Office of Environmental Management
Office of Technology Development

**Heavy Metals
Contaminated Soil Project,
Resource Recovery Project,
and Dynamic Underground
Stripping Project**

Technology Summary

February 1994

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HEAVY METALS CONTAMINATED SOIL PROJECT, RESOURCE RECOVERY PROJECT AND DYNAMIC UNDERGROUND STRIPPING PROJECT

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OFFICE OF TECHNOLOGY DEVELOPMENT OVERVIEW

The Department of Energy (DOE) established the Office of Technology Development (EM-50) (OTD) as an element of Environmental Restoration and Waste Management (EM) in November, 1989 (see Figure A). The organizational structure of EM-50 is shown in Figure B.

EM manages remediation of all DOE sites, as well as wastes from current operations. The goal of the EM program is to minimize risks to human health, safety and the environment, and to bring all DOE sites into compliance with Federal, state, and local regulations by 2019. EM-50 is charged with developing new technologies that are safer, faster, more effective and less expensive than current methods.

Figure A. DOE Organizational Structure as of June 1993.

In an effort to focus resources and address opportunities, EM-50 has developed Integrated Programs (IPs) and Integrated Demonstrations (IDs).

An Integrated Program focuses on developing technologies to solve a specific aspect of a waste management or environmental problem either unique to a site or common to many sites. An Integrated Program supports 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 Integrated Demonstration is a cost-effective mechanism that assembles a group of related and synergistic technologies to evaluate their performance individually, or as a complete system, in correcting waste management and environmental problems from cradle to grave.

Figure B. Office of Technology Development Organizational Structure as of June 1993.

HEAVY METALS CONTAMINATED SOIL PROJECT, RESOURCE RECOVERY PROJECT, AND DYNAMIC UNDERGROUND STRIPPING PROJECT OVERVIEW

DOE has performed its strategic mission through the operation of numerous research and production facilities. The DOE facilities occupy an area of approximately 2,800 square miles within the contiguous United States. Activities conducted at DOE facilities have included:

- multidisciplinary research;
- enrichment (e.g., uranium) and production (e.g. plutonium and tritium) of nuclear materials;
- spent fuel reprocessing;
- development, testing and fabrication of nuclear and non-nuclear weapons;
- construction and testing of nuclear reactors; and
- the management of various radioactive wastes and spent fuels.

Some wastes at DOE facilities are stored in tanks (e.g. high-level waste (HLW)) or in the ground in a retrievable form before permanent subsurface disposal. However, most wastes (by volume) have been disposed of to the ground surface, ponds, cribs, basins, pits, piles, injection wells, and landfills, leading to subsurface contamination. Subsurface contamination is also the result of leaks from process sewer lines, fuel and hazardous waste, underground storage tanks, and breached drums of buried chemicals and waste. In the early days of DOE operations, environmental disposal was common and was believed to have limited long-term implications. However, many of the individual chemical constituents in the wastes are now of health concern, and they either are regulated under Federal and state laws or are currently under evaluation for possible regulatory control.

More than 3,000 inactive waste sites have been identified at DOE facilities. The extent and complexity of the contamination by hazardous and mixed hazardous wastes at DOE facilities vary with the facility's mission, size and waste management practices. Even though many waste sites have been identified, the extent and complexity of subsurface contamination at DOE facilities are still largely unknown as a result of several factors. For example, completeness of records describing quantity and types of chemicals disposed of at an individual waste site varies. At some sites, a disparity exists between the chemicals reported to have been disposed of and those analytically determined to be in the underlying ground waters.

Soils and sediments are contaminated with radionuclides (e.g., uranium, plutonium, cesium, thorium, strontium, tritium, and technetium); metals (e.g., chromium, mercury and lead); and anions (e.g., nitrate, fluoride, and cyanide); chlorinated solvents such as trichloroethylene, tetrachloroethylene and carbon tetrachloride; fuel hydrocarbons such as benzene, toluene, xylene and polycyclic aromatic hydrocarbons; plasticizers such as phthalates; PCBs; alkyl phosphates; conventional explosives such as RDX, HMX and TNT; complexing agents, organic acids, pesticides and other miscellaneous materials and liquids. These compound classes have been reported in groundwaters at concentrations ranging from trace (ppb) to parts per thousand (ppt) levels. In the case of radionuclides, radioactivity in groundwaters has been reported in concentration ranges from picocuries per liter (pCi/L) or less, up to millicuries per liter (mCi/L).

It is with this in mind that OTD has begun to search out, develop, test and demonstrate technologies that can now or in the future be applied to the enormous remediation problem now facing the DOE and the United States public in general.

The following technology demonstration projects have been designed to attack a separate problem as defined by DOE. The Heavy Metals Contaminated Soil Project was conceived to test and demonstrate off-the-shelf technologies (dominantly from the mining industry) that can be brought to bear on the problem of radionuclide and heavy metal contamination in soils and sediments. The Resource Recovery Project is tasked with identifying, developing, testing, and evaluating new and innovative technologies for the remediation of metal contaminated surface and groundwater. An innovative twist on this project is the stated goal of recovering the metals, formerly disposed of as a waste, for reuse and resale, thereby transforming them into a usable resource. Finally, the Dynamic Underground Stripping Project was developed to demonstrate and remediate underground spills of hydrocarbons from formations that are 1) too deep for excavation, and/or 2) require in-situ remediation efforts of long duration. This project has already been shown effective in reducing the time for remediation by conventional methods from an estimated 200 years at the Lawrence Livermore National Laboratory (LLNL) to less than one year. The savings in time and dollars from this technology alone can be immeasurable.

Heavy Metals Contaminated Soil Project

Section 1.0

1.0 HEAVY METALS CONTAMINATED SOIL PROJECT

TASK DESCRIPTION

The primary objective of this project is to conduct treatability studies on soils from the Fernald site, Idaho National Engineering Laboratory (INEL), Hanford site, Los Alamos National Laboratory (LANL), and any other DOE site that may wish to participate, for the following purposes:

- To determine the decontamination efficiencies of various processes using soils contaminate with plutonium, uranium, or other heavy metals from DOE sites;
- To provide sufficient data concerning physical and chemical characteristics of the contaminated soils from the various participating DOE sites to permit optimization of treatment processes for specific soil. These data include: soil particle size distribution, its radionuclide distribution as a function of particle size, physical and chemical characteristics, and the mineralogical composition; and
- To minimize uncertainties in performance efficiency and cost as related to decontamination of soils.

Successful decontamination of the soils is defined as a minimum 80% reduction in the volume of soil that will need to be disposed of or further treated.

TECHNOLOGY NEEDS

The volume of contaminated soil requiring treatment and disposal throughout the DOE Com-

plex is large. An estimated 20-25 million cubic feet of plutonium-contaminated soil exists at the Nevada Test Site (NTS) and the adjacent Tonopah Test Range (TTR), and one area at INEL contains 12 million cubic feet of soil contaminated with plutonium and other heavy metals. Other sites that have plutonium- or uranium-contaminated soil volumes of this order of magnitude or larger, which must be excavated and disposed of, include Operable Unit 2 at the Rocky Flats Plant, Operable Unit 5 at the Fernald Environmental Management Project (FEMP), LANL, and the DOE Richland Operations Office's Hanford, Washington sites.

DOE has identified a need to develop, test, and demonstrate technologies for the remediation of soils contaminated by various metals. Such technology includes soil and vegetation removal, reduction of the volume of contaminated soil (the focus of this project), and ultimate disposal of the contaminated fraction. The costs of disposing of large volumes of contaminated soil in Land Disposal Facilities (LDFs) are relatively high. At the NTS, the current disposal fee for bulk wastes is \$10 per cubic foot, excluding excavation, handling and transportation expenses. Therefore, the theoretical minimum cost for disposing of plutonium-contaminated NTS soil would be on the order of \$200 million. Excavation using conventional methods produces waste volumes several times larger than the in situ contaminated volume. Estimates based upon the use of conventional excavation technologies indicate that the total remediation cost could be as much as ten times larger, thus increasing NTS costs alone to as much as \$2 billion.

Technologies developed in this project have the potential to significantly reduce these costs by

reducing the contaminated fraction to a maximum of 20% of the original volume.

ACCOMPLISHMENTS

- Completed testing of seven off-the-shelf technologies with surrogate doped soils.
- Arranged receipt of soils from Fernald, LANL, INEL, Hanford, and Mound.
- Designed and built, at the University of Nevada in Reno, a lab capable of handling these contaminated soils, while ensuring the health and safety of the workers, public, and environment.
- Enlisted the analytical expertise of the Environmental Protection Agency (EPA) in Montgomery, Alabama to ensure the accuracy of the testing and to provide the researcher with quality data from which to make their determinations.

COLLABORATION/TECHNOLOGY TRANSFER

This project is being executed for DOE by the University of Nevada at Reno (UNR) through a subcontract from MSE, Inc., of Butte, Montana. MSE has procured a Campbell Centrifugal Jig from Trans Mar, Inc., of Spokane, Washington, and an Air-Sparged Hydrocyclone from Advanced Processing Technologies, Inc., of Salt Lake City, Utah, for testing at the UNR facility. The United States Naval Academy (USNA) in Annapolis, Maryland, will supply the project with an air-classification unit obtained from SEPOR. High Gradient Magnetic Separation technology will be tested and evaluated at and by personnel from LANL. In addition, UNR has three technologies that will also be tested; these are a

Knelson Concentrator, a Denver Cell and Column Flotation technology. All seven of these technologies are described later in this report.

The data gathered from this project will be supplied to all DOE sites that are participating, as well as any other site that might be interested in this type of treatment. All information will also be transferred to EM's Office of Environmental Restoration (EM-40) for their evaluation and potential incorporation into their restoration activities. All test results will be made available to the public, the UNR library system, and anyone involved in the restoration of contaminated sites. Discussions are also being held with personnel from Australia.

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1.1 TECHNOLOGIES TO SEPARATE HEAVY METALS AND RADIONUCLIDES FROM SOIL

The Air-Sparged Hydroclone (ASH)

The Air-sparged hydroclone (ASH) flotation is a new particle separation technology that has been under development at the University of Utah and Advanced Processing Technologies, Inc. This technology combines froth flotation principles with the flow characteristics of a hydroclone, such that the ASH system can perform flotation separations in less than a second. This feature provides the ASH with a high processing capacity, 100-600 times greater than the capacity of conventional flotation or columns.

The ASH consists of two concentric right-vertical tubes, a conventional cyclone header at the top, and a froth pedestal at the bottom (Figure 1.1.a). The inner tube has a porous wall (plastic, ceramic, or stainless steel) through which air is

injected. The outer non-porous tube simply serves as an air jacket to provide for even distribution of air through the porous inner tube. The slurry is fed tangentially through the conventional cyclone header to develop a swirl flow of a certain thickness in the radial direction (called the swirl layer thickness) adjacent to the porous wall, leaving an empty air core centered on the axis of the ASH. This swirl flow shears the injected air to produce a high concentration of small bubbles. Hydrophobic particles in the slurry collide with these bubbles, and after attachment, lose some of their tangential velocity and centrifugal momentum, and are transported radially into a froth phase that forms at the surface of the air core on the cyclone axis. The froth phase is stabilized and constrained by a froth pedestal at the underflow and thus moves towards the vortex finder of the cyclone header and is discharged as an underflow product

through the annual opening between the inner porous wall and the froth pedestal.

The Campbell Centrifugal Jig (CCJ)

The Campbell Centrifugal Jig (CCJ) is a patented new technology developed by TransMar, Inc., of Spokane, Washington, to separate fine, heavy mineral particles from gangue material (i.e. waste). The CCJ is a combination of two

Figure 1.1.a Air-Sparged Hydroclone Technology.

widely used methods of dense particle separation: jigging and centrifuging. The CCJ combines the effectiveness of continuous flow and pulsating bed of the standard mineral jig with the high "g" forces of the centrifuge. The manner in which this is accomplished is shown in Figure 1.1.b, a schematic showing major elements and flow patterns in the CCJ. The slurry material enters the CCJ through the hollow shaft and is thrown radially outward by the vanes on the diffuser plate to impact on the batter plate, which distributes it over the rotating screen. Pulse blocks rotate with the hutch and screen, and each time they align with one of the inlet ports, the pulse blocks provide a high pressure intensity water pulse to the outside of the screen, keeping the material fluidized. Heavy particles migrate through the bed and screen and enter the hutch to be recovered through the discharge ports as concentrate. Lighter particles are flushed downward across the jig bed and become tailings.

The Heavy Metals Contaminated Soil Project Phase 1 testing indicated that the CCJ can reliably remove from 70 to over 90 percent of the contaminate from gangue material (to the extent

that bismuth is an adequate surrogate for plutonium oxide). In addition, it can reduce the contaminated volume by factors from close to 100 to over 600 in a single pass through the system; standard gravity separation uses several jigs in a series. It was also demonstrated that the CCJ can successfully operate on very small quantities of feed (1,500 to 2,000 pounds) and for short durations (30 minutes or less).

Centrifugal Gravity Concentrator

The Centrifugal Gravity Concentrator utilizes the principle of hindered settling combined with centrifugal action (Figure 1.1.c). This is made possible with a proprietary mechanism of a water-jacketed perforated cone fed through a hollow shaft-hydraulic device. Gravity concentration devices, like the Centrifugal Gravity Concentrator, depend upon differences in particle size, particle specific gravity, or both (i.e. particle mass) for their effectiveness.

The UNR unit is a centrifugal bowl concentrator with a water jacket around the bowl, essentially a modified centrifuge. Feed slurry

enters the rotating ribbed bowl where heavier particles are trapped between the ribs. Compaction of the material between the ribs is prevented by injecting water through holes in the bowl. The water fluidizes the bed and allows heavier particles to continuously displace lighter particles. The water addition is the key to the performance of the Centrifugal Gravity Concentrator. The degree of

Figure 1.1.b Schematic of the Campbell Centrifugal Jig Technology.

Figure 1.1.c Centrifugal Gravity Separation Technology.

fluidization controls the effectiveness of separation.

The Centrifugal Gravity Concentrator used in these experiments is a 3-inch stainless steel lab model. A motorized force of 60g is exerted on the medium. The concentrator handles either coarse or fine feed at 25% solids. The model's dimensions are 24 inches in length, 16 inches in width, and 20 inches in height.

Tall Column Flotation

The effectiveness of mechanical flotation devices decreases in ultra-fine

particle size largely because of the large bubble size (as large as 1 mm) and turbulent conditions present in the cell. The column flotation technology has been very popular and effective recently in the flotation of ultra-fine particles. Considering the fact that a large fraction of radionuclides is present in the 38 micron size soil and its concentration is in parts per billion (ppb) range, it is conceivable that a combination of conditions such as fine bubble size (30-60 microns), quiescent conditions, and froth drainage mechanism prevalent in the column will result in selective separation of discrete ultra-fine radionuclides from contaminated soil.

The column flotation is a tall device, having at least a length-to-diameter ratio of 10:1 (Figure 1.1.d). The reagentized slurry is fed

Figure 1.1.d Column Flotation Technology.

at the upper portion of the column and travels downward.

The hydrophobic particles attach to the rising stream of fine bubbles generated at the bottom of the column. The swarm of air bubble-laden particles are further washed at the top of the column to minimize the entrainment of unwanted material (in this case, clean soil). The radionuclide-enriched soil fraction overflows at the top of the column and hydrophilic clean soil unattached to bubbles is collected at the bottom.

The UNR column is made of plexiglass in four sections, measuring 2 inches in diameter and 10 feet tall. An external bubble generator system is attached to it at the bottom, which consists of an in-line mixer and a variable speed centrifugal pump. The level control system consists of overflow tubing, a sand-gate valve, and two flow meters (one for wash water and the other for air addition). The automatic level control system is made up of a pressure transducer, controller, and tailings discharge pump.

Automated Mechanical Flotation (Denver Unit)

Flotation is a physico-chemical process in which one mineral constituent can selectively be separated from another on the basis of surface properties. This is achieved by adding controlled additions of chemical reagents at a predetermined pH, thereby selectively altering the surface characteristics of radionuclide enriched particulates. This treatment renders soil particles contaminated with radionu-

clides as hydrophobic (water repellent). Phase separation is then followed by passing air through reagentized slurry. Air bubbles selectively attach to radionuclide-enriched soil particles and are levitated to the surface in the form of froth. The separation of soil particles contaminated with radionuclides thus renders the remaining soil clean.

The Automated Mechanical Cell (Figure 1.1.e), developed by UNR, is a modification of the Denver D-12 laboratory machine that incorporates a 120 VAC adjustable automated froth removal system and a controller to maintain constant pulp-froth interface. The modification to the Denver unit is in the mounting of the main shaft. The unit has been outfitted with a 90-degree pivoting elbow with a keyed shaft allowing height adjustment and rotation of the unit into operating position. The unit has an adjustable speed motor with a two-blade froth removing paddle. Critical operational adjustments are made by 1) moving the motor housing laterally on the shaft to regulate clearance in the paddle-dam relationship without the need for any locking mechanism, and 2) moving the vertical collar pivot up or down to set the paddle depth into the froth.

Figure 1.1.e Automated Mechanical Flow Technology.

The froth collection system consists of a tapered bottom and inclined trough to collect heavy radionuclides. The pulp-froth interface level control is achieved by sensing the vertical position of a float in a sight glass by a proximity switch. The switch is connected to solenoid valves and flow regulators.

High Gradient Magnetic Separation

Los Alamos National Laboratory, in conjunction with its industrial partner Lockheed Environmental Systems and Technology Co., is exploring a promising new technique that could be used to remove radioactive contaminants from soils. The technique, high-gradient magnetic separation (HGMS), takes advantage of the fact that all actinide compounds are slightly magnetic. Much of the contaminated soil contains plutonium and uranium oxide particles; these slightly magnetic particles are attracted by very strong magnetic fields and thus can be separated from the mostly nonmagnetic soil. The availability of reliable superconducting magnets, which create very strong magnetic fields, makes HGMS an attractive method for extracting actinide contaminants. Preliminary experiments with magnetic surrogates and modeling of the process have yielded encouraging results. Contaminated soil samples from DOE sites are now being tested, and the partners are working to develop the process for full-scale site remediation.

To begin the HGMS process, a slurry is made by mixing contaminated soil with water. This slurry then flows through a chamber filled with a matrix that can be magnetized, such as steel wool (see Figure 1.1.f). A superconducting magnet surrounding the chamber produces a magnetic field strong enough to cause the magnetic particles, including the actinides, to adhere to the matrix. After the batch of slurry has passed through the chamber, the magnetic field is removed and water flows through the matrix to flush out the radioactive particles. The residue is then concentrated and packaged for proper storage or disposal, the waste and matrix are recycled, and the soil from the slurry is returned to the environment, if it is sufficiently decontaminated.

Figure 1.1.f High Gradient Magnetic Separation Technology.

The Sepor System

The U.S. Naval Academy (USNA) Sepor system is a commercially available, bench-scale air separation technology being evaluated by the USNA to remove heavy metals from soils.

The system produces two effluent streams, one containing predominately smaller sized particles

cally imparts a greater radial velocity to the larger size particles. The soil particles, which on average are larger than the heavy metal particles, move more rapidly to the separating chamber wall, where they then drop down and are collected as they exhaust through the discharge pipe. The smaller particles are carried upward by the air, which is being circulated through the chamber by the main fan. Some of the smaller

particles reenter the separating chamber through baffles, which are located near the bottom of the separating chamber. Eventually most of the smaller sized particles drop through the fine discharge pipe. The USNA Sepor system is a bench-scale system with an 18" diameter. The system has a soil feed capacity of 800 lbs/hr. Feedrate of soil into the Sepor is controlled by a volumetric screw-type feeder, and can be varied through a wide range.

Sieving of the effluent is being investigated to improve the concentrating effect of the process. Airborne particulate emission is also being studied through the use of an MIE real-time airborne particulate monitor. System design modifications are being implemented in order to minimize the re-

lease of airborne particles during testing, as well as minimize soil hangup inside the Sepor.

Figure 1.1.g Sepor System.

and referred to as the fine discharge, and the other containing predominately larger particles, referred to as the coarse discharge. It is the goal of the evaluation to concentrate most of the heavy metal in one of the effluent streams, so as to reduce the volume of contaminated soil requiring site removal.

The USNA Sepor system uses a centrifugal force effect to achieve separation. A schematic of this system is shown in Figure 1.1.g. The contaminated soil is fed into this system through a feed pipe, whereupon it then falls into a separating chamber. Separation is achieved through action of a centrifugal fan, which aerodynami-

Resource Recovery Project

TASK DESCRIPTION

The Resource Recovery Project (RRP) will evaluate, test and demonstrate technologies, at pilot scale, for reclamation of both surface and groundwater from dilute heavy metal aqueous solutions. The project will emphasize recovery of valuable mineral resources, including heavy and/or precious metals, as well as industrial minerals. Economic analyses of each technology and the resources recovered will be used to project resource recovery and/or remediation costs for similar DOE and industrial sites using similar technologies. The project will focus on resource conservation and end-use applications of the recovered resources by maximizing resource utilization and minimizing non-useable byproducts. Resource utilization will address industrial, commercial, municipal/governmental, agricultural and recreational uses of water, metals, and other resources.

Economic and technical feasibility analyses of each technology demonstrated will be conducted. The analyses will include potential revenues from sales of water and mineral resources. Cost/benefit analyses will be an integral part of the project. The data obtained will demonstrate, at pilot scale, which technologies are the most effective at recovering resources and remediating contaminated waters, and which are the most cost efficient, including the cost realized from resource utilization. The data gathered will allow for the timely and cost-effective selection of appropriate reclamation technologies at various sites throughout the DOE Complex. Through technology transfer, the data generated can also be applied to other Federal agency (particularly, the Bureau of Mines) and private-sector sites.

TECHNOLOGY NEEDS

Heavy metal contaminated water is a nationwide problem. Heavy metals pose a significant threat to both human health and safety and aquatic environments. Some metals are neurotoxins (lead, mercury, cadmium), while others form potentially carcinogenic organometallics.

There are currently more than 300,000 abandoned hard rock mines in the United States that pose a threat to health and the environment due to acid mine drainage. Runoff containing acids, metals, and chemicals from abandoned mine sites has contaminated more than 12,000 miles of rivers and streams and more than 180,000 lakes and reservoirs.

Surface and groundwater contamination by heavy metals is a problem at numerous sites within the United States. Over 75% of all sites on the National Priorities List (Superfund) have surface or groundwater contamination. DOE has identified heavy metal contaminated ground and surface water at numerous facilities, while the Department of Defense (DoD) has identified heavy metal contamination at over 900 Army installations, and contamination from heavy metal-bearing wastewater from 93 industrial-type DoD installations.

ACCOMPLISHMENTS

- Completed legal and regulatory issues report.
- Issued Berkeley Pit Water Quality characterization interim report.
- Established technology selection criteria and formed technology selection committee.
- Currently identifying markets for clean water and recovered metals/minerals.
- Initiated government and industry partnerships for technology implementation.
- Began modification of existing facility to house demonstrations.
- Plan to issue Request for Proposal for FY94 technology demonstrations in 1994.
- Selection of three to five technologies for demonstration during FY94 will be made during the second quarter of FY94, with demonstrations beginning during the third quarter of FY94.

COLLABORATION/TECHNOLOGY TRANSFER

The RRP is in active partnership with many public and private sector interests. Public sector participants include DOE, the State of Montana, the EPA, the Western Governors' Association, the Montana Bureau of Mines and Geology, the Colorado Center for Environmental Management, the National Institutes of Water Resources,

the Montana College of Mineral Science and Technology (Montana Tech), and the American Alliance for Environment and Trade. Private sector participants include industrial mining and smelting companies, technology providers from throughout the United States, Superfund responsible parties, environmental public interest groups, and others.

The RRP prepared a Business Plan to be used on specific technologies not yet commercialized. The plan is designed to assist and facilitate technical and business alliances between technology providers, remedial problem-holders, venture capitalists, and other financial institutions. These government/industry alliances and partnerships play a key role in the national effort to reclaim contaminated water and recover those same "contaminants" as marketable industrial/commercial resources.

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Dynamic Underground Stripping Project

Section 3.0

3.0 DYNAMIC UNDERGROUND STRIPPING PROJECT

TASK DESCRIPTION

This project has demonstrated integrated techniques for rapid and efficient stripping of gasoline from the ground. Dynamic Underground Stripping is a technology integration of vacuum extraction and direct electric heating or steam injection (depending on the substrate), and geophysical imaging for the remediation of saturated and unsaturated soil zones. Cyclic steam injection combined with vacuum extraction has been successfully demonstrated for sandy soils, whereas the integration of electrical heating and vacuum extraction has been demonstrated for clay soils. These combined techniques have enhanced both the speed and efficiency of the removal process. The concentrated effluent waste stream has been treated by a number of methods, providing for the comparison of the effectiveness and efficiency of each technique. Evaluation and testing of new techniques for site characterization and monitoring was also carried out throughout the cleanup phase. Integrated hydrologic, geophysical and chemical models were developed, demonstrated and validated during the operation of the project. The successful demonstration of these technologies has yielded an integrated, transferrable cleanup methodology(ies) that are much more rapid, controllable and efficient than existing technology (pump-and-treat with vacuum extraction).

TECHNOLOGY NEEDS

- 2.5 million underground storage tanks (containing petroleum products) exist in the United States, thousands of which

have leaked to form concentrated plumes of contamination.

- It is amenable to all types of liquid contamination including non-aqueous phase liquids (NAPLS) and dense NAPLS (DNAPLs), and potentially mixed waste.
- Dynamic stripping is applicable to free-phase organic plumes below 20 foot depths, the general limit for excavation.

ACCOMPLISHMENTS

- The system was tested at a clean site and appropriate changes were made prior to use at the contaminated site.
- The first full-scale test of the process has recently been completed at LLNL.
- Results indicate that the process is fifty times as effective as the conventional pump-and-treat process, now being used at 300 designated Superfund sites.
- The technique has removed more than 8,000 gallons of gasoline trapped above and below the water table, and above the clay layer.
- Differential Ultraviolet Absorption Spectroscopy (DUVAS) was successfully demonstrated for use in real-time control of the dynamic underground stripping process.

- Electrical resistance tomography was successfully used for between-well imaging of heated zones for control of steam injection rates.
- The use of tilt meters, a non-invasive technique, to measure shallow hydrogeologic phenomena, was successfully accomplished.
- Free product (gasoline) appears to have been removed from the treated area.
- Direct electrical heating has been successfully used as an aid in polishing the remaining free product at the site.
- Thirteen basic patents have been applied for.
- Licensing agreements with several companies are under discussion.

COLLABORATION/TECHNOLOGY TRANSFER

The remediation process was developed and implemented in collaboration with the University of California at Berkeley, LLNL, and ORNL. The process has been successfully transferred to EM's Office of Environmental Restoration in October 1993 for continued and expanded remediation of LLNL and other DOE sites.

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How To Get Involved

Section 4.0

4.0

HOW TO GET INVOLVED

WORKING WITH THE DOE OFFICE OF ENVIRONMENTAL RESTORATION AND WASTE 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 and management and operating contractors, EM uses conventional and innovative mechanisms to identify, integrate, develop, and adapt promising emerging technologies. These mechanisms include contracting and collaborative arrangements, procurement provisions, licensing of technology, consulting arrangements, reimbursable work for industry, and special consideration for small business.

Cooperative Research and Development Agreements (CRADAs)

EM will facilitate the development of subcontracts, R&D contracts, and cooperative agreements to work collaboratively with the private sector.

EM uses CRADAs as an incentive for collaborative R&D. CRADAs 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 access to facilities and expertise; however, no Federal funds are provided to external participants. Rights to inventions and other intellectual property are negotiated between the laboratory and participant, and certain data that are generated may be protected for up to 5 years.

Consortia will also be considered for situations where several companies will be combining their resources to address a common technical problem. Leveraging of funds to implement a consortium can offer a synergism to overall program effectiveness.

Procurement Mechanisms

DOE EM has developed an environmental management technology development acquisition policy and strategy that uses phased procurements to span the RDDT&E continuum from applied R&D concept feasibility through full-scale remediation. DOE EM phased procurements make provisions for unsolicited proposals, but formal solicitations are the preferred responses. The principle contractual mechanisms used by EM for industrial and academic response include Research Opportunity Announcements (ROAs) and Program R&D Announcements (PRDAs). EM uses the ROA to solicit advanced research and technologies for a broad range of cleanup needs. The ROA supports applied research ranging from concept feasibility through full-scale demonstration. 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 and the Commerce Business Daily, and multiple awards are made.

PRDAs are program announcements used to solicit a broad mix of R&D and DT&E proposals. Typically, a PRDA is used to solicit proposals for a wide-range of technical solutions to specific EM problem areas. PRDAs may be used to solicit proposals for contracts, grants, or cooperative agreements. Multiple awards, which may have dissimilar approaches or concepts, are generally made. Numerous PRDAs may be issued each year.

In addition to PRDAs and ROAs, EM uses financial assistance awards when the technology is developed for public purpose. Financial assistance awards are solicited through publication in the Federal Register. These announcements are called Program Rules. A Program Rule can either be a one-time solicitation or an open-ended, general solicitation with annual or more frequent announcements concerning specific funding availability and desired R&D agreements. The Program Rule can also be used to award both grants and cooperative agreements.

EM awards grants and cooperative agreements if fifty-one percent 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 use, advancement of present and future U.S. capabilities in domestic and international environmental cleanup markets, technology transfer, advancement of scientific knowledge, and education and training of individuals and business entities to advance U.S. remediation capabilities.

Licensing of Technology

DOE contractor-operated laboratories can license DOE/EM-developed technology and software to which they elect to take title. In other situations where DOE owns title to the resultant inventions, DOE's Office of General Counsel will do the licensing. Licensing activities are done within existing DOE intellectual property provisions.

Technical Personnel Exchange Assignments

Personnel exchanges provide opportunities for industrial and laboratory scientists to work together at various sites on environmental restoration and waste management technical problems of mutual interest. Industry is expected to 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 exchanges, which can last from 3 to 6 months, are opportunities for the laboratories and industry to better understand the differing operating cultures, and are an ideal mechanism for transferring technical skills and knowledge.

Consulting Arrangements

Laboratory scientists and engineers are available to consult in their areas of technical expertise. Most contractors operating 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 industry, or 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 and unique facilities at DOE laboratories are an incentive for the private sector to use DOE's facilities and contractors expertise in this reimbursable work for industry mode. An advanced class patent waiver gives ownership of any inventions resulting from the research to the participating private sector company.

EM Small Business Technology Integration Program

The EM Small Business Technology Integration Program (SB-TIP) seeks the participation of small businesses in the EM Research, Development, Demonstration, Testing and Evaluation programs. Through workshops and frequent communication, the EM SB-TIP provides information on opportunities for funding and collaborative efforts relative to advancing technologies for DOE environmental restoration and waste management applications.

EM SB-TIP has established a special EM procurement set aside for small firms (500 employees or less) to be used for applied research projects, through its ROA. The program also serves as the EM liaison to the DOE Small Business Innovation Research (SBIR) Program Office, and interfaces with other DOE small business offices, as well.

CONTACT

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Environmental Restoration and Waste
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EM Central Point of Contact

The EM Central Point of Contact is designed to provide ready access to prospective research and business opportunities in waste management, environmental restoration, and decontamination and decommissioning activities, as well as information on EM-50 IPs and IDs. The EM Central Point of Contact can identify links between industry technologies and program needs, and provides potential partners with a connection to an extensive complex-wide network of DOE Headquarters and field program contacts.

The EM Central Point of Contact is the best single source of information for private-sector technology developers looking to collaborate with EM scientists and engineers. It provides a real-time information referral service to expedite and monitor private-sector interaction with EM.

To reach the EM Central Point of Contact, call 1-800-845-2096 during normal business hours (Eastern time).

Office of Research and Technology Applications

Office of Research and Technology Applications (ORTAs) serve as technology transfer agents at the Federal laboratories, and provide an internal coordination in the laboratory for technology transfer and an external point of contact for industry and universities. To fulfill this dual purpose, ORTAs license patents and coordinate technology transfer activities for the laboratory's scientific departments. They also facilitate one-on-one interactions between the laboratory's scientific personnel and technology recipients, and provide information on laboratory technologies with potential applications in private industry for state and local governments.

**For more information about these programs and services,
please contact:**

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Acronyms

Section 5.0

5.0

ACRONYMS

ASH	Air-Sparged Hydrocyclone
CCJ	Campbell Centrifugal Jig
CRADA	Cooperative Research and Development Agreement
DNAPLs	dense NAPLS
DoD	Department of Defense
DOE	Department of Energy
EM	Environmental Restoration and Waste Management
EPA	Environmental Protection Agency
FEMP	Fernald Environmental Management Project
HGMS	high-gradient magnetic separation
HLW	high-level waste
ID	Integrated Demonstrations
IP	Integrated Programs
INEL	Idaho National Engineering Laboratory
LANL	Los Alamos National Laboratory
LDFs	Land Disposal Facilities
LLNL	Lawrence Livermore National Laboratory
NAPLs	non-aqueous phase liquids
NTS	Nevada Test Site
ORTAs	Office of Research and Technology Applications
OTD	Office of Technology Development (EM-50)
PRDAs	Program R&D Announcements
ROAs	Research Opportunity Announcements
RRP	Resource Recovery Project
SBIR	Small Business Innovation Research
SB-TIP	Small Business Technology Integration Program
TTR	Tonopah Test Range
UNR	University of Nevada at Reno
USNA	United States Naval Academy

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