ground and below-ground barriers. In arid environments, capillary barriers are often used in containment systems. Incorporating dry barriers into the containment systems would allow inexpensive isolation in many circumstances, and would extend the probable life of the capillary barrier. The dry barrier concept addresses a number of issues associated with landfills. If a low-maintenance dry barrier can be incorporated into the design, the cover design can be improved and its longevity may be extended. Dry barriers used as liners can serve as both a redundant barrier to liquid flow and as a means of stripping gas-phase contaminants. For existing landfills on alluvial deposits, it may be possible to use an existing coarse layer as a dry barrier.

Accomplishments

- Demonstrated feasibility of the dry barrier concept in bench-top tests.
- Measured site-specific soil properties required for dry barrier design.
- Conducted a numerical and analytical study of dry barrier performance.
- Completed engineering assessments of an active dry barrier for Albuquerque, Los Alamos, and Salt Lake City sites.
- Conducted active and passive field measurements of dry barrier performance.
- Initiated test of "dry barrier with coarse layer storage" concept.
- Initiated test of passive means to circulate air.

Collaboration/Technology Transfer

This project involves collaboration with the following entities:

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Bibliography of Key Publications

None at this time.

4.8 Advanced Landfill Cover Demonstration

Task Description

The Advanced Landfill Cover Demonstration (ALCD) is developing technology to improve current landfill cover systems. Covers reduce the mobility of contaminants by preventing moisture from entering a landfill and carrying waste leachate out into surrounding soils and potentially into the groundwater system. Specifically, the ALCD will provide alternatives to the EPA's landfill cover designs for use in arid climates. EPA admits "In arid regions, a barrier layer composed of clay (natural soil) and a geomembrane is not very effective. Since the soil is compacted 'wet of optimum,' the layer will dry and crack."

The ALCD will coordinate input from four other LSFA technology development projects to improve evaluation of landfill barrier selection, materials, and monitoring technologies. See Figure 4.8. These four areas are: 1) Migration Barriers - provide a design for a bio-engineered landfill cover, 2) Dry Barriers - provide a design for an enhanced capillary barrier (a type of dry barrier where water is absorbed by the cover until it can be carried away), 3) Post-Closure Monitoring - provide a design for monitoring equipment instrumentation and for installation of this instrumentation, and 4) Decision Support System - develop software to assist with consistent selection of the "best" design for a given situation.

The ALCD will also oversee the testing of the innovative landfill covers mentioned above. Five covers will be constructed "side-by-side" in a field scale demonstration. In 1995 testing begins for a traditional EPA clay cover, a new "geosynthetic clay liner" (simulates the properties of a clay liner with a combination of synthetic materials and compressed clay) cover, and a soil cover. In 1996 tests are planned on two alternative covers. One side of the test plot will be evaluated under regular conditions and the other side will be evaluated under "stressed" conditions (a sprinkler system will simulate extremely wet/dry conditions). The covers will be evaluated and compared based on construction, cost, and performance criteria.

Technology Needs

The ALCD will address problems identified in an EPA study of 163 landfills that found: 1) ground water was contaminated at 146 sites (contamination varied from elevated chemical concentrations in on-site groundwater to severe contamination of groundwater at water supply well fields), 2) 35 sites were reported to force changes in the water supply for impacted communities where federal/state drinking water standards were exceeded, 3) surface water contamination was reported at 73 sites, and 4) ecological impacts to local plants, animals, and/or fish were reported in 13 cases. These data show that the majority of problems identified could be attributed to lack of con-

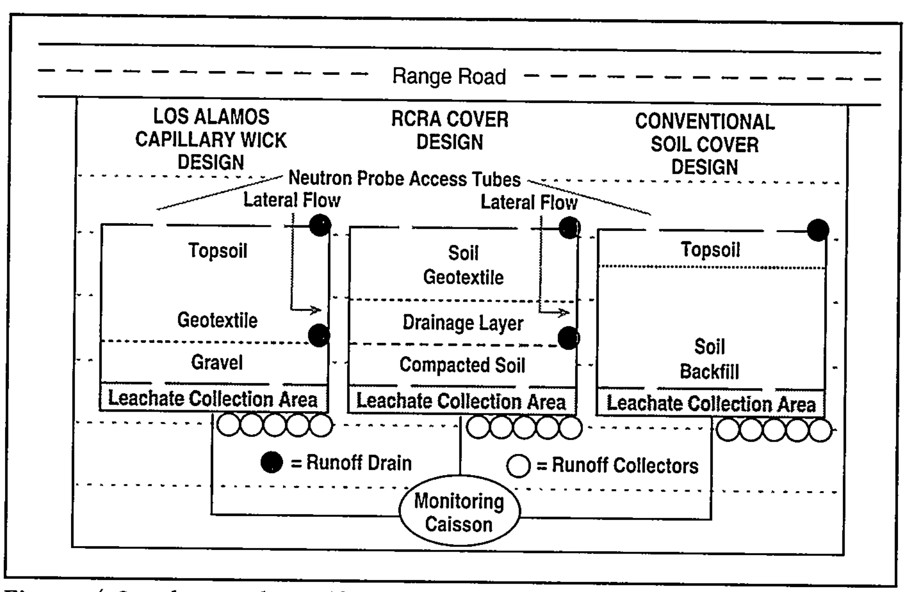

Figure 4.8. Advanced Landfill Cover Demonstration.

trol of water infiltration and flow through the landfill that carried landfill waste leachate into the soil below the landfill and eventually into the ground water. This lack of control, allowing water infiltration and flow, stems from design problems with the final landfill cover, liners, and water collection systems, and from poor locational features such as permeable soils, shallow ground water, and nearby wetlands.

Two major technical challenges exist: 1) coordinate and design various cover technologies into a final set of specifications and drawings, and 2) design a generalized methodology for applying these cover technologies so that this approach can be applied to a wide variety of arid sites. The ALCD is still in the early stages of design. Quantitative data on whether these covers actually work on a long-term basis and relevant cost data will be acquired during field tests planned for 1995.

ACCOMPLISHMENTS

This project is endorsed by the Western Governors' Association/Develop On-Site Innovative Technologies (DOIT) Committee. Past studies have shown that the likelihood of regulatory acceptance is the key determining factor in choosing environmental remediation technology. Recognizing this, regulators from most of the western states, as well as EPA, have been included from the beginning in working with the ALCD, increasing the possibility of this technology's acceptance.

BENEFITS

The ALCD will be cheaper in two ways. First, by coordinating with other LSFA technologies, duplication of effort will be greatly reduced. Costs should be approximately 50 percent lower than current systems. Second, this effort should result in more efficient landfill cover designs that will be tailored to specific site requirements through the use of the decision support system. This effort should result in designs that are more repeatable in construction, thus simplifying the landfill cover permitting process, and that are longer lasting (through the use of innovative materials). These materials will be identified during the process of testing multiple covers side-by-side.

COLLABORATION/TECHNOLOGY TRANSFER

The ALCD is a collaborative effort between LANL, SNL, Colorado State University, University of New Mexico, EPA, the Western Governors' Association, and the New Mexico State Environment Department.

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None at this time.

4.9 IN SITU VITRIFICATION

TASK DESCRIPTION

In situ vitrification (ISV) is a thermal treatment technology being developed for permanent stabilization of radioactivity contaminated soils. The technology is especially applicable to sites with a variety of different contaminants (e.g., radionuclides, heavy metals, organics, etc.). The project is structured to address key issues associated with three near-term technology needs:

- Melting low-alkali soils,
- Increasing ISV treatment depth, and
- Quantifying the behavior of organic and inorganic volatile compounds in and around the ISV melt.

The project began at the conclusion of FY93, however no research was initiated until FY94.

Low-alkali soils are difficult to melt using ISV due to their low flux content. Before this task, bench-scale ISV tests were conducted by PNL in 1989 on uncontaminated soils from SRS to determine the feasibility of ISV on these soils. Test results showed that the SRS soils could be melted if fluxants were mixed in with the soil to increase its alkali concentration. While effective, this approach is undesirable for processing the target SRS sites (highly contaminated with radioactive and other hazardous chemical compounds), because it defeats the in situ treatment advantages offered by ISV. The first element of this task will evaluate and demonstrate (at the engineering scale) methods to implement ISV on SRS soils without intrusively mixing fluxants directly into the target contaminated region. If successful, this will allow the ISV technology to process the radioactive and mixed waste contaminated soil sites, such as the L Area Oil and Chemical Basin at the SRS.

An ISV treatment depth of 5m has been successfully demonstrated in the field. Applicability of the ISV technology to DOE sites will be greatly increased if the depth capability can be increased to 10m or more. Results from computational models of the ISV melt process have indicated that the majority of the joule heat energy dissipated in the soil is concentrated in the upper regions of the melt. If a greater proportion of this energy could be redirected to dissipate in the lower portion of the melt (in the proximity of the advancing melt front), greater melt depths should result.

Numerous concepts have been proposed and documented in previous ISV efforts at PNL. One concept that appears to hold great promise for depth enhancement, while simultaneously requiring virtually no modifications to the existing ISV system or its operation, is the modified or hot-tip electrode. This concept also appears to allow scale-up to application in the field with the pilot- and large-scale systems.

This task will investigate several hot-tip electrode modifications. Several engineering-scale ISV melts and numerous computational and analytical modeling efforts will be performed to assess the efficacy of the hot-tip electrode against the present electrode configuration.

TECHNOLOGY NEEDS

The ISV technology was invented in 1980, patented by Battelle for DOE in 1983, and commercialized by Battelle in 1989 with the formation of Geosafe Corporation. Because the ISV technology is commercially available, issues associated with treatment of unconfined contaminated soils at depths less than 5 m are closed, and the application is straightforward. As described, the extension of the ISV capability to the treatment of low-alkali soils will allow its consideration as a candidate for effective remediation of numerous contaminated sites at SRS. In addition, however, the majority of the soils along the Eastern seaboard of North America have low-alkali concentrations. There are many DOE, DoD, and private-sector contaminated sites located in this region. The ISV process has been shown to produce a very durable waste form at a much lower cost relative to other existing technologies. Therefore, when the ISV technology is demonstrated to effectively remediate contaminated sites in low-alkali soils, a significant return on investment is expected. In addition, while the contamination zones of many known contaminated sites are in the upper 5 m of the site, an even greater number have contaminated regions that extend below this 5-m depth. Preliminary surveys indicate that at DOE sites alone, if the treatment depth capability were doubled, the number of applicable sites for remediation would more than double. Therefore, enhancements to the ISV technology which allow its extension to greater depths will greatly expand its realm of applicability.

ACCOMPLISHMENTS

While funds for this project were initially allocated at the conclusion of FY93, all of the research work has been conducted during FY94. Significant progress has been made toward achieving the goals of the project, and is described below.

Melting Low-Alkali Soils

An engineering-scale application of ISV has successfully melted soil from SRS. In this test, SRS soil at a depth over 22 cm, was melted at an average melt rate of approximately 5.5 cm/hr (2.2 in/hr). This compares very favorably with the nominal ISV processing rate of 2.5 cm/hr (1 in/hr). Melt temperatures approaching 2,000°C were obtained. Moreover, these results were achieved with existing ISV technology and equipment and without the addition of chemical fluxants designed to lower the melting point of the soil region.

SRS soil is very low in sodium, potassium, calcium, and magnesium oxides. Consequently, the soil has a low electrical and thermal conductivity and a high melt temperature. These conditions are detrimental to the straight forward application of the ISV process. With graphite electrodes and the electrode feed system, however, the ISV process can tolerate and attain very high temperatures. Therefore, while low melt temperatures are certainly desirable from an energy efficiency standpoint, they are not a prerequisite for suitable application of the process. Still, the soil must be able to pass an electrical current in order to produce the joule heat necessary to raise the soil to its melt temperature. To accomplish this, the upper 7.5 cm of the SRS soil in this test was mixed with starter material (14 weight percentage). In the actual field application of the ISV process to the SRS site, this layer may be generated with uncontaminated SRS soil and placed as an overburden on the contaminated site before processing. Consequently, virtually no disruption to the contaminated waste zone is necessary in this scenario. Follow-on tests are planned to use strategies involving even less pre-test preparation of the soil.

Additional concerns exist with the high melt temperatures regarding the effects of increased oxidation of the graphite electrodes at the melt surface. These effects were mitigated through the use of a durable insulation media floating on the surface of the melt. The results of these tests were presented in a final letter report at the end of FY93.

Two engineering-scale tests were performed in FY94 to help assess the benefits of the modified electrode concept. These tests were conducted in collaboration with the Geosafe Corporation. Geosafe equipment, personnel, and facilities were combined with PNL personnel and instrumentation to perform these tests. In this way, the available DOE funds were significantly leveraged to further enhance the goals of this ISV project.

The first of these tests involved applying the standard engineering-scale ISV system to uncontaminated Hanford soil. This test was heavily instrumented with 200+ thermocouples, together with heat flux, pressure, and flow meter gages. The electrode configuration employed in this test was the usual 5-cm-diameter, gravity-fed, graphite electrode. Results from this test provide the baseline for comparison against future modified electrode tests. A target melt depth of 1 m was attained in this melt in approximately 29 hours. An average power of 25 kW was applied throughout this test.

A second engineering-scale test was also performed. In this test, the electrode configuration was modified so that the bottom 30 cm of the electrode (once fully inserted into the melt) is left directly exposed to the melt. The upper portion of the electrodes was coated with an electrically insulating material. Thus, at electrode insertion depths of greater than 30 cm, current was supplied to the melt only through the lower uncoated portion of the electrode. As with the first test, this test was conducted until a melt depth of 1 m was achieved. This melt was developed in the same soil conditions, the same nominal power level, and with the same level of instrumentation as used for the baseline test described above. The target melt depth was achieved in 25 hours—a 14 percent savings in run time over the base case. Moreover, the melt shape produced with this configuration exhibited less lateral growth relative to the melt of the base case test.

The results of these two tests are encouraging and indicate that several benefits can be realized with the modified electrode configuration. Follow-on tests will investigate the effects of alternative electrode coatings and hot-tip lengths in an effort to further optimize the design.

Schedule of Development

Efforts associated with the low-alkali soils portion of the ISV project are being driven by the immediate needs of SRS. Therefore, the successes realized in applying ISV to SRS soil should have a near-term impact on the decision-making process of EM-40 at SRS. Currently, EM-40 is collecting site characterization data at the L Area Oil and Chemical Basin in preparation for field treatability studies. If ISV is the method of choice for remediation of some of the contaminated sites at SRS, a virtually immediate application of the technology developments funded by this project could be realized.

As indicated above, the depth enhancement portion of the ISV project was conducted in direct collaboration with Geosafe Corporation. Benefits from this effort will be realized in the near term by both the private sector and DOE.

Collaboration/Technology Transfer

The low-alkali soil task is being performed with close ties to the interest and application of ISV by EM-40 at SRS. The modified electrode concept is being developed in close collaboration with the Geosafe Corporation and has potential for becoming the baseline technology for all ISV applications.

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4.10 EVALUATION OF TWO NEW FLOWABLE GROUT MATERIALS AND APPLICATION TECHNIQUES

TASK DESCRIPTION

This project is evaluating the potential application of two new grouts as barrier materials for DOE sites: a mineral wax/bentonite emulsion developed in Germany (montan wax) and a glyoxal-modified sodium silicate grout developed in France. Since these materials are being used abroad in various grouting applications, regulatory and public acceptance in the United States should be rapid. The montan wax was developed by two German companies: MIBRAG and DBI, with over $9 million invested in product development and testing, including three field-scale pilot studies performed in Germany. The sodium silicate grout was developed by the French chemical company Societe Francaise Hoechst. No field tests for barrier suitability of this grout had been performed before this study, but the grout had been used extensively as a soil stabilizer.

This investigation involves both laboratory and field tests. The laboratory phase was completed in FY93 and involved grout injection experiments with soils from several DOE sites to evaluate the effectiveness of the grouts in reducing hydraulic conductivities of unconsolidated soils under ideal conditions. Soil samples from three demonstration sites were used in the tests: the Buried Waste demonstration at INEL, the Underground Storage Tank demonstration at Hanford, and the Mixed Waste Landfill (MWL) demonstration at SNL. The laboratory program also evaluated the compatibility of the grouts with common types of industrial and hazardous wastes.

The field tests are being conducted in two phases: single-borehole injection tests and a multiple-borehole injection test were completed in FY94. The single-borehole tests were performed in unsaturated soils at SNL in conjunction with cement grout injection studies conducted by SNL as part of the MWL demonstration. The first phase involved relatively small-scale injection tests to evaluate permeation characteristics of the grouts in a range of soil types and conditions. The second study will attempt to construct a large-scale (tens-of-meters) horizontal barrier by connecting grout injecting from an array of boreholes. Technical challenges include lateral permeation within soils to form horizontal barriers, physical and hydrologic stability of the barrier over time, and the regulatory acceptance of the overall approach and grout materials.

The permeation tests will be performed on the multiple-borehole installation during FY95. Also, a technical report will be completed that contains guidelines for the use of the grouts (favorable and unfavorable soil conditions, contaminant types, permeation methods, etc.) and recommendations for any further evaluation and testing.

TECHNOLOGY NEEDS

A ground water control system is needed that is injectable from the surface, forming an effective barrier in the aquifer or vadose zone, and eliminating the need to excavate trenches and construct barriers. An injectable material that is resistant to deterioration from soil, ground water, and contaminant chemistry would meet significant waste site remediation needs across the DOE Complex.

This investigation is examining some currently available injectable grouts that have shown promise in Europe. The feasibility of using conventional grout permeation methods for placement of a barrier and the resistance of the materials to waste components are the focus of this study.

ACCOMPLISHMENTS

A preliminary laboratory assessment of grout penetration characteristics was completed for both the montan wax and sodium silicate grouts using soils from several DOE sites. The reduction in permeability resulting from grout penetration was quantified for the soil samples.

Several small-scale injection tests were performed under field conditions at SNL's MWL demonstration site, with permeation of grout confirmed. The tests indicated that both the montan wax and sodium silicate grouts can be emplaced in unconsolidated vadose zone soils with conventional grout permeation methods., provided the soils have sufficiently high permeability. The minimum hydraulic conductivity for permeation grouting appears to be around 5×10^{-4} cm/s for both grouts.

Downhole geophysical methods were used to track the movement of grout away from the injection boreholes. The results are consistent with soils samples collected during post-test characterization.

Two reports were issued: (1) "Laboratory Tests Results for Evaluating the Performance of Montan Wax and Sodium Silicate Barrier Materials in Unconsolidated Soils," and (2) "Preliminary Results of Permeation Tests using Montan Wax and Sodium Silicate Barrier Materials in Unconsolidated Soils at the Mixed Waste Landfill Integrated Demonstration (MWLID)."

Final agreements between DOE and the technology vendors on licensing and nondisclosure have been secured.

BENEFITS

Current grout technologies require mixing soil with clay-based grout or cements to plug the permeability of a water-transmitting zone. Mixing often involves excavation, contact with hazardous materials, and the generation of additional waste management problems. Injection of fluids from surface wells to fill the soil pores of an aquifer forms a hydraulic control barrier where needed with minimal waste and surface disturbance.

COLLABORATION/TECHNOLOGY TRANSFER

This project is being carried out by Golder Associates, Inc. in cooperation with the European grout licensees MIBRAG (Germany) and Societe Hoechst Francaise (France). The materials were identified through the International Technology Exchange Program (ITEP). Results will be made available through this and other international efforts.

Landfills and underground storage tank sites at Hanford, ORNL, SRS, Fernald, and INEL will all potentially benefit from these relatively advanced technologies. Other potential users include a number of DoD sites with leaking underground storage tanks and industrial facilities such as refineries and fuel terminals. The single-borehole injection tests were conducted at SNL's MWL, and it is anticipated that the multiple-borehole injection tests will also be conducted at SNL.

With DOE's assistance this technology should mature rapidly. The German company is searching for an American affiliate to manage applications in North America. The French group has a U.S. division to manufacture and distribute its formulation. Rapid transfer to the private sector is expected.

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4.11 Develop and Demonstrate Methods of Placing a Horizontal In Situ Barrier

Task Description

This investigation is examining a method of in situ emplacement of barriers beneath a waste site. The process begins with two horizontal drill holes curving down from the surface at one end of the area, passing beneath the waste, and returning to the surface at the other end. The drill pipe is detached from the drill rig left in two parallel holes, and attached to a winch or tractor. At the opposite end, jet grouting equipment is attached to the drill pipe. As it is pulled down and through the subsurface, the jet grouter injects and mixes the soil and grout mix, leaving a horizontal slab about ten feet wide and two feet thick. Additional slabs are laid down in a slightly overlapping configuration, building a subsurface barrier spanning the length and width of the site.

The investigation is focusing on laying down a series of four strips and joining the edges into a contiguous sheet, forming a horizontal barrier or containment floor. Emplaced panels will be excavated and tested for gaps or zones of inadequate soil-grout mixing. Additional development will address widening the panels and placing this type of barrier in soils with rock fragments and other characteristics that can restrict grouting tool movement and mixing effectiveness.

Technology Needs

Temporary or long-term containment of mobile contaminants from existing waste sites requires effective surrounding barriers. Vertical barriers are relatively well known from standard construction project work, but methods for building horizontal barriers in situ have not been developed. For old sites, the problem is to place a containment barrier without disturbing the waste. Any excavation of the waste represents additional health and regulatory problems that are expensive and difficult to solve.

DOE needs a technique for site containment and remediation that allows barrier construction with minimal waste, that uses different barrier materials, and works in a wide variety of soil matrices.

Accomplishments

- A single-pass panel 1.5' x 12' x 100' was designed and emplaced at a depth of 12 feet.
- The panel was excavated and the workability of the concept was verified.
- Prototype equipment for making a larger panel was designed.
- A work plan to install a multiple panel horizontal barrier was drafted. The multiple panel will be installed at Fernald in FY95.

Benefits

Emplacement technologies currently available for installing a horizontal barrier beneath a waste deposit involve either excavation of the waste, laying the barrier, and redeposition of the waste, or drilling through the waste to deep soil to mix or injecting a grout barrier. Both require contact with the waste, management of new waste material, and significant surface disturbance. This investigation will provide a technology that avoids contact with the waste, and can be done without disturbing surface operations.

Collaboration/Technology Transfer

This work will be supported through collaboration with the technology owner, Halliburton NUS, with consulting support on grout and barrier materials from BNL. Performance testing of the emplaced panels will be performed by the University of Cincinnati.

Potential users of this technology are widespread across the DOE Complex and the country. A method for in situ emplacement of horizontal barriers is needed for the waste sites and tanks at Hanford. The technology may also have applications to the waste pits at Fernald.

Because the need is so widespread, this technology is also readily transferrable to containment problems outside DOE. Uncontrolled dump sites, leaking chemical and fuel storage tanks, and engineered but failing waste disposal facilities are additional candidates for this in situ containment system.

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4.12 BARRIERS IN THE VADOSE ZONE

TASK DESCRIPTION

This program is developing advanced polymer barrier materials and investigating their durability and performance characteristics under typical waste site conditions. The materials being evaluated include sulfur polymer cement, vinylester styrene, polyester styrene, furfuryl alcohol, a high molecular weight acrylic, and asphalt. Portland concrete used in hydraulic dams is being used as a performance baseline. Formulation studies have optimized aggregate type/quantities (stone, crushed glass, and sand) and binders used to produce the samples. Formulations have been developed that are capable of being placed vertically and horizontally using conventional construction methods.

Bench-scale samples are being evaluated for permeability to water, ionic diffusivity, wet/dry cycling, and chemical resistivity to acid, base, and solvent conditions. Compressive, tensile, and flexural strengths will be measured as indicators of structural integrity of a monolithic barrier wall. Preliminary testing indicates good performance and durability characteristics have been achieved. Final material testing is now underway, and those barrier materials that prove to be superior in performance when compared to conventional Portland cement concrete will be detailed in a final database report. The report will list the acceptable conditions, performance achievements, and basic economics of each concrete.

TECHNOLOGY NEEDS

Contaminated soils, buried waste, and leaking USTs pose a threat to the environment through contaminant leakages. One of the options for control of contaminant migration from buried waste sites is to construct a subsurface barrier consisting of a wall of low permeability material. A subsurface barrier could be constructed to completely surround the waste site. Application of subsurface barriers can reduce exposure by several orders of magnitude, also reducing costs of remediation by many millions of dollars compared with retrieval and treatment alternatives. Use of interim subsurface barriers can provide waste management operations sufficient time to select appropriate remediation alternatives.

Portland cement grout curtains have been used for barriers around waste sites. However, large castings of hydraulic cements invariably result in cracking due to shrinkage and thermal stresses induced by the hydration reactions. The inability to ensure the impermeability of Portland-based grout makes it an undesirable construction material for waste site barriers. Other low-permeability, high-integrity materials are needed for subsurface barriers.

ACCOMPLISHMENTS

- Issued the report, "Regulatory Issues and Assumptions Associated with Barriers in the Vadose Zone Surrounding Buried Waste."
- Formulation and optimization of 18 barrier materials was completed. This included choosing binder types and determining optimum aggregate composition and binder to aggregate ratios.
- Sample fabrication and preliminary testing were completed.
- Final testing is nearing completion and results indicate polymer materials to be durable under a wide range of waste site conditions.

BENEFITS

The available technology for subsurface hydraulic barriers currently depends on clay-based grouts and hydraulic cements. The barrier materials under investigation will provide alternatives to these inorganic systems in waste situations where they are deficient in performance. The organic polymer materials will decrease susceptibility to degradation by acid or high-salt wastes. Where structural integrity is needed as when hydraulic cements are used, a number of the new materials will act as sedimentary adhesives without the shrinkage cracking of the older materials. In addition, some of the materials are suitable for direct injection to the subsurface to form barriers without excavation and mechanical mixing. This eliminates secondary waste management problems and potential exposure of workers.

COLLABORATION/TECHNOLOGY TRANSFER

Technology transfer will include an expert review panel workshop that will include BNL, DOE, and industry personnel. A summary report will be issued containing the workshop results. Further technology transfer will include dissemination of information at symposia and society meetings.

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4.13 SUBSURFACE BARRIER EMPLACEMENT DEVELOPMENT

TASK DESCRIPTION

The Subsurface Barrier Emplacement Program consists of placing an impermeable barrier beneath an existing waste site. The barrier, which is composed of a grouting material, has to be emplaced without disturbing the waste site. Two emplacement technologies are being tested: permeation and jet grouting. Permeation grouting injects a low viscosity grout into the soil at low pressure, filling the voids without significantly changing the soil's structure or volume. Jet grouting, on the contrary, injects grout at high pressure and velocity, thereby completely destroying the soil's structure. The grout and the soil are intimately mixed, forming a homogeneous mass.

Initially, feasibility of each technique will be evaluated, followed by evaluation of design parameters such as borehole separation, depth, limitations, etc.

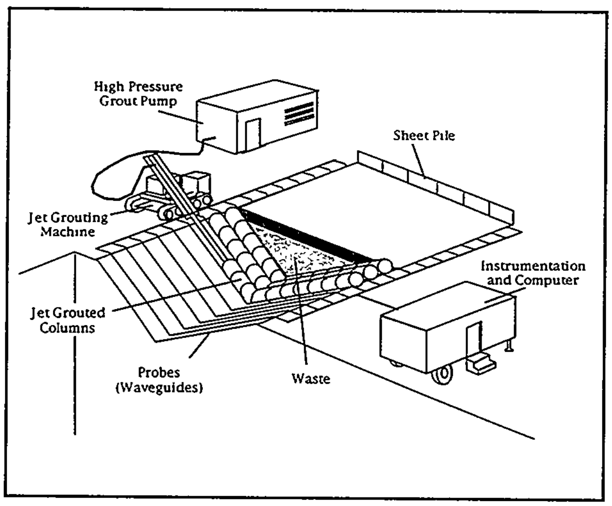

Figure 4.13. Subsurface Barrier Emplacement.

TECHNOLOGY NEEDS

The current state-of-the-art for emplacement of subsurface barriers in near surface soils lies primarily with vertically emplaced barriers. Subsurface horizontal to sub-horizontal barriers that retard vertical mass movement are not currently employed in the civil engineering applications.

ACCOMPLISHMENTS

- Completed report/literature review summarizing the technological aspects of all system components required for demonstrating a subsurface barrier emplacement.
- Completed field-scale permeation grouting experiment. Field-testing consisted of grouting in vertical and horizontal boreholes using four different barrier materials. The barrier materials used were two ultra fine cements, a mineral wax/bentonite mixture, and a sodium silicate grout. Numerous non-intrusive geophysical techniques were used to identify where the grout flowed. Geophysical techniques used included: cross-hole seismic tomography, ground penetrating radar, electromagnetic induction, and neutron probe and downhole temperature logs. Finally, the cementitious grout site was excavated exposing the grout. Observations were compared with the crosshole tomography results. Comparisons were quite favorable, but the geophysical techniques are still limited in that they can only identify grout masses but not flaws in the continuity of the grouted soil.
- Completed field-scale jet grout demonstration employing a variety of shapes using multiple materials. Installed configurations include: v-trough, cone, and rectangular monolith. Again, geophysical techniques were employed to image subsurface grout bodies. The preliminary results again indicate that current geophysical techniques are inadequate to verify the continuity of a grout barrier.

BENEFITS

The anticipated benefits of installed barriers are that the waste volume will remain fixed, allowing additional time to develop remedial treatments. In some instances, the remediation alternative may be enhanced by the installed barrier. In addition, the timing of cleanup becomes less critical.

COLLABORATION/TECHNOLOGY TRANSFER

The industrial partner is Applied Geotechnical Engineering and Construction, Inc., a very small spinoff company from Westinghouse Hanford Company. They have a very strong interest in the success of subsurface barriers since they are based in Richland, WA, and have many contacts and tremendous knowledge regarding the needs of Hanford and EG&G Idaho.

For further information, please contact:

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TTP Number: AL231004

BIBLIOGRAPHY OF KEY PUBLICATIONS

Dwyer, B.P. Feasibility of Permeation Grouting for Constructing Subsurface Barriers, Proceedings of the Thirty-Third Hanford Symposium on Health and the Environment, November 7-11, 1994, Pasco, WA. 1993.

Dwyer, B.P. Feasibility of Permeation Grouting for Constructing Subsurface Barriers, SAND94-0786, Sandia National Laboratories, NM.

DOE
Business Opportunities

Section 5.0

5.0 DOE Business Opportunities

Working with the DOE Office of Environmental Management

DOE provides a range of programs and services to assist universities, industry, and other private-sector organizations and individuals interested in developing or applying environmental technologies. Working with DOE Operations Offices, as well as management and operating contractors, EM employs a number of mechanisms to identify, integrate, develop, and adapt promising emerging technologies. These mechanisms include contracting and collaborative arrangements, procurement provisions, licensing of technologies, consulting arrangements, reimbursable work for industry, and special consideration for small business. EM facilitates the development of subcontracts, R&D contracts, and cooperative agreements to work collaboratively with the private sector.

Cooperative Research and Development Agreements (CRADAs)

CRADAs are mechanisms for collaborative R&D. They are agreements between a DOE R&D laboratory and any non-federal source to conduct cooperative R&D that is consistent with the laboratory's mission. The partner may provide funds, facilities, people, or other resources. DOE provides the CRADA partner with access to facilities and expertise; however, external participants receive no federal funds. Rights to inventions and other intellectual property are negotiated between the laboratory and the participant. Certain generated data may be protected for up to five years. Several companies may combine their resources to address a common technical problem. Funds can be leveraged to implement a consortium for overall program effectiveness.

Procurement Mechanisms

DOE-EM procurement mechanisms are for technology development in the form of unsolicited proposals and formal solicitations, although the latter are preferable. The principal contractual mechanisms used by EM for industrial and academic response include Research Opportunity Announcements (ROAs) and Program R&D Announcements (PRDAs).

EM utilizes the ROA to seek advanced research and technologies for a broad scope of cleanup needs. The ROA supports applied research ranging from concept feasibility to full-scale testing. In addition, the ROA is open continuously for a full year following the date of issue and includes a partial procurement set-aside for small businesses. Typically, ROAs are published annually in the Federal Register, announced in the Commerce Business Daily, and provide multiple awards.

PRDAs are program announcements which solicit a broad mix of advanced development and demonstration proposals. A PRDA requests proposals for a wide-range of technical solutions to specific EM problem areas. Multiple awards, which may have distinct approaches or concepts, are generally made. Numerous PRDAs may be issued each year.

EM awards grants and cooperative agreements if 51% or more of the overall value of the effort is related to a public interest goal. Such goals include possible non-DOE or other federal agency participation and advancement of present/future U.S. capabilities in domestic and international environmental cleanup markets. They may also include technology transfer, advancement of scientific knowledge, or education and training of individuals as well as business entities.

For more information about PRDAs and ROAs, contact:

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U.S. Department of Energy
Morgantown Energy Technology Center
P.O. Box 880, MS I07
Morgantown, West Virginia 26507
(304) 285-4087

LICENSING OF TECHNOLOGIES

DOE contractor-operated laboratories can license DOE/EM-developed technology and software. In situations where DOE retains the ownnership of a new technology, the Office of General Counsel will serve as the licensing agent. Licensing activities are conducted according to existing DOE intellectual property provisions.

TECHNICAL PERSONNEL EXCHANGE ASSIGNMENTS

Personnel exchanges provide opportunities for scientists from private industry and DOE laboratories to work together at various sites on environmental restoration and waste management problems. Private industry must contribute substantial cost-sharing for these personnel exchanges. To encourage such collaboration, the rights to any resulting patents go to the private sector company. These personnel exchanges, which can last from three to six months, result in the transfer of technical skills and knowledge.

CONSULTING ARRANGEMENTS

Laboratory scientists and engineers are available to consult in their areas of technical expertise. Most contractors which operate laboratories have consulting provisions. Laboratory employees who wish to consult can sign non-disclosure agreements, and are encouraged to do so.

REIMBURSABLE WORK FOR INDUSTRY

DOE laboratories are available to perform work for private industry and other federal agencies, as long as the work pertains to the mission of a respective laboratory and does not compete with the private sector. The special technical capabilities at DOE laboratories are incentives for the private sector to use DOE's facilities and contractor expertise. An advanced class patent waiver gives ownership of any inventions resulting from the research to the participating private sector company.

INTERACTIONS WITH SMALL BUSINESSES

EM seeks the participation of small businesses in its RDDT&E programs (1) through collaborative efforts with the National Laboratories, or (2) directly via solicitations issued by the DOE Small Business Innovation Research (SBIR) Program Office and the Small Business Technology Transfer (T2) Pilot Program (STTR). EM also has established a partial procurement set-aside for small firms (500 employees or less) for applied research projects through its ROA.

For further information about SBIR and STTR programs, please contact:

U.S. Department of Energy
Small Business Innovation Research Program Hotline
ER-16 GTM
Washington, D.C. 20585
(301) 903-5707

EM Center for Environmental Management Information

The EM Center for Environmental Management Information is designed to provide ready access to prospective research and business opportunities in waste management, environmental restoration, and decontamination and decommissioning activities. The Center can identify links between industry technologies and program needs. It connects potential partners to an extensive complex-wide network of DOE headquarters and operations office contacts.

To reach the EM Center for Environmental Management Information, call 1-800-736-3282.

Offices of Research and Technology Applications

The Offices of Research and Technology Applications (ORTA) serve as technology transfer agents for the federal laboratories. They coordinate technology transfer activities among laboratories, industry, and universities. ORTA offices license patents and foster communication between researchers and technology customers.

ORTA Contacts:

Laboratory	Contact	Phone Number
Ames Laboratory	Todd Zdorkowski	(515) 294-5640
Argonne National Lab	Shari Zussman	(708) 252-5361
Brookhaven National Lab	Margaret Bogosian	(516) 282-7338
Fermilab	John Vernard	(708) 840-2529
Idaho National Engineering Lab	Ann Rydalch	(208) 526-1010
Lawrence Berkeley Lab	Cheryl Fragiadakis	(510) 486-6467
Lawrence Livermore National Lab	Dave Conrad	(510) 422-7839
Los Alamos National Lab	Pete Lyons	(505) 665-9090
Morgantown Energy Technology Ctr	Rodney Anderson	(304) 285-4709
National Renewable Energy Lab	Dana Moran	(303) 275-3015
Oak Ridge Institute/Science & Ed	Mary Loges	(615) 576-3756

Laboratory	Contact	Phone Number
Oak Ridge National Lab	Bill Martin	(615) 576-8368
Pacific Northwest Lab	Marv Clement	(509) 375-2789
Pittsburgh Energy Technology Center	Kay Downey	(412) 892-6029
Princeton Plasma Physics Lab	Lew Meixler	(609) 243-3009
Sandia National Lab	Warren Siemens	(505) 271-7813
Savannah River Technology Center	Jack Corey	(803) 725-1134
Stanford Linear Accelerator Center	Jim Simpson	(415) 926-2213
Westinghouse Hanford Company	Dave Greenslade	(509) 376-5601

Acronym Listing

Section 6.0

6.0 ACRONYMS

A&PCT	Active and Passive Computed Tomography
ABS	Aqueous Biphasic Separation
AC	Alternating Current
AEM	Analytical Electron Microscopy
AGV	Automatically Guided Vehicle
ALCD	Advanced Landfill Cover Demonstration
ARAR	Applicable or Relevant and Appropriate Requirements
ARS	Agricultural Research Service
ASME	American Society of Mechanical Engineers
ATD	Alpha Track Detector
ATR	Automatic Target Recognition
BETA	Beta Scintillator Counting
BRC	Below Regulatory Concern
BNL	Brookhaven National Laboratory
BSE	Back Scatter Electron
CAM	Continuous Air Monitor
CAT	Computer Automated Tomography
CCU	Contamination Control Unit
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CERL	Construction Engineering Research Laboratory
CFR	Code of Federal Regulations
cm	Centimeter
cm/s	Centimeter Per Second
CMEHRS	Contaminated Material Excavation Handling and Retrieval System
CRADA	Cooperative Research and Development Agreement
CTEN	Combined Thermal/Epithermal Neutron
CTP	Cold Test Pit
CT	Computed Tomography

D&D	Decontamination and Decommissioning
3DDST	3-Dimensional Dynamic Simulation Tool
DAC	Derived Air Concentration
DC	Direct Current
DDT	Differential-Dieaway Technique
DoD	Department of Defense
DOE	Department of Energy
DOIT	Develop On-Site Innovative Technologies
DOT	Department of Transportation
DRCT	Digital Radiography and Computed Tomography
DR	Digital Radiography
DSS	Decision Support System
EDS	Energy Dispersive Spectroscopy
EELS	Electron Energy Loss Spectroscopy
EIC	Electret Ionization Chamber
EM	Office of Environmental Management
ER/WM	Environmental Restoration/Waste Management
EPA	Environmental Protection Agency
FANES	Furnace Atomization Non-Thermal Excitation Spectrometric
FDEM	Frequency Domain Electromagnetics
FEMP	Fernald Environmental Management Project
FERMCO	Fernald Environmental Restoration Management Company
FTIR	Fourier Transform Infrared
FY	Fiscal Year
GAM	Gamma-Ray Spectroscopy
GHz	Gigahertz
GIS	Geographic Information System
GPH	Ground Penetrating Holography
GPM	Gallons Per Minute

GPR	Ground Penetrating Radar
GPS	Geographic Positioning System
GTCC	Greater Than Class C
He	Helium
HECS	Human Engineered Control Station
HELP	Hydrologic Evaluation of Landfill Performance
HEPA	High Efficiency Particulate Air
HFS	High Frequency Sensor
HPGe	High Purity Germanium
HVPM	High Vapor Pressure Metal
ICP-MS	Inductively Coupled Plasma Mass Spectroscopy
ID	Integrated Demonstration
INEL	Idaho National Engineering Laboratory
in/hr	Inch Per Hour
IP	Integrated Program
ISV	In Situ Vitrification
ITEP	International Technology Exchange Program
IWMF	Interim Waste Management Facility
KAFB	Kirtland Air Force Base
KBS	Knowledge-Based System
kg	Kilogram
kg/day	Kilogram Per Day
kW	Kilowatt
LA-ICP-AES	Laser Ablation-Inductively Coupled Plasma-Atomic Emission Spectroscopy
LAMS	Landfill Assessment and Monitoring System
LANL	Los Alamos National Laboratory
LCMS	Landfill Characterization and Monitoring System
LIBS	Laser-Induced Breakdown Spectroscopy
LITCO	Lockheed Idaho Technology Company

LLMW	Low-Level Mixed Waste
LLW	Low-Level Waste
LRAD	Long Range Alpha Detector
LSFA	Landfill Stabilization Focus Area
MAWS	Minimum Additive Waste Stabilization
MCT	Mercury Cadmium Telluride
MDL	Method Detection Limit
mg	Milligram
mg/kg	Milligram Per Kilogram
MHM	Machine Health Monitoring
M&O	Management and Operating
MTA	Magnetometer Towed Array
MMC	Multi-Manipulator Capability
MVA	Megavolt Ampere
MWL	Mixed Waste Landfill
MWLID	Mixed Waste Landfill Integrated Demonstration
NDA/NDE	Non-Destructive Assay/Non-Destructive Evaluation
NRC	Nuclear Regulatory Commission
NRL	Naval Research Laboratory
NTP	Non-Thermal Plasma
NTS	Nevada Test Site
ORNL	Oak Ridge National Laboratory
ORR	Oak Ridge Reservation
ORTA	Offices of Research and Technology Applications
OTD	Office of Technology Development
OU	Operable Unit
pCi/g	Picacurie Per Gram
PCT	Product Consistency Testing
PEG	Polyethylene Glycol

PI	Principal Investigator
PNL	Pacific Northwest Laboratory
ppm	Parts Per Million
PRDA	Program R&D Announcement
Pu	Plutonium
RCED	Requirement Compliance Evaluation Document
RCRA	Resource Conservation and Recovery Act
RDBMS	Relational Data Base Management System
RDDT&E	Research, Development, Demonstration, Testing, and Evaluation
RDS	Regulatory Database System
RES	Remote Excavation System
RFP	Rocky Flats Plant
RHMMS	Radiological and Hazardous Material Measurement System
RI/FS	Remedial Investigation/Feasibility Study
ROA	Research Opportunity Announcement
RTDM	Real-Time Dust Monitor
RTML	Rapid Transuranic Monitoring Laboratory
RWMC	Radioactive Waste Management Complex
SA	Stripping Analysis
SBPD	Simulated-Based Planning and Design
SBIR	Small Business Innovation Research
SCR	Selective Catalytic Reduction
SCS	Supervisory Control System
SDA	Subsurface Disposal Area
SDSM&T	South Dakota School of Mines and Technology
SEDSS	Sandia Environmental Decision Support System
SIMS	Secondary Ion Mass Spectrometer
SNL	Sandia National Laboratories
SRS	Savannah River Site

STOLS™	Surface Towed Ordnance Locator System
STTR	Small Business Technology Transfer Pilot Program
TBC	To Be Considered
TCLP	Toxicity Characteristic Leaching Procedure
TDEM	Time Domain Electromagnetics
TDR	Time Domain Reflectometry
TEM	Transmission Electron Microscopy
TMGS	Tensor Magnetic Gradiometer System
TRU	Transuranic
TSI	TechniScan, Inc.
TTP	Technical Task Plan
UWB	Ultrawide Band
U	Uranium
UNCAP	Unlined Chromic Acid Pit
UMTRA	Uranium Mill Tailings Remedial Action
USBOM	United States Bureau of Mines
USDA	United States Department of Agriculture
USGS	United States Geological Survey
UST	Underground Storage Tank
VOC	Volatile Organic Compounds
VETEM	Very Early-Time Electromagnetic System
VSL	Vitreous State Laboratory
WAC	Waste Acceptance Criteria
WAMIS	Waste Assay Measurement Integration System
WIT	Waste Inspection Tomograph
wt	Weight
XRF	X-ray Fluorescence Detector

APPENDIX

Section 7.0

7.0 APPENDIX

Technical Task Plans (TTPs) identify and summarize funded work managed by OTD at headquarters, the field and the national laboratories. All tasks require a TTP number, which contains eight characters assigned by DOE Headquarters. The format consists of two alpha characters followed by six numerical characters. Characters 1 and 2 designate the DOE Operations Office/Funding Allotment Code. Character 3 denotes the laboratory/contractor/university designator. Character 4 denotes the fiscal year in which the task is first funded. The below characters reflect TTPs from FY94-95.

Characters 1, 2 & 3

AL0 Albuquerque Operations Office

AL1 Los Alamos National Laboratory (LANL)

AL2 Sandia National Laboratory, Albuquerque (SNLA)/Martin Marietta

AL3 Sandia National Laboratory, Livermore (SNLL)

AL4 Kansas City Plant (KCP)/Allied-Signal Aerospace

AL9 RUST GEOTECH

CH0 Chicago Operations Office

CH1 Ames Laboratory

CH2 Argonne National Laboratory (ANL)/University of Chicago

CH3 Brookhaven National Laboratory (BNL)/Associated Universities, Inc.

CH5 National Renewable Energy Laboratory

FN0 Fernald Environmental Management Project (FEMP)

FN1 Fluor Daniel Environmental Restoration Management Company

HQ0 OTD Headquarters

ID0 Idaho Operations Office

ID1 Idaho National Engineering Laboratory (INEL)/EG&G

ID4 Westinghouse Idaho Nuclear Company

ID6 Babcock & Wilcox, Inc

ID7 Lockheed Idaho Technology Company

ME0 Morgantown Energy Technology Center (METC)

NV0 Nevada Operations Office

OH0 Ohio Operations Office

OH1 Fernald Environmental Management Project (FEMP)

OH2	EG&G Mound Applied Technologies
OR0	Oak Ridge Operations Office
OR1	Martin Marietta Energy Systems (MMES)
OR3	Oak Ridge Institute for Science and Education
PE0	Pittsburgh Energy Technology Center
PE1	MSE, Inc.
RF0	Rocky Flats Environmental Technology Office
RF1	Rocky Flats Plant/EG&G
RL0	Richland Operations Office
RL2	Kaiser Engineers Hanford Company (KEH)
RL3	Pacific Northwest Laboratory (PNL)/Battelle Memorial Institute
RL4	Westinghouse Hanford Company
SF0	Oakland Operations Office
SF1	Lawrence Berkeley Laboratory (LBL)/University of California
SF2	Lawrence Livermore National Laboratory (LLNL)/University of California
SF3	Energy Technology Engineering Center (ETEC)
SR0	Savannah River Operations Office
SR1	Westinghouse Savannah River Company (WSRC)

Character 4

1	FY 1991
2	FY 1992
3	FY 1993
4	FY 1994
5	FY 1995
6	FY 1996
7	FY 1997
8	FY 1998
9	FY 1999
0	FY 2000