

Office of Environmental Management  
Office of Technology Development

**Oakland  
Operations Office  
Oakland, California**

**Technology Summary**

————— **November 1994**

**MASTER**

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# OAKLAND OPERATIONS OFFICE

## TECHNOLOGY SUMMARY

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## Foreword

This document has been prepared by the Department of Energy's (DOE) Environmental Management (EM) Office of Technology Development (OTD) to highlight its research, development, demonstration, testing, and evaluation (RDD&E) activities funded through the Oakland Operations Office. Technologies and processes described have the potential to enhance DOE's cleanup and waste management efforts, as well as improve U.S. industry's competitiveness in global environmental markets. The information has been assembled from recently produced OTD documents which highlight technology development activities within each of the OTD program elements. These Technology Summaries (as well as other OTD documents) can be obtained through the EM Central Point-of-Contact at 1-800-845-2096 and include the following:

*VOCs in Non-Arid Soils Integrated Demonstration, February 1994 - DOE/EM-0135P*  
*VOCs in Arid Soils Integrated Demonstration, February 1994 - DOE/EM-0136P*  
*Mixed Waste Landfill Integrated Demonstration, February 1994 - DOE/EM-0128P*  
*Uranium in Soils Integrated Demonstration, February 1994 - DOE/EM-0148P*  
*Characterization, Monitoring, and Sensor Technology Integrated Program, February 1994 - DOE/EM-0156T*  
*In Situ Remediation Integrated Program, February 1994 - DOE/EM-0134P*  
*Buried Waste Integrated Demonstration, February 1994 - DOE/EM-0149P*  
*Underground Storage Tank Integrated Demonstration, February 1994 - DOE/EM-0122P*  
*Efficient Separations and Processing Integrated Program, February 1994 - DOE/EM-0126P*  
*Mixed Waste Integrated Program, February 1994 - DOE/EM-0125P*  
*Rocky Flats Compliance Program, February 1994 - DOE/EM-0123P*  
*Pollution Prevention Program, February 1994 - DOE/EM-0137P*  
*Innovative Investment Area, March 1994 - DOE/EM-0146P*  
*Robotics Technology Development Program, February 1994 - DOE/EM-0127P*

This document represents one in a series for each of DOE's Operations Offices and Energy Technology Centers. For more information on activities funded through the Oakland Operations Office or its affiliated laboratories, please contact:

**Richard Scott**  
Technical Program Officer  
Oakland Operations Office  
(510) 637-1623



## INTRODUCTION

### DOE's Office of Technology Development

DOE's Office of Technology Development manages an aggressive national program for applied research, development, demonstration, testing, and evaluation. This program develops high-payoff technologies to clean up the inventory of DOE nuclear component manufacturing sites and to manage DOE-generated waste faster, safer, and cheaper than current environmental cleanup technologies.

OTD programs are designed to make new, innovative, and more effective technologies available for transfer to users through progressive development. Projects are demonstrated, tested, and evaluated to produce solutions to current problems. Transition of technologies into more advanced stages of development is based upon technological, regulatory, economic, and institutional criteria. New technologies are made available for use in eliminating radioactive, hazardous, and other wastes in compliance with regulatory mandates. The primary goal is to protect human health and prevent further contamination.

OTD technologies address three specific problem areas: (1) groundwater and soils cleanup; (2) waste retrieval and processing; and (3) pollution prevention. These problems are not unique to DOE, but are associated with other Federal agency and industry sites as well. Thus, technical solutions developed within OTD programs will benefit DOE, and should have direct applications in outside markets.

OTD's approach to technology development is an integrated process that seeks to identify technologies and development partners, and facilitates the movement of a technology from applied research to implementation. In an effort to focus resources and address opportunities, OTD 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. Integrated Programs support applied research activities in key application areas 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, for solving waste management and environmental problems from cradle to grave. In addition to the IDs and IPs, OTD supports crosscutting research and development in the area of robotics. The Robotics Technology Development Program (RTDP) is a "needs-driven" effort. RTDP program activities are funded through most of the DOE Operation Offices and focus on solving site-specific as well as complex-wide environmental problems.

OTD's technology maturation philosophy consists of three components: (1) *technology infusion* - technology transfer from industry, universities, and other Federal agencies; (2) *technology adoption* - shared technology demonstration among DOE laboratories, integrated demonstra-

tions, and programs, and (3) *technology diffusion* - technology transfer from demonstration to industry. To enhance opportunities for technology commercialization, OTD is seeking partnerships with private-sector companies during the technology development and demonstration phases. Industry partners will facilitate implementing these emerging technologies to solve the nation's environmental problems.

## **Oakland's Contributions**

The Oakland Operations Office began as an Atomic Energy Commission regional office which regulated and coordinated the programs at the Ernest O. Lawrence Radiation Laboratory, now known as the Lawrence Berkeley Laboratory. As industry and new laboratories with diverse interests became established in the area, the expanding Oakland Operations Office became responsible for more contracts and program management. Today, Oakland supports a wide range of research activities—high-energy particles physics, alternative fuel research, advanced electronics, and biomedicine.

Oakland employs more than 375 full-time Federal staff across a main site in Oakland, California, and oversees four laboratory sites: Lawrence Livermore National Laboratory (LLNL), Lawrence Berkeley Laboratory (LBL), the Stanford Linear Accelerator Center (SLAC), and the Energy Technology Engineering Center (ETEC). Together, the contractor-managed laboratories employ more than 10,000 people.

While remaining committed to programs of national defense, the National Laboratories will continue to diversify by leading research in global warming, space science, and biotechnology and will emphasize environmental safety and health. The future will include more technology transfer and resource sharing among universities, private industries, and the National Laboratories. Oakland's technology transfer program encourages industries to use laboratory research facilities and provides patent assistance so that the technology developed at the laboratory can be transferred to the private sector. This cooperative relationship between the National Laboratories and industry enhances scientific research and improves competitiveness.

### *Dynamic Underground Stripping*

At hundreds of industrial and government sites across the United States, permanent containment systems are being built for underground contaminants such as hydrocarbon fuels, cleaning solvents, and industrial chemicals. In quantities of thousands of liters or more, these chemicals threaten to contaminate drinking water supplies for hundreds of years. Typical containment systems (such as deep wells of cement or clay, or hydraulic pumping to control groundwater movement) can keep chemicals from further contaminating groundwater if they are properly maintained, but they do not remove the contaminants.

As an example of this problem, between 1952 and 1979, tens of thousands of liters of gasoline leaked from an underground storage tank at a former LLNL filling station. In the 1970's, agriculture pumping in the vicinity ceased. The water table rose, trapping gasoline below it and "smearing" the gasoline through clay-rich soils of low permeability. Hydrocarbons trapped below the water table are especially difficult to clean up by traditional methods. The pump-and-treat method, now in use at many Superfund sites, requires pumping huge amounts of groundwater up through an extraction well, followed by removal of any captured contaminant

that comes up with the water. Attempts were made to use this method on the LLNL spill, but little contamination was removed. Another, more innovative method was needed.

A team of researchers from LLNL and the University of California at Berkeley demonstrated a new combination of technologies, collectively called dynamic underground stripping, to rapidly remove gasoline from beneath the LLNL site. In dynamic underground stripping, a targeted volume of earth is heated to vaporize the trapped contaminants. Two methods of heating, steam injection and electrical heating, are used to heat all layers of the soil. Once vaporized, the contaminants are removed by vacuum extraction. All processes, from the heating of the soil to the removal of the contaminated vapor, are monitored and guided by underground imaging.

By late 1993, dynamic underground stripping had removed about 29,000 liters of gasoline from the treatment site. At the surface, about one-third of the fuel was condensed for recycling. Now, after the bulk of contamination has been removed, other methods of soil and groundwater cleanup can be used to remove the remaining contamination.

#### *In Situ Microbial Filters*

Groundwater contaminated with volatile organic compounds, such as trichloroethylene (TCE), is costly and time consuming to remediate with the current pump-and-treat technology. In situ bioremediation of TCE-contaminated groundwater is seen as a possible alternative to pump-and-treat. But this approach, which involves injecting nutrients to stimulate indigenous contaminant-degrading organisms, has been difficult. An interdisciplinary research team at Lawrence Livermore Laboratory has completed laboratory development of in situ microbial filters that shows potential as a more reliable and cost effective field technology.

The technology consists of a sand filter containing TCE-degrading microbes. When this type of filter is placed within a TCE plume, the microbes degrade the TCE and decontaminate the water as the groundwater moves through the filter. Groundwater moves naturally through the in situ microbial filter. Thus, no pumping of water is required. Contaminants are treated below the surface.

A joint DOE/NASA treatability study has been performed for this technology at NASA's Wilson Corners site, part of the Kennedy Space Center in Cape Canaveral, Florida. Groundwater contamination beneath Wilson Corners originated from TCE degreasing operations. In a treatability test, the microbial filter technology was shown to degrade contaminants *in situ*.

About 3 kg of cells is necessary for any pilot-scale study. This mass far exceeds the current biomass production of any DOE facility. The Oakland Operations Office and LLNL are constructing an Environmental Microbial Biotechnology Facility to grow the required biomass for this and other field applications. This unique DOE facility is scheduled to be operational in the near future.

#### *Containment of Contamination by Means of Viscous Liquid Subsurface Barriers*

The strong adsorption of many contaminants to soil particles makes physical extraction slow or ineffective. Excavation of contaminated soils and disposal in protected facilities is very expensive. Containment on-site and control of groundwater transport can limit the off-site

threat. A barrier containment system that does not require excavation may be a useful groundwater contamination control technique.

Formation of a barrier with surface-injected components that change their viscosity under aquifer temperature and pressure conditions would allow barrier emplacement without excavation. Lawrence Berkeley Laboratory is investigating containment of contamination with viscous liquid subsurface barriers. This project will identify and characterize promising barrier materials and will evaluate their potential by laboratory pilot-scale experiments with field testing and demonstrations. In some areas, aquifer mineralogy or regulatory restrictions may limit the use of one or another barrier component. A variety of barrier systems must be available to match the range of contaminants and circumstances.

The first type of barrier fluid under examination belongs to the polybutene family. Polybutenes are chemically and biologically inert, and hydrophobic and impermeable to water and gases. Their performance is unaffected by the soil and waste type, but they are temperature dependent. The second type is colloidal silica, which is a silicone-based chemical grout that poses no health hazards. It is chemically and biologically inert. In addition, it is unaffected by filtration. The third type of barrier fluid contains silicon-based polymers that have been used for medical implants.

#### *Volatile Organic Compounds in Arid Soils Integrated Demonstration (VOC-Arid ID)*

Integrated demonstrations are part of DOE's innovative program to speed up development and testing of new technologies for cleaning up hazardous and radioactive wastes. The VOC in Arid Soils ID focuses on technologies to clean up VOCs and associated contaminants in soil and groundwater at arid sites.

The initial host site is located at Hanford's 200 West area.

The primary VOC contaminant is carbon tetrachloride, in association with heavy metals and radionuclides. An estimated 1,000 tons of carbon tetrachloride were disposed of at Hanford between 1955 and 1973, resulting in extensive soil contamination and a groundwater plume that extends more than seven miles.

The VOC-Arid ID is demonstrating technologies in five major areas: (1) site characterization; (2) retrieval and ex situ treatment of contaminants; (3) in situ destruction or immobilization of contaminants; (4) remediation system design and evaluation; and (5) enhanced drilling. This ID is linked directly to an Expedited Response Action, a cleanup effort that focuses on rapid removal of carbon tetrachloride from the soil. A top priority is transferring new technologies to meet the needs of other arid sites. Success will be the transfer to industry of technologies that are ready for immediate use.

#### *In Situ Remediation Integrated Program (ISR-IP)*

The In Situ Remediation Integrated Program was instituted out of recognition that in situ remediation could fulfill three important criteria:

- Significant cost reduction of cleanup by eliminating or minimizing excavation, transportation, and disposal of wastes.

- Reduced health impacts on workers and the public by minimizing exposure to wastes during excavation and processing.
- Remediation of inaccessible sites, including:
  - deep subsurfaces.
  - in, under, and around buildings.

Buried waste, contaminated soils and groundwater, and containerized wastes are all candidates for in situ remediation. Contaminants include radioactive wastes, volatile and non-volatile organics, heavy metals, nitrates, and explosive materials. The ISR-IP intends to facilitate development of in situ remediation technologies for hazardous, radioactive, and mixed wastes in soils, groundwater, and storage tanks. Near-term focus is on containment of the wastes, with treatment receiving greater effort in future years.

#### *Efficient Separations and Processing Integrated Program (ESPIP)*

DOE sponsors research and development in advanced radiochemical separations to reduce the volume of high-level waste that must be disposed of in deep geological repositories, and to cut the toxicity and volume of low-level acceptable for near-surface disposal. These research and development activities are sponsored throughout the DOE Office of Technology Development ESPIP. ESPIP also develops separation processes to extract high-value materials and non-radioactive hazardous components from nuclear waste and will transfer separations processing to commercial markets.

ESPIP research and development activities are designed to remove radionuclides and hazardous material and chemicals from radioactive defense waste. Radionuclides and other materials under consideration for separation include transuranic elements, such as neptunium, plutonium, americium, and cerium, highly radioactive elements (Strontium-99 and Cesium-137), and long-lived soluble fission products, including technetium-99 and iodine-129. Separation processes will also be developed to extract the long-lived soluble activation product carbon-14; aluminum, phosphorous, and chromium, and the elements that degrade borosilicate glass waste forms; the strategic metals rhodium, palladium, and ruthenium; and Resource Conservation and Recovery Act (RCRA) elements and compounds.

The program oversees efficient separations research and development for DOE sites. Current priorities are the cleanup of high-level waste in USTs at Hanford Production Operation, Hanford, Washington, and the cleanup of high-level waste at Idaho National Engineering Laboratory (INEL), Idaho Falls, Idaho. Many of the technologies developed for high-level waste will be applicable to other waste streams throughout the DOE Complex and ESPIP will transfer technologies as appropriate.

#### *Tank Waste Retrieval Robotics Test Bed*

Emptying the underground storage tanks (USTs) is a technically challenging task made difficult because of the hazardous nature of the tank contents. This waste material is chemically complex and includes physical forms ranging from thick, sticky sludge to a crystalline saltcake. The sludge has a consistency of soft mud and the saltcake approximates low-grade concrete. Most of the tanks also contain small amounts of liquid.

Pacific Northwest Laboratory (PNL), Oak Ridge National Laboratory (ORNL), and Sandia National Laboratory (SNL) are working together with the OTD to develop an advanced robotics retrieval system that will use robots - remote manipulators to get into the tanks to break up and remove the sludge and solidified waste. Since the project is technically complex, and because hazardous materials are involved, the development team is creating a full-scale, realistic mockup of the tank structure.

The facility, located at Hanford, will be used to test and fine tune all major subsystems of tank retrieval robotics using harmless simulated waste forms. The facility will use a 75 by 100-foot wide self-supporting platform that sits over the ground surrounding the underground tank. The platform supports the "long reach manipulator," a robotics arm that positions and operates waste-dislodging tools within the waste storage tank. Researchers hope to start using the test bed facility in 1994, with plans for it to become fully operational in 1996.

The project has several important objectives: (1) to explore the capabilities of retrieval manipulator systems and acquire data necessary to develop specific remediation equipment and techniques; (2) to provide performance guidelines for large manipulator-based retrieval systems; (3) to improve the productivity and safety of such systems by first using them in a non-hazardous environment; and (4) to reduce costs for long-term national remediation requirement. Developers expect lessons learned from this testing to have applications to nuclear waste sites throughout the country.

# **Groundwater and Soils Cleanup**

## **Section 1.0**



## 1.0

## GROUNDWATER AND SOILS CLEANUP OVERVIEW

Some of the most pressing environmental restoration needs for DOE involve cleanup or containment of radioactive and hazardous contaminants (including heavy metals and toxic organic compounds) in soils and groundwater. Sources of this contamination include previous disposal of contaminated wastes in ponds, seepage pits, trenches, and shallow land burial sites; spills and leakage from waste transport, temporary storage facilities, and underground storage tanks; and unregulated discharges to the air and surface waters. EM soils and groundwater programs are designed to identify, develop, and demonstrate innovative technology systems capable of removing or reducing potential health and environmental risks resulting from these previous storage and disposal practices.

VOC-contamination of soils and groundwater is one of the most common environmental problems in the United States and the DOE Complex. When VOCs are released into the soil, they rapidly migrate throughout the environment, forming large plumes that eventually result in contaminated groundwater. Two of the more prominent examples of VOC-contamination can be found at the Savannah River Site (a non-arid environment) where there is a plume larger than three square miles; and at the Hanford Site (an arid site), where an eleven square kilometer mile plume resulted from the disposal of an estimated 580-920 metric tons of carbon tetrachloride between 1955 and 1973. Over 220 sites with similar contamination have been identified in arid environments within the DOE Complex. Add radioactive contamination to these hazardous constituents and the result is a DOE problem for which few adequate remediation solutions exist. Complicating remediation efforts further is the fact that techniques for accessing and removing contaminants differ in arid and non-arid environments. As a result, technologies must be demonstrated and evaluated at multiple sites.

Also prevalent throughout the DOE Complex is the contamination of surface soils with heavy metals resulting from weapons assembly and testing processes during weapons production. At the Nevada Test Site, over 5-square miles of soil is contaminated with plutonium. Cleanup of this area will require the treatment of approximately 25 million cubic feet of soil. Five other DOE sites have similar plutonium contamination problems and eight other DOE sites have identified problems associated with uranium-contaminated soils. At Fernald, near Cincinnati, Ohio, uranium has been transported by rain and snow to varying depths below the surface, making remediation difficult. Estimates indicate there are 1.5 million cubic meters ( $m^3$ ) of uranium-contaminated soil at Fernald. Heavy-metal-contamination is also a problem in surface and groundwater. The Berkeley Pit at Butte, Montana, contains 17 billion gallons of contaminated water, with an inflow of 5-7 million gallons per day of surface water and groundwater.

The contaminants discussed above exhibit high concentration levels, high mobility, and high toxicity, as well as long-term persistence in the environment. For these reasons they represent some of the highest priority problems for which innovative technologies are sought. However, technologies are also under development for treatment of non-volatile organics, dense non-aqueous phase liquids, radionuclides, nitrates and explosive materials. In most cases, non-

intrusive or in situ methods (methods that characterize or treat the contaminants in place) for environmental restoration are preferable from technical and regulatory standpoints. From a regulatory standpoint, these technologies are preferable because they minimize (1) harm to the environment, (2) public exposure, and (3) volume of waste. Technically, these methods avoid the risks and costs associated with handling contaminated soils and groundwater. Nevertheless, cases exist for which non-intrusive and in situ methods may not be applicable. Given this circumstance, other innovative technologies must be explored, including extraction, containment, recovery, and processing alternatives that reduce or eliminate environmental and health risks.

One of the biggest challenges facing DOE is effective characterization of contamination in soil and groundwater. Characterization must take place before a contaminated site can be properly prioritized for remediation. To accomplish this, non-invasive, field-deployable methods are being developed that are capable of mapping vast areas at depths up to 250 feet below ground level. Results are three-dimensional images that are valuable tools for proper selection and placement of remediation technologies.

The necessity to develop innovative technologies for characterization and treatment of groundwater and soils is not unique to DOE. Other Federal agencies, as well as private industry, are in need of improved methods for these types of cleanup. The Environmental Protection Agency (EPA) has identified 1,235 sites with sufficient contamination to place them on its National Priorities List (NPL). In the past two years, the number of sites entering remedial action has grown steadily.<sup>1</sup> Out of 712 NPL sites with Records of Decision (ROD), an estimated 80 percent require remediation of groundwater, 74 percent need soil remediation, and 15 percent require action to clean up sediments. It is estimated that NPL sites without RODs contain similar types of contamination. In an effort to promote the development of new technologies to expedite clean up of the NPL sites, EPA established the Superfund Innovative Technology Evaluation (SITE) program. The U.S. Department of Defense (DoD) is responsible for clean up of its facilities contaminated as a result of training, industrial, or research activities. As of September 1991, DoD identified 7,000 sites that will require remediation. The largest of these DoD remediation

<sup>1</sup> U.S. Environmental Protection Agency, Office of Policy, Planning and Evaluation, Environment Investment: The Cost of a Clean Environment, EPA-230-11-90-083, November 1990.

## 1.1

## CHEMICAL FIBER-OPTIC SENSOR

### TASK DESCRIPTION

The chemical fiber optic sensor is used to monitor in situ contaminant levels in soils (see Figure 1.1). The sensor can be placed in a cone penetrometer or isolated via packers in discretely screened intervals in monitoring wells.

The principle of detection for the sensor is a quantitative chemical reaction that forms visible light absorbing products on exposure to trichloroethylene (TCE). Absorption of light relative to reaction time is directly related to contaminant concentration. The measurement system has three major components: a pumping system, an electro-optic instrument that provides filtered light to the sensor and detects the returning transmission light, and the sensor.

### TECHNOLOGY NEEDS

Current DOE policy requires characterization of sites where TCE has been discharged into the soil and groundwater. Contaminated samples are currently collected and analyzed by an outside laboratory. This is an expensive and time consuming process. An alternative is to use a sensor that can be put down monitoring or vadose zone wells or punched into the soil using a penetrometer-type device. This allows measurements to be made continuously and at relatively low cost. In situ measurements can also be made at ambient temperatures using this method. An example of this type of sensor is the TCE chemical fiber-optic sensor. This sensor is selective for TCE, and can detect this compound at levels below the EPA groundwater standards.

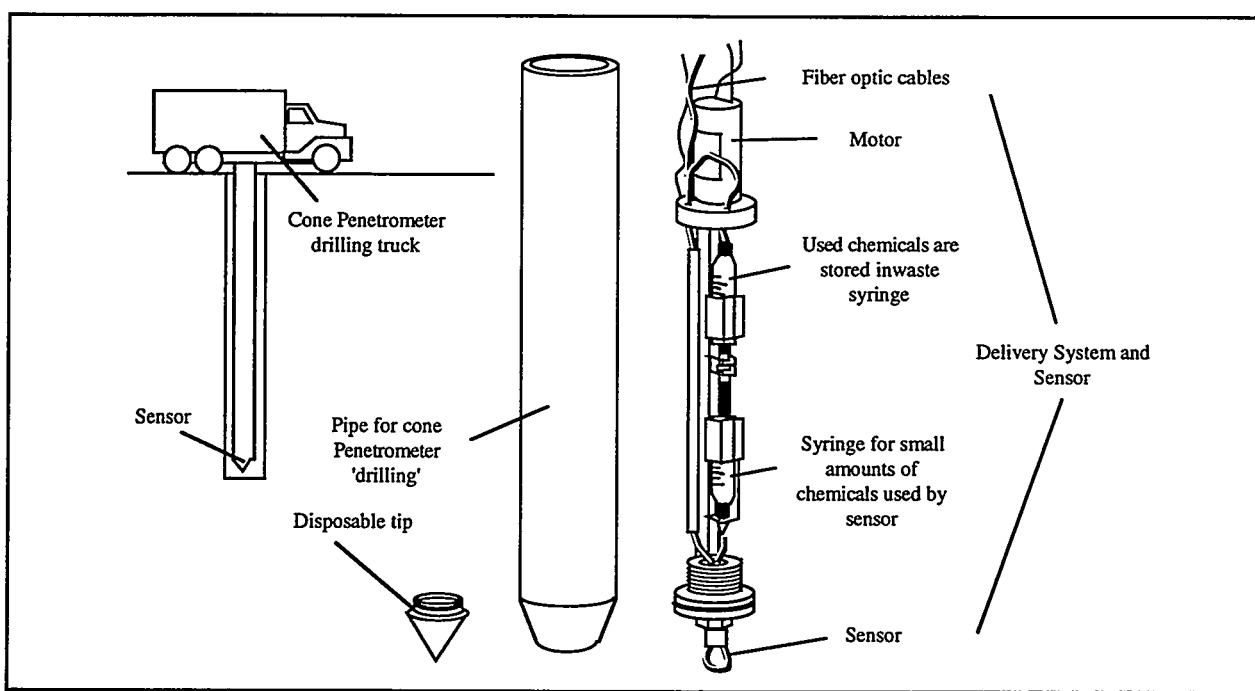
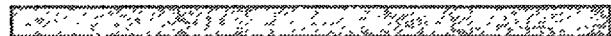


Figure 1.1. Chemical Fiber-Optic Sensor.

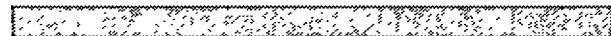
## ACCOMPLISHMENTS

The system has been successfully demonstrated and has been licensed to industry for monitoring use and other applications.



## COLLABORATION/TECHNOLOGY TRANSFER

This technology was developed jointly by LLNL, Westinghouse Savannah River Co. and Burge and Associates. The technology is non-exclusively licensed to Burge and Associates and Purus, Inc. Other corporations have expressed interest in licensing the technology.



**For further information,  
please contact:**

**Fred Milanovich**

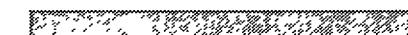
Principle Investigator  
Lawrence Livermore National  
Laboratory  
(510) 422-6338

**Ann Heywood**

Technical Program Manager  
Lawrence Livermore National Laboratory  
(510) 422-8203

**Kurt D. Gerdes**

Program Manager  
U.S. Department of Energy  
(301) 903-7289



## 1.2

# ELECTRICAL RESISTANCE TOMOGRAPHY

### TASK DESCRIPTION

Electrical resistance tomography is used to create a three-dimensional visualization of *in situ* remediation processes, such as air stripping, bioremediation, and subsurface heating.

The task involves inducing an electrical current in the ground and measuring the potential distribution that results from the current flowing in the conductive subsurface. Pairs of electrodes are buried with some pairs acting as current source electrical dipoles and others acting as potential measuring dipoles (see Figure 1.2).

Electrical Resistance Tomography (ERT) inversion process involves solving both the forward and inverse resistivity problems.

The solution to the forward problem uses the finite element method to compute the potential electrical response in the soil due to the current source. The final products of the process are images (tomographs) showing the distribution of resistivity in the plane between the two boreholes used. By interconnecting a network of boreholes, a three-dimensional representation of the area being investigated can be developed. By analyzing the resistivity images before, during, and after a remediation process, three-dimensional subsurface saturation changes can be inferred.

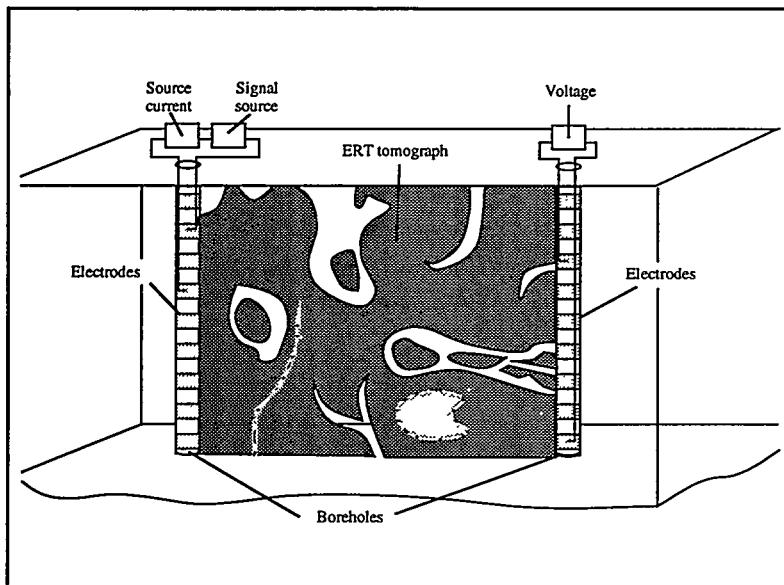


Figure 1.2. Electrical Resistance Tomography.

The resistivity distribution of the area in the vicinity of the borehole is then calculated. The current paths are dependent on the resistivity distribution within the geologic material in the vicinity of the borehole. The

### TECHNOLOGY NEEDS

Many remediation processes can interact with a contaminated area in ways that are difficult to predict; therefore, it is advantageous to be able to monitor this interaction so that the effectiveness of the remediation process can be assessed and process parameters can be modified to improve the effectiveness of the remedial process. There are no alternative methods currently available to image the fluid saturation distributions in two- and three-dimensional cross-sections of the subsurface. Point sampling of fluid saturation can be performed by acquiring core samples, and line measurements of fluid saturation along boreholes can be performed by using well-logging techniques.

Electrical resistance tomography is being developed as a tool to allow the three-dimensional visualization of underground processes such as those used in remediation. This technology, when used either separately or in conjunction with other geophysical, hydrologic, or geochemical methods, is a powerful tool in defining the initial conditions and the interactions between the remedial process and the contaminated environment.

At the Savannah River Site this technique has been effectively used to monitor the effectiveness of air permeation in the air injection and vacuum extraction tests.

## ACCOMPLISHMENTS

This technique has been successfully tested at the Savannah River Site. The technique mapped changes in fluid saturation as the subsurface conditions were modified by the remedial process during air stripping. This technique has also been used to evaluate the effectiveness of the Radio Frequency Heating and Six-Phase Heating tests.

## COLLABORATION/TECHNOLOGY TRANSFER

Several companies are currently negotiating with LLNL to obtain licenses to use the technology and to cooperate in further development. British Petroleum has received a non-exclusive license to use the algorithm for the data inversion process.

### For further information, please contact:

#### **Abelardo Ramirez**

Principle Investigator

Lawrence Livermore National Laboratory

(510) 422-6909

#### **Ann Heywood**

Technical Program Manager

Lawrence Livermore National Laboratory

(510) 422-2803

#### **Kurt D. Gerdes**

Program Manager

U.S. Department of Energy

(301) 903-7289

## 1.3

## CRYOGENIC DRILLING

### TASK DESCRIPTION

This task provides a temporary method for stabilizing the borehole while drilling. Prevention of borehole collapse is an important consideration when drilling in unconsolidated sandy or gravelly sediments and in particular when drilling horizontal wells.

In cryogenic drilling, horizontal or vertical holes are drilled using super-cooled air as the drilling fluid, allowing holes to be stabilized by freezing a ring of soil around the borehole during the drilling process (see Figure 1.3). It results in a minimum alteration of the soil as well as minimization of surface wastes, due to the fact that liquid and volatile contaminants are frozen in place and the returns are limited to air and the

volume of soil excavated from the hole. This method also precludes the need for the use of drilling liquids or hole stabilization additives.

### TECHNOLOGY NEEDS

Many DOE and industrial sites are contaminated with toxic substances that have leaked into the near surface soils. In order to characterize and remediate these sites, boreholes must usually be drilled. One of the difficulties that arises in the drilling of near-surface boreholes in unconsolidated formations is the poor stability of the borehole. This can be an acute problem in drilling horizontal boreholes, which may be advantageous for economic reasons as

well as necessary when surface obstacles prevent direct access. The problem is complicated further by the fact that it is desirable or required by environmental regulations, in some cases, that no drilling fluids be used to stabilize the boreholes.

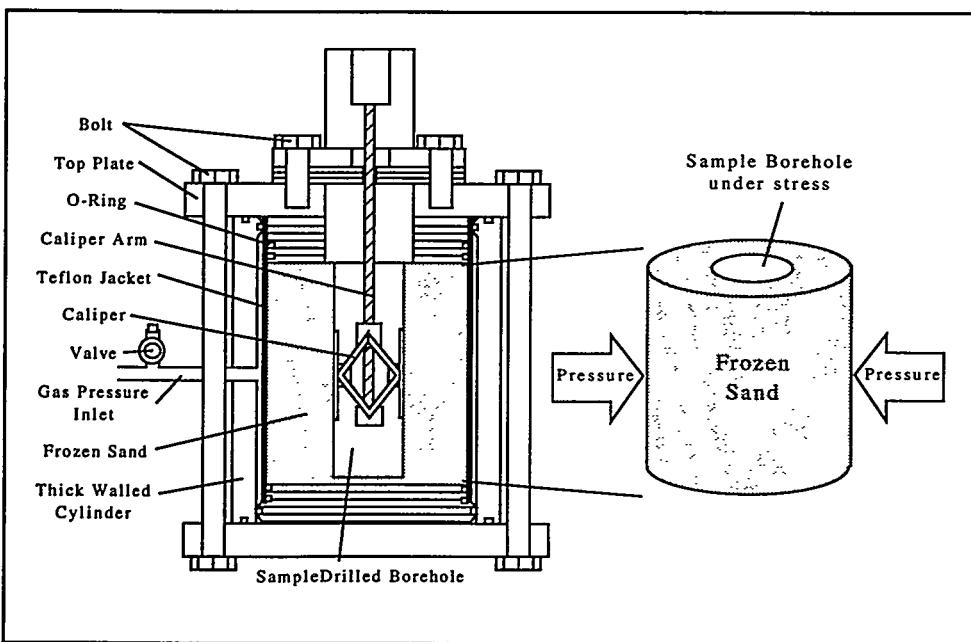
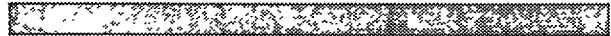


Figure 1.3. Frozen Borehole Test Apparatus.

## **ACCOMPLISHMENTS**

This effort has focused on laboratory and bench-scale studies to evaluate the feasibility of future drilling demonstrations.

Because of the pending closeout of this ID, the demonstration of this technology is being pursued at other sites.



## **COLLABORATION/TECHNOLOGY TRANSFER**

This technology is being developed by the University of California at Berkeley. To date there has been no collaboration with industry on this project, but a number of potential partners do exist.



**For further information,  
please contact:**

**George Cooper**

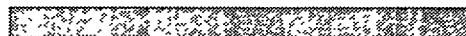
Principal Investigator

University of California at Berkeley  
(510) 642-2996

**Kurt D. Gerdes**

Program Manager

U.S. Department of Energy  
(301) 903-7289



## 1.4

## CHARACTERIZATION BY CROSSHOLE SEISMIC IMAGING

### TASK DESCRIPTION

The objective of this task is to determine the applicability of high-frequency seismic crosshole imaging for characterizing contaminated subsurface sites. The technology utilizes seismic sources (high-frequency piezoelectric) and receivers (accelerometers) clamped to the borehole walls. A high-voltage signal energizes the piezoelectric crystal and causes an acoustic signal to be transmitted through the earth, where it is picked up by the receiver. The time of flight of the signal and amplitude of the signal are measured, as well as the details of the effect and the propagation path. These signals are then processed for information on the mechanical properties of the earth.

A primary goal is to demonstrate the frequency range, resolution, and sensitivity of borehole seismic methods in boreholes that cannot be filled with water (arid sites), or in which conventional clamping devices cannot be used for coupling the seismic sources and receivers to the borehole walls (see Figure 1.4). An equally important goal is to demonstrate that high-resolution seismic imaging can be used to characterize structure and lithology related to transport properties in a routine and cost-effective manner.

The scope of this project is to start with existing technology that uses piezoelectric transducers for transmitting and receiving high-frequency seismic energy in water-filled boreholes, and adapting this technology to

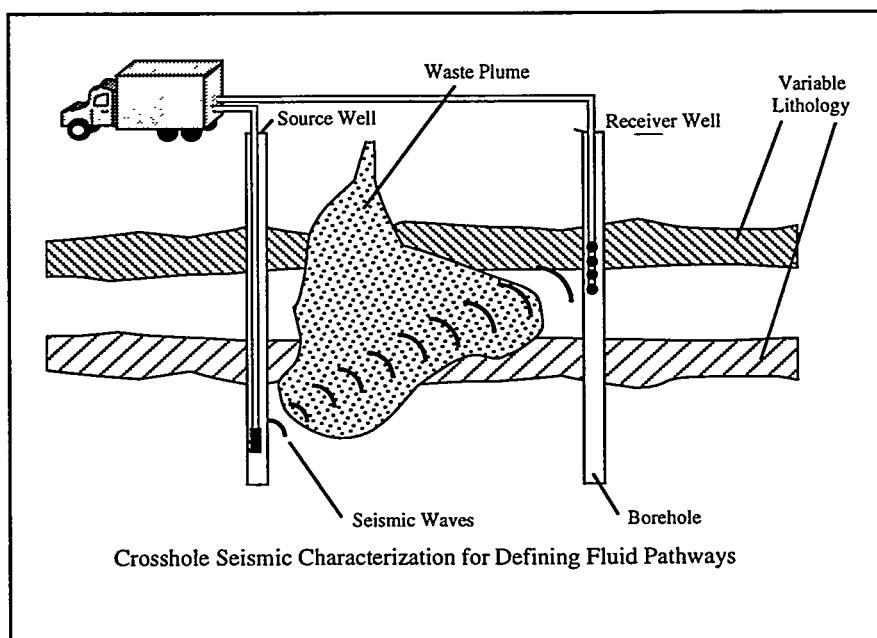


Figure 1.4. Seismic Imaging.

boreholes which are often only partially filled with water or completely dry. In addition, boreholes in contaminated sites are generally lined with a relatively fragile material, so conventional clamping devices cannot be used.

The approach is staged to first evaluate different mechanisms for borehole coupling, which will affect frequency content and amplitude of the seismic signals. If successful, the sources and clamping mechanisms will be improved to allow shear wave transmission in addition to compressional wave transmission. An equally important task is to demonstrate in-field data collection and imaging methods,

such that the imaging results can be obtained in an efficient and cost-effective fashion. The latter phases of the project will use this technology at an arid site that will be remediated. The last phase will be to transfer as much technology as possible to private industry through Science and Engineering Associates, Incorporated.

## TECHNOLOGY NEEDS

Seismic imaging has proven effective and useful in oil and gas exploration and reservoir characterization. Seismic techniques are the established method for mapping the structural geology of sites deep within the earth. Recent technological advances have made it possible to identify fluid-saturated regions. This advanced technology, appropriately applied, is very suitable for identifying, locating, and characterizing hazardous waste sources, waste plumes, and local geologic structure and hydrology. Seismic methods are also capable of penetrating up to tens of feet with resolutions of less than three feet, compared to standard geophysical approaches using electrical or electromagnetic approaches which can not resolve targets less than 10 feet or depths greater than 15 feet.

## ACCOMPLISHMENTS

Successfully demonstrated the seismic crosshole system at the UNCAP holes. Kilohertz seismic energy was used to image the area between UNCAP 3 and UNCAP 2. The coupling mechanism performed as designed.

## COLLABORATION/TECHNOLOGY TRANSFER

The project involves collaboration with

**Science & Engineering Associates**  
1570 Pacheco, Suite D-1  
Santa Fe, NM 87501  
Contact: William Lowry  
Phone: (505) 983-6698

**For further information,  
please contact:**

**Ernest Majer**  
Principal Investigator  
Lawrence Berkeley Laboratory  
(510) 486-6709

**Richard Scott**  
Technical Program Manager  
Lawrence Berkeley Laboratory  
(510) 273-7878

**Skip Chamberlain**  
Program Manager  
U.S. Department of Energy  
(301) 903-7295

## 1.5 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

- Two and one-half million underground storage tanks (containing petroleum products) exist in the United States, thousands of which have leaked to form concentrated plumes of contamination.
- Dynamic Underground Stripping is amenable to all types of liquid contamination including non-aqueous phase liquids (NAPLS) and dense NAPLS (DNAPLs), and potentially mixed waste.
- Dynamic Underground 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.
- Thirteenasic patents have been applied for.
- Licensing agreements with several companies are under discussion.

**For further information,  
please contact:**

**Roger Aines**

Principal Investigator

Lawrence Livermore National Laboratory  
(510) 423-7184

**Tye Ed Barber**

Principal Investigator

Oak Ridge National Laboratory  
(615) 574-6248

**S. P. (John) Mathur**

Program Manager

U. S. Department of Energy  
(301) 903-7922

**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 for continued and expanded remediation of LLNL and other DOE sites.

## 1.6 MULTI-ANALYTE, SINGLE-FIBER, OPTICAL SENSOR

### TASK DESCRIPTION

The objective of this task is to adapt Tufts University's unique optical-fiber-sensor technology to site-specific DOE needs. Multi-analyte, sensitive, single-fiber, optic sensors will be prepared containing sensitivity to RCRA metals, anions and hydrocarbons. Indicator chemistries and prototype multi-analyte fiber-optic sensors and readout instrumentation will be designed and constructed. Sensors will be delivered to LLNL, where a field-hardened instrumentation package will be used for testing and eventual transfer of technology to DOE remediation sites and industry. The successful completion of this project will require significant collaboration with Tufts University, which holds relevant patents and unique expertise in the chemical basis and design of multicomponent sensor arrays.

sensor and instrument to make determinations of numerous analytes, thus greatly simplifying field applications.

### ACCOMPLISHMENTS

The ability to place and read 12 individual pH sensors on a single-optical fiber terminus (see Figure 1.6) has been demonstrated. These results indicate the potential of placing as many as twenty sensors on one fiber.

The suite of target analytes -  $\text{Al}^{+3}$ ,  $\text{UO}_2^{+2}$ , hydrocarbon (nonspecific), and pH have been selected in collaboration with the Rocky Flats facility as the initial multi-analyte sensor. Researchers at Tufts University have already demonstrated pH and aluminum ion sensors

### TECHNOLOGY NEEDS

Current methods for detecting nearly all priority contaminants require sampling and subsequent laboratory analysis. Sensors give the analyst the ability to measure contamination *in situ*, and in real time, thus saving time and expense. However, many DOE sites have a multitude of contaminants present that challenge the current state-of-the-art in sensor technology. This challenge is in both analyte specificity and sensitivity and in the complexity of instrumentation that would be required to measure many analytes simultaneously. The work described herein not only provides sensors for needed measurements, but also has the unique distinction of requiring only one

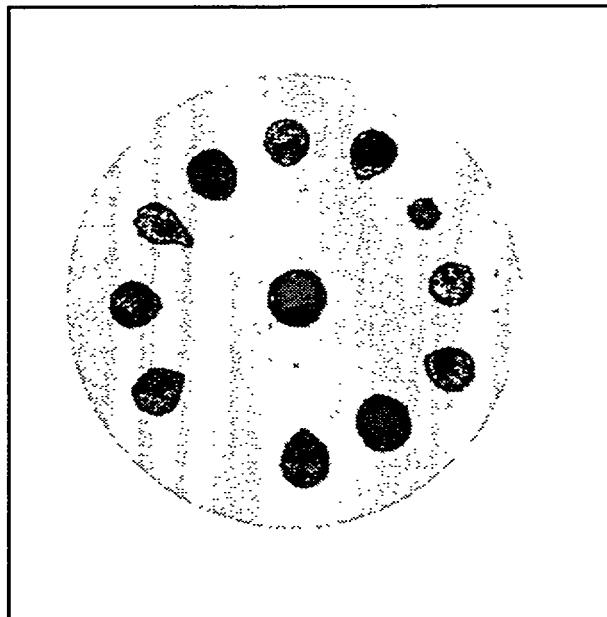


Figure 1.6. Photo-micrograph of the distal end of a single 500 micron diameter imaging fiber.

adequate for demonstration. Optical transduction schemes for hydrocarbon and the  $\text{UO}_2$  ion have also been identified. This project is on schedule for a laboratory demonstration of a four analyte sensor by late FY94.

Initial success with measuring pH optically has opened up the possibility of an underground storage tank application. Here a wide range of pH sensors can be used to monitor for corrosive conditions, as well as a redundant number of individual sensors to mitigate the effects of the harsh environment. The potential application of a new concept recently demonstrated by Tufts University will also be explored. The combination of slow release polymer technologies with fluoroimmuno-analysis has the potential for a continuous reading antibody-based biosensor. Success would greatly increase the number of different analytes that could be measured with the multi-analyte sensor.

## **COLLABORATION/TECHNOLOGY TRANSFER**

This project is a major collaboration among researchers at LLNL, the Chemistry Department at Tufts University, and the Hybridoma Center of the University of California at Berkeley. Tufts University has received three patents covering the core technology. It is anticipated that application-specific technology developed under the collaboration will be available for field-use licensing. Informal collaborations with Princeton Instruments, Ames Laboratory, and Hamamatsu Corporation have also been established for various aspects of instrument component development.

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**For further information,  
please contact:**

**Fred P. Milanovich**

Principal Investigator  
Lawrence Livermore National Laboratory  
(510) 422-6838

**Ann Heywood**

Technical Program Manager  
Lawrence Livermore National Laboratory  
(510) 422-8203

**Caroline B. Purdy**

Program Manager  
U.S. Department of Energy  
(301) 903-7672

## 1.7

## ANALOG SITE FOR CHARACTERIZATION OF FRACTURED ROCK

### TASK DESCRIPTION

This project is designed to identify reliable tools and methodologies for characterizing the fractures that control flow and transport in specific geologic settings. Characterization tools will be used to predict the outcome of flow and transport experiments in fractured rock in order to assess the utility of these tools for characterizing important hydrologic features in similar contaminated sites.

At this proposed analog site two series of measurements would be performed. The first series would be designed to characterize the hydrology of the site. The second set would be a flow and transport experiment designed to test the predictive capability of the characterization methodology. For example, the characterization methodology at Stripa was confirmed by using the fracture zones identified in the characterization process as the basis of successful predictions of the measured fluid flow and transport in the block.

The characterization phase would begin with a geologic investigation designed to identify the style of fracturing and the likely fracture patterns. Then a suite of geophysical investigations would be performed that are expected to give indications of fractures that control permeability. Techniques such as seismic tomography, three-dimensional seismic, electro magnetic tomography, radar reflection and tomography, hydraulic interference testing, etc., will be used. Any method judged to be useful at the particular site could be tried. The interpretation(s) of these measurements would consist of one or more estimates of the location of important hydrologic fractures.

These features would then become the subject of a series of hydraulic tests designed to diagnose the hydrologic properties of the system. Tests would include fluid logging, interference testing and tracer tests. Conceptual models for flow and transport would be constructed based on this characterization.

The flow and transport tests would consist of tests designed to confirm the hydrologic flow paths. These might be tracer tests designed to prove the hydrologic connections between two or more points. In addition, a combination of hydrologic and geophysical monitoring tests will be performed. These could include radar tomography done during the progress of a saline tracer test, or perhaps seismic monitoring during the injection of a gas or fluid of different elastic properties than water. The idea here is to image the flow-through-flow-induced changes in geophysical properties. Comparison of the flow experiments with the flow patterns predicted in the first phase will provide a format for identifying those methods or combination of methods that successfully identify the fractures that control flow.

### TECHNOLOGY NEEDS

Some contaminated sites have fractured rock. For example, the Oak Ridge National Laboratory has significant contamination in fractured shale. INEL and Hanford sites have problems in fractured basalt. The characterization of these sites in order to predict the transport of contaminants can be problematic. The location of fractures is often a mystery; their effect on flow can be dramatic. The

fractures themselves may be leached by reactive waste material. Containment of the waste may require the sealing of fractures. Thus, the three key issues that influence remediation of these sites are:

- Finding the fractures that control fluid flow and transport.
- Analyzing fluid flow and transport in the fracture system.
- Predicting and controlling of induced or purposeful changes to the fracture system.

## ACCOMPLISHMENTS

Field work should commence in FY95. Contacting of site offices to determine the extent of contamination problems in fractured rock has begun. A type of geology will be chosen for the analog site based on identifying a significant need as well as field site availability.

## COLLABORATION/TECHNOLOGY TRANSFER

Partners are sought from traditional geophysical service companies and other geotechnical firms who might be interested in learning from this project, either by direct participation or through the results of the project.

Additional partners are sought from other National Laboratories with expertise in fractured rock.

**For more information,  
please contact:**

**Jane C.S. Long**  
Principal Investigator  
Lawrence Berkeley Laboratory  
510-486-6697

**Caroline B. Purdy**  
Program Manager  
U.S. Department of Energy  
(301) 903-7672

**TASK DESCRIPTION**

The task is to perform cooperative Russian-American studies of Russian contamination sites, to evaluate site characterization and monitoring data from these sites, to carry out field measurements, and to develop approaches for site evaluation and remediation drawing upon Russian and American experience and technology.

Russia and the United States share a variety of environmental problems. Some have been caused by the operation of facilities supporting the production of nuclear weapons over the past 50 years. During this period, a large amount of radioactive and hazardous wastes have been produced and a significant quantity discharged into the environment. Much effort is being spent in both countries in cleaning up or controlling the contamination in the soil, surfacewater and groundwater systems. In the process, both countries have developed scientific expertise and databases or case histories in characterizing contaminated sites, modeling flow and transport phenomena, and designing optimal restoration or containment strategies.

In FY94, a selection of five to seven Russian scientists will be invited to stay in the U.S. for a duration of one to two months. They will participate in the project and add important Russian scientific inputs. Nomination of these scholars has been coordinated with the Russian Ministry of Atomic Energy (MINATOM), the Russian Academy of Sciences, and DOE, and their visits are jointly funded by DOE-ER and DOE-EM.

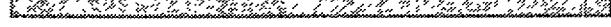
In FY94, it is planned to continue the work started in FY93 to make a careful study of contaminant transport at the Chelyabinsk site over the last forty years. The important physicochemical processes occurring in contaminant transport over kilometer distances and over long time periods will be identified. Some of these may not be observable in short-term experiments. The goal is to summarize these processes, describe their characteristics and understand their temporal and spatial properties. These will be of great importance to the environmental site characterization method development and optimal approaches to remediation.

Since the establishment of the connections with the Russian organizations involved in Chelyabinsk site-specific studies, much available data from Russian sources have been collected, reviewed, and are in the process of being published as ten reports in English. Based on this information, a plan will be developed to investigate important physico-chemical processes in contaminant transport in the soil and groundwater system at Chelyabinsk. Part of this study will be a field measurement program, which will focus on a preliminary reconnaissance-level survey for radionuclides in Myshelyak riverbank soils and river water, and in soils between Lake Karachai. This field study is intended to confirm and complement Russian efforts. Also, such a survey will provide information to evaluate site characterization and monitoring methods.

For FY94, a major field visit to the Chelyabinsk site will be proposed to the MINATOM. The proposed field study will be focused on several of the following possible topics:

- River Myshelyak survey: field radiometry along transects and sampling of water, soils, rock cuttings, and cores for laboratory analyses to identify sorption/desorption of radionuclides and rock/water interactions.
- Unsaturated zone sampling: collection of water and soil samples in the near-surface layers along rivers and near Lake Karachai.
- Vertical survey of geological structures, hydrological property variation, and plume migration with wells designed for detailed distribution sampling.
- Geophysical survey of the basement structures and deep geological structures with seismic and/or electromagnetic tomographic techniques to define the flow domains for contaminant containment and remediation.

Other important benefits include the stimulation of increased collaboration among Russian and U.S. scientists on technology development for environmental studies. This will also facilitate identification of key resources for inclusion in the DOE Environmental Restoration Program.



## ACCOMPLISHMENTS

The collaboration with Russian experts and institutions has been successfully established, including the government, research institutes, academia and commercial companies. Due to the established U.S./Russian partnership, it was possible to collect important data from Russian sources. Based upon this information, a field study plan has been developed to investigate important physicochemical processes in contaminant transport in the soil and groundwater system at Chelyabinsk and to test site characterization technologies.

So far ten reports have been produced due to this collaboration and these are now under the review process. These reports are listed below:

1. Drozhko, E.G., Mironenko, V.A., Pozdniakov, S.P., Samsonova, L.M., Shestakov, V.M., *Previous investigations and field hydrogeological data for Chelyabinsk region*.
2. Drozhko, E.G., Mokrov, Yu.G., Glagolenko, Yu.V., Samsonova, L.M., *Determination of hydrodynamic parameters of cleaved rock mass according to regime examination data in the Lake Karachai area*.
3. Drozhko, E.G., Samsonova, L.M., Zinin, A.I., Yinkin, V.P., *Computer model of solutions to unsteady migration in groundwater*.

## TECHNOLOGY NEEDS

The benefits to be derived from this project include the identification and assessment of a most comprehensive database and a real, large-scale contaminated site to test current understanding and site characterization technologies that are used in evaluating contaminated sites. This is unique among current projects. The project will strive to test and demonstrate new field technologies and thereby lead to their rapid infusion into the DOE Environmental Restoration Program.

4. Mironenko, M.V., Y.G., Glagolenko, Drozhko, Eu.G., Khodakovskiy, I.L., Mokrov, G.Yu., Polyakov, V.B., Smirnov, A.B., Spasennykh, M.Yu., *The cascade of reservoirs of the RMAYAKS plant: case history and the first version of a computer simulator.*
5. Mironenko, V.A., Rumynin, V.G., *Analysis of hydrogeological consequences of hazardous accidents at designed nuclear reactors: forecast and field investigation.*
6. Mironenko, V.A., Rumynin, V.G., Shestakov, V.M., Konosavsky, P.K., Pozdnyakov, S.P., Roshal, A.A., *Development of analytical and numerical models for the assessment and interpretation of hydrogeological field tests at the key sites of the Lake Karachai area.*
7. Pek, A.A., Malkovsky, V.I., *Modelling of the fault-controlled hydrothermal ore-forming systems.*
8. Malkovsky, V.I., Pek, A.A., *Computer simulation of nuclear waste transport from the deep drill hole repository: thermal convection model.*
9. Pek, A.A., Malkovsky, V.I., *High-level nuclear waste geological disposal: utilization of HLW heat generation in the design of engineering barriers.*
10. Pozdniakov, S.P., Shestakov, V.M., *Quasi-3D variable density flow model.*

development, commercialization, and application of novel environmental technologies, thereby creating a major source of new business opportunities in both Russia and the United States. The project also aims at creating partnerships between industry, research and educational institutions, regulatory agencies and the central governments.

**For more information,  
please contact:**

**Dr. Chin-Fu Tsang**  
Principal Investigator  
Lawrence Berkeley Laboratory  
(510) 486-5782

**Caroline B. Purdy**  
Program Manager  
U.S. Department of Energy  
(301) 903-7672

## **COLLABORATION/TECHNOLOGY TRANSFER**

Through the Lawrence Berkeley Laboratory Russian-American Center for Contaminant Transport Studies, communications have been established with Bechtel, General Atomics' Environmental Technology Division, and other U. S. companies. The project will expedite the

## 1.9 ELECTRICAL RESISTANCE TOMOGRAPHY FOR SUBSURFACE IMAGING

### TASK DESCRIPTION

The purpose of this task is to develop and demonstrate a system for detecting and locating leaks in the single-shell tanks at the Hanford site in Richland, Washington; develop very high-resolution imaging techniques for monitoring electrokinetic remediation, demonstrate the effectiveness of the technology at the Sandia testing of electrokinetic remediation; and transfer the basic ERT technology to RIMTech, Inc., through formal training and by working in actual field applications of the technology.

### TECHNOLOGY NEEDS

*Detecting Leaks from the Hanford Single-Shell Tanks (SSTs):* DOE has approximately 149 SSTs that have been used to store high-level mixed wastes. Many of these tanks are at the Hanford, Washington site. It is known that 60 to 70 (66 assumed) of these tanks are leaking and releasing their contents in the surrounding soil. Other tanks may be leaking, but the existing techniques for determining leakage prevents an accurate count. In line with the potential for danger such releases pose to site personnel, and the longer-term danger to the surrounding communities, environmental regulations require that even small volume releases from these tanks be reported. There is a clear need to be able to

detect when a tank begins to leak so corrective measures can be taken before damage is great. There is also a need to be able to isolate the leak location in the event that tank repairs are practical.

Currently there are two methods for detecting leaks and neither is useful for locating the leak point. The simplest method is a careful inventory of tank contents. Unfortunately, the precision needed in level sensing is not simple due to the heterogeneities and chemical conditions of tank contents. Even level sensors are troublesome due to the "bergs" and the crusts in some tanks. The other approach is to drill beneath the tank and install sensors. This approach also has its problems, since it provides only point measurements under the tank,

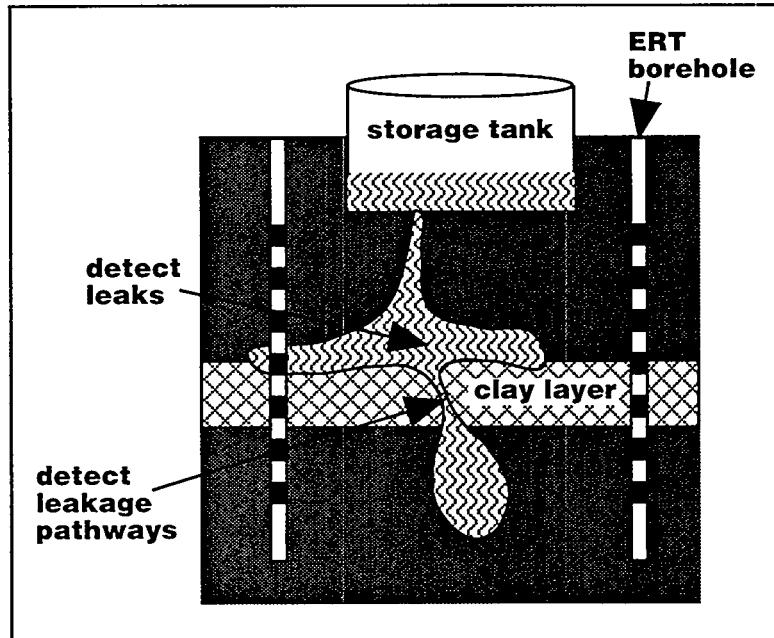


Figure 1.9a. Schematic representation of electrical resistance tomography to delineate leaks from an underground storage tank.

and any leakage will probably be highly channeled due to the heterogeneous soil at Hanford, and therefore the leak will likely be missed.

**Monitoring Electrokinetic Processes:** Electokinetic remediation of metals and other contaminants from soils is not a new idea. The technique is even commercialized in Europe. Unfortunately, much of the physics, chemistry and influence of hydrogeology on the process is not well understood. As a result, it is likely that much electrokinetic remediation now practiced may be ineffective. The test to be performed at Sandia later this year is designed to provide the overdue basic research. To meet this goal, detailed information is needed of the test site and the process itself. Electrical resistance tomography is being done at the site before and during the test to help provide some of the needed detail. First, ERT will be used to obtain five high-resolution images to fill in borehole data about the site lithology (see Figures 1.9a and 1.9b). The hydraulic permeability distribution will be inferred from borehole cores and interpolated between holes using ERT and the fact that more permeable sands are resistive and less permeable clays are conductive. During the test, moisture content changes will be mapped in the test area from the well-documented correlation of electrical properties to soil water content. It is also planned to estimate the amount of water lost out the bottom of the system based on the images.

**Technology Transfer:** As prescribed by DOE, the accumulated experience and know-how of ERT will be given to RIMTech and the 2.5 D inversion code will be licensed by them.

## ACCOMPLISHMENTS

**Detecting Leaks from the Hanford Single Shell Tanks:** A fairly detailed test plan has been written and approved by Hanford personnel. Permitting for the test has begun. Hanford operations is doing the permitting for the site. After some negotiation, details of the test site have been settled and Hanford operations has agreed to start construction this spring.

**Monitoring Electrokinetic Processes:** Many of the details of the test have been worked out with Sandia. Preliminary measurements at the test site have been made to set some of the parameters for later data acquisition. Experiments at the site have been performed using a method of placing ERT electrodes using SEAMIST™. The technique worked, but was determined to be too expensive. An alternate method has been designed and a prototype is now being built to test in the laboratory before field deployment at Sandia.

**Technology Transfer:** Personnel from RIMTech have visited LLNL to become familiar with the operation of ERT data collection hardware and use of the inversion code OCC2D3D. Two more sessions are planned for later in the project to continue this training. Work is being planned with RIMTech personnel during each phase at Hanford and Sandia so they will be familiar with all aspects of planning and executing a project using ERT.

## COLLABORATION/TECHNOLOGY TRANSFER

LLNL and Ames Laboratory are actively working with RIMTech, Inc., a Denver based geo-physical service company, to transfer the basic ERT technology. That work will continue throughout FY94.

Collaboration is also occurring with the University of Arizona. The contribution is computer code development for the project. Collaboration with Westinghouse Hanford Company (EM-30) in the development of a test bed for the work at the site is occurring. They will do all site construction in accordance with the test plan.

For more information,  
please contact:

**William Daily**

Principal Investigator

Lawrence Livermore National Laboratory

(510) 422-8623

**Abe Ramirez**

Technical Program Manager

Lawrence Livermore National Laboratory

(510) 422-6909

**Caroline B. Purdy**

Program Manager

U.S. Department of Energy

(301) 903-7672

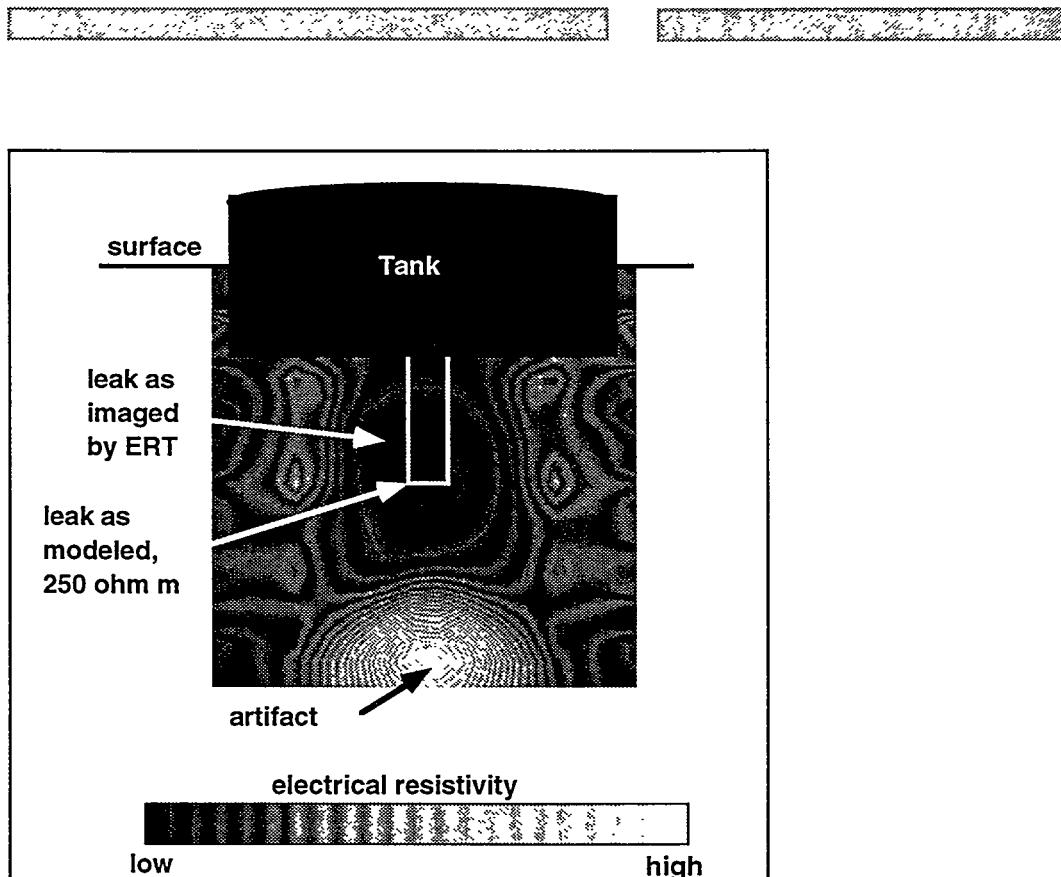


Figure 1.9b. Computer simulation of electrical resistance tomography below a steel tank with a conductive plume of 250 ohm-m beneath the tank center.

## 1.10 CONTAINMENT OF CONTAMINANTS THROUGH PHYSICAL BARRIERS FORMED FROM VISCOUS LIQUIDS EMPLACED UNDER CONTROLLED VISCOSITY CONDITIONS

### TASK DESCRIPTION

This investigation is examining liquids which, when injected into the subsurface, produce nearly-inert impermeable barriers through a very large increase in viscosity. Appropriate emplacement of these substances provides an effective containment of the contaminated zone by trapping and immobilizing both the contaminant and the plume. (See Figure 1.10).

This project will identify and characterize promising materials and evaluate their containment potential by means of laboratory pilot-scale experiments and field testing and demonstration. The general purpose TOUGH2™ model, developed at LBL, is being modified to simulate barrier fluid behavior and to design experiments.

The first type of barrier fluid under examination belongs to the polybutene family. Polybutenes are chemically and biologically inert, hydrophobic and impermeable to water and gases, and are approved by the Federal Drug Administration for food contact. Their performance is unaffected by the soil and waste type, and is only controlled by their drastic viscosity dependence on temperature.

The second type, colloidal silica, is a silicon-based chemical grout that poses no health hazard, is unaffected by filtration, and is chemically and biologically inert. Its con-

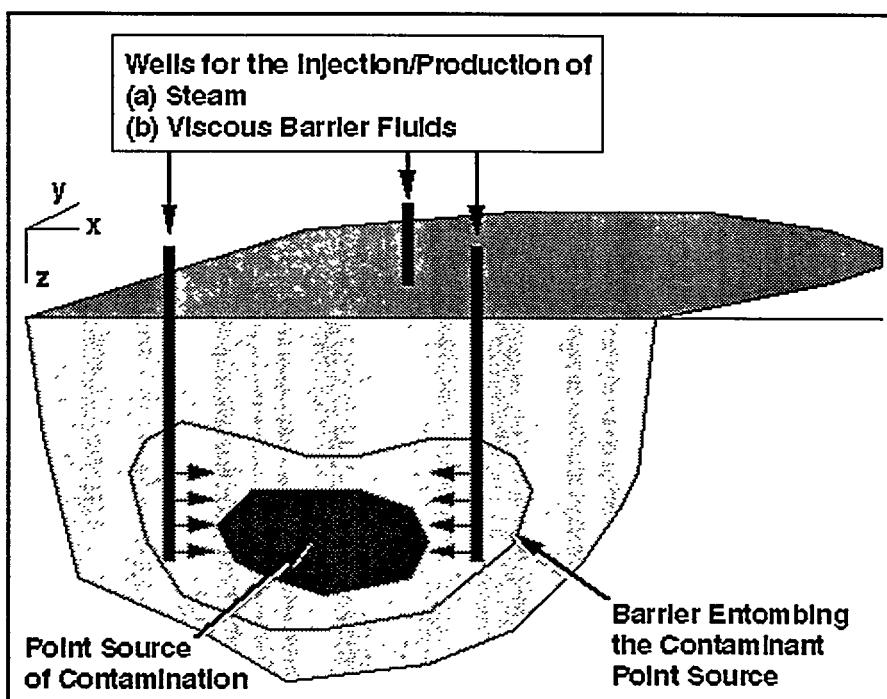


Figure 1.10. Identify and evaluate the feasibility of producing in situ barriers.

tainment performance is controlled by the gelation time, which depends on pH, temperature, the chemistry of the injected suspension, and chemistry and mineralogy of the aquifer porous medium. The third type of barrier fluid is polySiloXane. These fluids are chemically and biologically inert silicon-based polymers used for medical implants. They are mixtures of two fluids, are unaffected by the aquifer or waste chemistry, and their containment performance depends on temperature and the ratio of the two constituents.

## TECHNOLOGY NEEDS

The strong adsorption of many contaminants to soil particles makes physical extraction slow or ineffective. Excavation of contaminated soils and disposal in protected facilities is very expensive. Containment on-site and control of groundwater transport can limit the off-site threat, and may supply a long-term solution.

A barrier containment system that does not require excavation would be a useful groundwater contamination control technique. Formation of a barrier with surface injected components that polymerize or change their viscosity under aquifer temperature and pressure conditions would allow barrier emplacement without excavation. In situations where complete control is necessary, an impermeable barrier is preferred over the sorption barrier.

In some areas aquifer mineralogy or regulatory restrictions may preclude the use of one or another barrier component. A variety of barrier systems must be available to match the range of contaminants and circumstances.

## ACCOMPLISHMENTS

- Completed a wide search for fluids with desired properties.
- Identified three types of promising substances for evaluation as barrier fluids: polybutenes, colloidal silica, and polysiloxanes, and selected the most promising uses of these fluids.
- Completed analysis of the rheological properties of the barrier fluids.

- Conducted laboratory studies of barrier fluid flow and emplacement in porous media in columns and three-dimensional flow chambers. Determined that all three types of liquids are effective in sealing porous media.
- Identified the dominant mechanisms in colloidal silica gelation in porous media. Developed processes to control the gel time and the texture of the gels. Determined the need and designed protocol for the sequential injection of colloidal silica.

## COLLABORATION/TECHNOLOGY TRANSFER

Texas A&M University in College Station is evaluating the performance of barrier fluids in large two-dimensional laboratory experiments using their specialized facilities. UC Berkeley is involved in the selection and rheological study of polymer-type barrier fluids.

The new technologies and the corresponding design package will be made available for use throughout the DOE Environmental Restoration program, as well as other U.S. agencies (EPA and DoD). Contamination problems expected to be especially amenable to barrier containment include localized ("point-like") sources. Many DOE sites would be candidates for the pilot- and field-scale application of the technologies, including the Hanford Underground Storage Tanks Integrated Program, Mixed Waste Integrated Program, the Buried Waste Integrated Demonstration Program, as well as the Rocky Flats site, the Nevada Test Site, the Savannah River site (for localized sources), and the Lawrence Livermore National Laboratory (where much pertinent in-

formation may be available from the "clean site" steam injection pilot). Many industrial sites with "point-like" contamination problems are also candidates for the application of these technologies.

**For more information,  
please contact:**

**Karsten Pruess**

Principal Investigator  
Lawrence Berkeley Laboratory  
(510) 486-6732 or 486-4746

**Sally Benson**

Technical Program Manager  
Lawrence Berkley Laboratory  
(510) 486-7347

**Jeff S. Walker**

Program Manager  
U.S. Department of Energy  
(301) 903-7915

## 1.11

## IN SITU MICROBIAL FILTERS

### TASK DESCRIPTION

This task will develop and evaluate an in situ microbial filter to remediate contaminant plumes at their expanding boundaries using methanotrophic bacteria (see Figure 1.11).

In the first field demonstration, specialized non-pathogenic TCE degrading bacteria will be injected to establish an in situ fixed biofilter around a suitable injection well located within the contaminant plume. The fixed microbial filter will be quasi-cylindrical in shape and have a height of about 2 m and a radius of about 1 m. After a predetermined period of time, the inoculation process will stop and groundwater will be extracted from the same well. Contaminated groundwater will flow through the attached in situ microbial filter, it will be decontaminated to regulatory limits by the microbes, and clean water will be produced at the well-head. After the filter has reached its longevity limit, the filter will be replenished.

In both cases, the enhanced activity of the biocurtain will cause biotransformation of TCE at a rate equivalent to the rate at which TCE is delivered to the filter. Thus, the microbe curtain will serve as a contaminant-specific fixed filter, capable of remediating substantial amounts of TCE in groundwater.

### TECHNOLOGY NEEDS

TCE is probably the most prevalent chlorinated solvent contaminating groundwater at DOE and other sites, and is sufficiently soluble in water to be easily transported and broadly disseminated. Because of TCE's wide dispersion at relatively low (but unacceptable) concentrations, in situ treatment technologies are sorely needed.

### ACCOMPLISHMENTS

*Methylosinus trichosporium* strain OB3b has been optimized for use on the biofilter. Growth of the microorganism under conditions of copper starvation and careful nutrient management induced the production of large quantities of soluble methane monooxygenase (sMMO), the enzyme responsible for the cometabolic degradation of TCE. OB3b has been optimized such that the

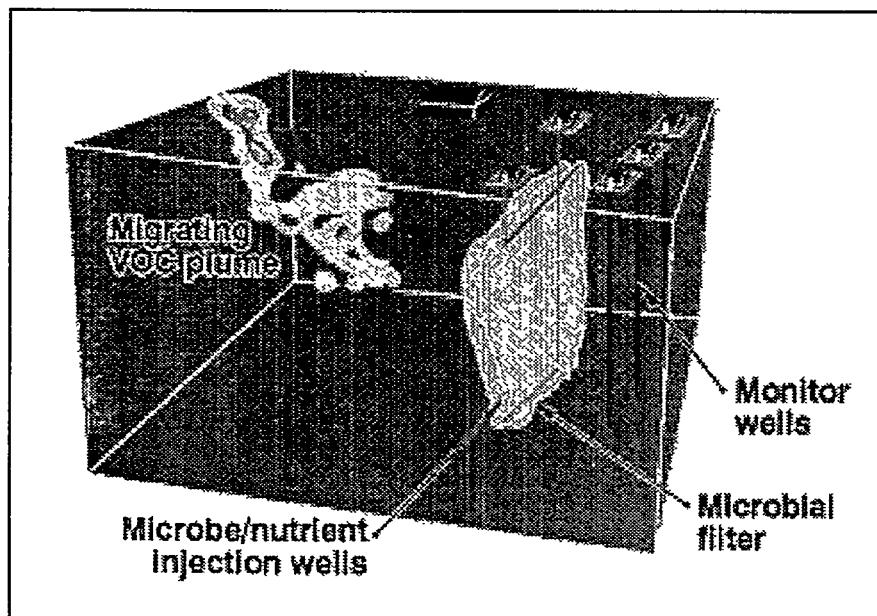


Figure 1.11. The biodegradation of trichloroethylene.

sMMO will degrade TCE for over 30 days without a need for inducer (i.e., methane). This means that once the in situ filter is injected with the microorganisms, TCE-degrading activity should last for 30 days.

A proof-of-principle experiment has been successfully completed. In this experiment, TCE-contaminated water was allowed to flow through a bench-scale, one-meter model biofilter. Microbes within the filter region degraded 100 percent of the TCE.

A 10 cm long column has been designed and set up, such that 100 percent of the TCE has been recovered. The standard flow rate of 1.5 cm/hr is being used. A greater than 3-week enzyme longevity has been established, and complete degradation of a 230 ppb pulse of TCE has been shown.

A large-scale bioreactor facility will be built for the mass production of OB3b for use on the in situ microbial filter. Cost estimates for this remodeling task have been completed, and steps are now being taken to seek a design and build contract from a bidding process.

Long term experiments have shown that the addition of a mixture of  $MgCl_2$ ,  $FeSO_4$ , and agar to the aqueous media increases microbial attachment rates and reduces the rate of cell detachment. Cell detachment rates depend on fluid flow velocities, but these experiments have demonstrated that a significant enhancement of cell attachment can be achieved even at high flow velocities.

## **COLLABORATION/TECHNOLOGY TRANSFER**

NASA is interested in field-testing this technology.

**For more information,  
please contact:**

**R. B. Knapp**

Principal Investigator

Lawrence Livermore National Laboratory  
(510) 423-3328

**Ann Heywood**

Technical Program Manager

Lawerence Livermore National Laboratory  
(510) 422-8203

**Jeff S. Walker**

Program Manager

U.S. Department of Energy  
(301) 903-7915

## 1.12

# OPTIMAL REMEDIATION DESIGN: METHODODOLOGY AND USER-FRIENDLY SOFTWARE FOR CONTAMINATED AQUIFERS

## TASK DESCRIPTION

A critical question in site remediation is how to manage and optimize the long-term groundwater remediation process. The locations and rates of pumping for each groundwater remediation well, which may change with time, must be selected carefully, as well as the locations and sampling intervals of monitoring wells. Operation and maintenance costs associated with these decisions can be enormous when projected over realistic remediation periods of typically 30 to 100 years.

This project focuses on the development of a methodology and associated tools for the management and optimization of groundwater contamination in both unsaturated and saturated systems.

More efficient tools will be investigated for the optimization of large-scale, three-dimensional groundwater systems that are hydrodynamically constrained. Despite recent advances in optimal design techniques, a number of problems remain, including, for example, the effects of "clay caps," "cutoff walls," and "horizontal drains" on the optimization schemes.

Specific tasks include the development of three-dimensional groundwater simulators coupled with optimization based on hydrodynamic and solute transport constraints. These codes will allow optimal design of both saturated and unsaturated systems, and will be coupled with a realistic economic model and user-friendly graphical interfaces.

Research on more robust and efficient optimization methods, such as the outer approximation method, will address non-linear optimization of solute transport in groundwater systems. This research is directly applicable to other important subsurface contamination problems, such as multi-phase flow and the use of subsurface chemical treatments. Work will also be performed on the development of more realistic constraint functions that include improved economic descriptions. This will allow the quantitative optimization problem under consideration to be closer to a decision-maker's verbal description of the problem.

Graphical interfaces will be developed for a variety of computers. These graphical interfaces will not only increase the potential for technical transfer, but will also provide an important tool for the exploration of data, proposed solutions, and other "what-if" scenarios that involve large amounts of numerical information.

## TECHNOLOGY NEEDS

The need for optimization procedures during the evaluation, selection, and implementation of biological and non-biological in situ treatments has been identified by many sites. Sites performing environmental restoration must make informed decisions with respect to the location and pumping rate of groundwater remediation wells, the location of monitor wells, and the use of drains, caps, or cutoff walls.

To make these decisions, calibrated groundwater modelling of contaminant flow and transport must provide realistic simulations of flow and transport through saturated and unsaturated porous media. The results of this modelling must be coupled with economic and risk evaluation models to determine the optimal remediation that minimizes risk and cost and addresses the needs of the stakeholders in the decision making process. The need to communicate the risk and cost impact of potential remedial alternatives to non-technical decision makers is a critical element in the optimization process.

## ACCOMPLISHMENTS

The contract with the University of Vermont, the major developer of the software for this task, has been completed. Interface parameters (i.e., menus, model result processing, and point-and-click parameters) have been established for software development.

A three-dimensional groundwater simulator coupled with optimization based on hydrodynamic constraints was delivered in September 1993. A three-dimensional groundwater simulator coupled with optimization based on solute transport constraints was delivered in September 1994. The simulators will include coupled transport in the unsaturated zone, a realistic economic model, and user-friendly interfaces for the field application of the saturated and unsaturated zone models.

## COLLABORATION/TECHNOLOGY TRANSFER

This work is being performed in collaboration with Dr. George Pinder, Research Center for Groundwater Remediation Design at the University of Vermont. Additional participants include David E. Dougherty of the University of Vermont, and David P. Ahlfield of the University of Connecticut. The tasks in this project are being performed primarily by the University of Vermont. Investigators at Lawrence Livermore National Laboratory ensure that unnecessary overlap with related research projects is avoided and that the research provided by the University of Vermont is relevant to the Department of Energy.

**For more information,  
please contact:**

**David W. Rice, Jr.**

Principal Investigator

Lawrence Livermore National Laboratory  
(510) 423-5059

**Ann Heywood**

Technical Program Manager

Lawrence Livermore National Laboratory  
(510) 422-8203

**Jeff S. Walker**

Program Manager

U.S. Department of Energy  
(301) 903-7915



## **Waste Retrieval and Processing**

### **Section 2.0**



## 2.0

## WASTE RETRIEVAL AND PROCESSING OVERVIEW

Waste retrieval and processing constitutes one of the largest DOE problems. Within the DOE Complex, large quantities of high-level waste, low-level waste, and transuranic waste have been buried or stored and need retrieval and treatment. Before 1970, most low-level and transuranic wastes were buried in common shallow land burial grounds. A majority of the high-level waste was stored in underground storage tanks.

DOE has identified more than 1 million 55-gallon drums and boxes of waste in storage, and 3 million m<sup>3</sup> of buried waste. Over the years, many of the older disposal containers have been breached, resulting in contamination of the adjacent soil. Considering transuranic solid waste, approximately 190,000 m<sup>3</sup> have been buried, and 60,600 m<sup>3</sup> have been retrieved and stored. Mixed transuranic waste composes 58,000 m<sup>3</sup> of this inventory. High-level waste stored at four DOE sites represent another 381,000 m<sup>3</sup> of volume. Of this, 77 million gallons of high-level waste are contained in 332 underground storage tanks as sludge/liquids and approximately 4,000 m<sup>3</sup> are stored as granular calcined solids. Since most of the high-level waste is mixed with hazardous contaminants, it is considered mixed waste. The remainder of the stored waste, about 3,000,000 m<sup>3</sup>, is low-level waste and includes 247,000 m<sup>3</sup> of mixed low-level waste. No effective treatment is known for 107,000 m<sup>3</sup> of this mixed low-level waste.

Effective May 8, 1992, all DOE mixed-waste streams fell under EPA's land disposal restrictions and, as such, can no longer be disposed of without prior treatment to destroy, separate, or immobilize the hazardous component. All mixed low-level and high-level waste must be treated before final disposal. In the case of mixed transuranic wastes destined for deep geologic disposal, the hazardous components must not exceed established waste acceptance criteria. Most of the hazardous components of the mixed wastes have not been characterized; however, from past knowledge, they represent the entire gamut of organic and inorganic hazardous wastes. Available technology is inadequate to solve many of the problems at hand.

Another form of waste, representing potentially large volumes, is associated with decontamination and decommissioning of contaminated buildings and equipment. More than 500 separate facilities have been identified, and it is possible that as many as 7,000 facilities at 39 different sites could be scheduled for decontamination and decommissioning. Although materials will be recycled when possible, this activity will result in new waste generation that is immeasurable at this time. Additionally, as much as 20,000 m<sup>3</sup> of mixed waste, in 100 separate waste streams, is still being generated on an annual basis from ongoing facility deactivation and transition activities.

Developing cost-effective innovative hazardous and mixed waste characterization and treatment technologies is not only a requirement for DOE, but for other Federal agencies and commercial businesses. EPA estimates a total present value cost of about \$18.7 billion, and an annual cost of about \$1.8 billion using available technologies. Furthermore, EPA assumes there exists approximately 773,000 sites with underground storage tanks that are subject to

regulation and remediation.<sup>2</sup> Most of these tanks contain petroleum products and require remediation of the tank as well as the surrounding soil as a result of leakage problems. Although occurrences of radioactive contaminated waste is less frequent in the public sector, there are no widely accepted technologies available to treat this waste. Development of efficient, low-risk mixed waste treatment systems and facilities is one of the most pressing issues facing public and private environmental restoration and waste management efforts.

<sup>2</sup> U.S. Environmental Protection Agency, Office of Policy, Planning and Evaluation, Environment Investment: The Cost of a Clean Environment, EPA-230-11-90-083, November 1990.

## 2.1

# REMOTE CHARACTERIZATION SYSTEM

### TASK DESCRIPTION

This project demonstrates the feasibility of remote, high-precision characterization of buried waste by deploying and operating multiple geophysical sensors over a waste site. The Remote Characterization System (RCS) consists of a vehicle, multiple geophysical radiation and/or chemical sensors, on-board video cameras, data communication equipment, a Global Positioning System, and a control base station (see Figures 2.1a and 2.1b). The vehicle was designed and fabricated specifically for the RCS to minimize the amount of ferrous metal in the vehicle, which would interfere with the operation of the sensors.

Sensors include flux gate, proton precession, and optically pumped magnetometers; ground penetrating radar; and an EM-31. Other detectors may be added to the array to accommodate different waste stream situations. The control system enables integration of subsurface data with excavation planning, controls the vehicle, and has an ethernet radio frequency link with the sensors and vehicle controls.

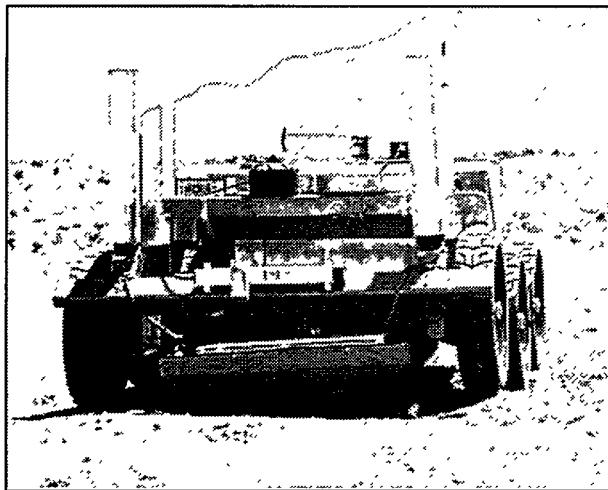


Figure 2.1a. Remote Characterization System at the INEL Cold Test Pit.

The RCS allows simultaneous use of multiple sensors, thereby reducing remediation cost by rapidly characterizing waste sites. The RCS also improves safety by not requiring workers at hazardous waste sites to enter these hazardous areas.

The RCS is still in the development stage and not yet ready for field implementation. However, once field deployable, the RCS can be used at any DOE or industrial facilities that have buried hazardous and/or radioactive waste.



Figure 2.1b. Remote Characterization System Control Station.

## TECHNOLOGY NEEDS

Current non-intrusive subsurface mapping techniques are labor intensive and time consuming. Manual methods of data acquisition from geophysical sensors are obtained from one sensor at a time. A system is needed to more quickly and remotely deploy a suite of sensors at the same time to provide information about and identify metallic objects, hot spots, pit and trench boundaries, radiation and levels.

This system will allow improved data quality through automated data acquisition, improved data display for interpretation, and increased safety for personnel, especially when access to the waste site represents risk to personnel.

## ACCOMPLISHMENTS

The RCS was demonstrated and tested at the INEL Cold Test Pit in June 1993. The demonstration showed that data from three geophysical sensors can be collected simultaneously and transmitted to the control base station for real-time display. The RCS, while making numerous advances in the technology of remote site characterization, was shown to be still in the development stage. Specifically, further development of the sensors and communication system is needed before reliable operation can be achieved.

## COLLABORATION/TECHNOLOGY TRANSFER

The system was developed utilizing INEL, ORNL, SNL, LLNL, and PNL.

**For further information,  
please contact:**

**R. Kane**

Principal Investigator  
Lawrence Livermore National Laboratory  
(510) 422-0410

**Jaffer Mohiuddin**

Program Manager  
U.S. Department of Energy  
(301) 903-7919

## 2.2

# REMOTE EXCAVATION SYSTEM

### TASK DESCRIPTION

The objective of this project is to demonstrate and evaluate a system to remotely excavate radioactive waste, unexploded ordinances and other hazardous wastes. A standard military vehicle, the Small Emplacement Excavator (SEE), was modified by ORNL for remote operation and computer-assisted control. The excavator boasts automated dig and dump functions, multiple video cameras, joint encoders and other sensor feedback. Video and control data is transmitted to the control station via radio frequency links or fiber optics. A novel 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 Remote Excavation System (RES) is designed for relatively small excavations. Remote operation of the system demonstrated a retrieval rate of approximately  $2.4 \text{ ft}^3/\text{min}$ . Manual operation under test conditions was

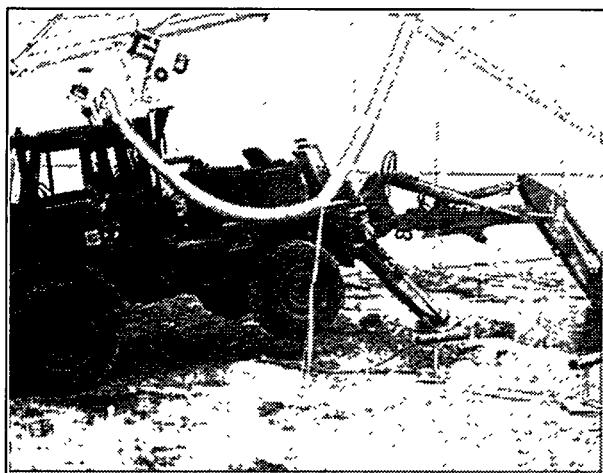


Figure 2.2a. Remote excavation operations at the INEL Cold Test Pit.

able to achieve rates 50 percent higher. However, actual manned operation at a waste site would likely not be able to achieve these rates because of protective equipment and monitoring requirements.

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. With the RES, materials can be excavated and retrieved in a hazardous environment without endangering operator personnel.

### TECHNOLOGY NEEDS

Several DOE sites have significant amount of buried waste and contaminated soil. The mixture varies from site to site, but the waste and contaminated soil consists of low-level, TRU, and high-level radionuclides, pyrophoric and possibly explosive materials in many forms. The methods of remediation will vary, but given the hazards of the waste, robotic and remote handling techniques will be necessary to reduce the risk to the worker.

### ACCOMPLISHMENTS

The RES was demonstrated at the INEL Cold Test Pit and at the U.S. Army Redstone Arsenal to evaluate the feasibility of excavating buried waste and unexploded ordinances with a remotely-operated vehicle (see Figure 2.2a). At each of these demonstrations, the relative performance benefits of teleoperation and

telerobotic excavation were evaluated and documented. It was demonstrated 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 inexperienced and experienced operators alike (see Figure 2.2b).



## **COLLABORATION/TECHNOLOGY TRANSFER**

The system was developed utilizing INEL, ORNL, SNL, LLNL, and PNL. The Department of the Army also provided the platform, which was remotized for use by both DOE and the Army.

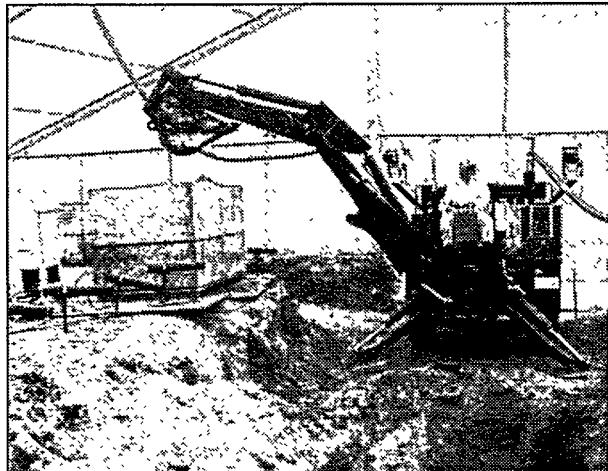
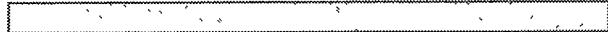


Figure 2.2b. Manual operation of the Remote Excavation System equipment.

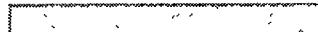
**For further information,  
please contact:**

**S. Killough**

Principle Investigator  
Oak Ridge National Laboratory  
(615) 574-4537

**Jaffer Mohiuddin**

Program Manager  
U.S. Department of Energy  
(301) 903-7919



## 2.3 FIBER-OPTIC LASER RAMAN SPECTROSCOPIES FOR TANK WASTE CHARACTERIZATION

### TASK DESCRIPTION

Fiber-Optic Laser Raman Spectroscopy systems will be developed and tested in this task for characterization of tank wastes. These systems are designed so they can be deployed in either hot cells or in waste tanks, enabling both ex- (see Figure 2.3a) and in-situ characterization.

Two different ways to chemically profile waste surface inside waste tanks will be investigated. One consists of a mechanically-driven fiber-optic probe that will be swept over the surface to be interrogated; the Light Duty Utility Arm will be used to precisely position the probe (Remote Fiber-Optic Raman Spectroscopy). The other involves a scanner that will directly sweep a laser beam and the field-of-view of a spectrometer across the surface; in this case the simple rotation of a mirror can

be used to guide the laser beam and collect the scattered radiation (non-contact Raman spectroscopy). Relatively modest laser powers (100 mW) and small collection optics (22 mm) have been found to be effective to characterize samples up to tens of feet away in non-contact Raman spectroscopy. Performance parameters (e.g., spatial resolution, sample to probe distance) of the two systems will be evaluated and compared.

In situ characterization of core sections will be achieved with the use of a Raman fiber-optic probe fitted inside a cone penetrometer. Such a probe is being developed at Westinghouse Savannah River Company (WSRC). Elements that define performance objectives of the Raman probe include the expected tank environment, cone penetrometer requirements, and contaminants to be measured.

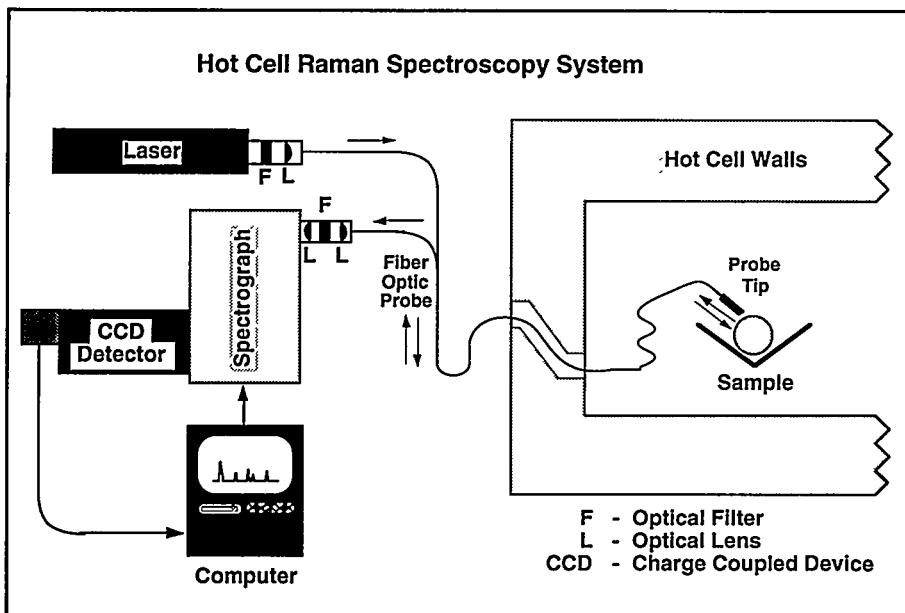


Figure 2.3a. Hot Cell Laser Raman Spectroscopy System.

Complementing these activities in a system approach are two other subtasks. One is the development of a Raman library/database to support qualitative and quantitative applications of the spectroscopic techniques. The library/database will contain archived Raman spectra that have been obtained from pure material, simulated and real tank waste (see Figure 2.3b). The database will initially hold

spectroscopic information on ferrocyanide, ferricyanide, nitrate and nitrite, but will be expanded to include other chemical species such as organic compounds. The other subtask is the radiation testing of fiber-optics. Two aspects will be addressed in this subtask: sur-

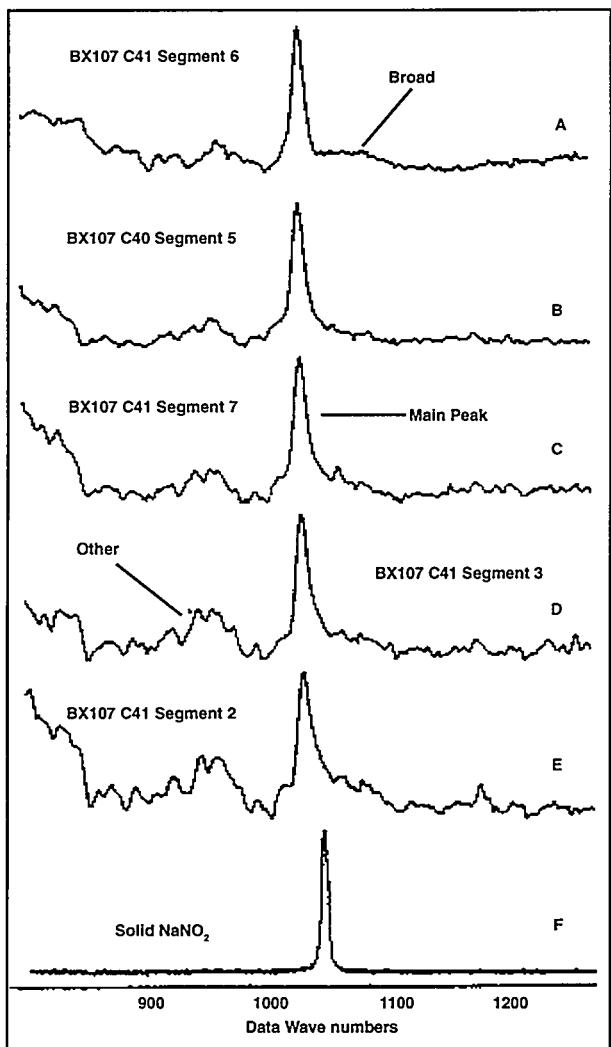


Figure 2.3b. Laser Raman Spectra of various nitrate-containing materials.

vival of optical fiber material in radiation environments; and changes in Raman spectral signal induced by the radiation.

## TECHNOLOGY NEEDS

Laboratory analysis of tank waste is both time consuming and expensive. While Raman spectroscopy will not replace established regulatory analysis, its development as a screening technique for both ex- and in-situ characterization offers significant reduction in time, cost, and secondary waste generation; minimizes radiation exposure of personnel; and provides valuable guide to sampling and analysis of core waste material.

An in situ waste probe will also provide data on the homogeneity, location and mapping of key waste materials (e.g., ferro/ferricyanide) inside the tanks; these are data necessary to direct and monitor waste retrieval.

## ACCOMPLISHMENTS

The feasibility of applying laser Raman spectroscopy to tank waste characterization has been demonstrated. Analyses of pure materials and surrogates showed that unique Raman scattering can be used to identify major tank waste components including ferrocyanide, ferricyanide, nitrates and nitrites. In addition, a remote fiber-optic probe has been installed in a hot cell at Hanford and used to record Raman spectra of real tank waste material.

## **COLLABORATION/TECHNOLOGY TRANSFER**

Basic support and coordination for the development, integration and testing of the spectroscopic systems are provided by the Westinghouse Hanford Company. LLNL will evaluate the two spectroscopic methods — remote fiber-optic and non-contact Raman spectroscopies — and recommend a conceptual design for a Raman probe suitable for incorporation in a cone penetrometer; the Raman probe will be designed and developed by WSRC. Florida State University and the Naval Research Laboratory have been contracted to establish the Raman library/database and perform the radiation testing, respectively.

**For more information,  
please contact:**

**R. C. Eschenbaum**

Characterization and Retrieval  
Program Manager  
Westinghouse Hanford Company  
(509) 376-7439

**R. L. Gilchrist**

Integrated Demonstration Coordinator  
Westinghouse Hanford Company  
(509) 376-5310

**Jaffer Mohiuddin**

Program Manager  
U.S. Department of Energy  
(301) 903-7919

**TASK DESCRIPTION**

LLNL has teamed with Quest Integrated, Inc. to develop an efficient method of breaking up large blocks of hard saltcake that have developed in underground storage tanks within the DOE complex. These remaining wastes often surround tank risers and equipment, making their removal doubly difficult. LLNL and Quest are developing a water cannon rubblizer as a hydraulic tool capable of fracturing the hard saltcake.

The system uses ultra-high pressure (276 MPa, 40,000 psi) to generate a powerful hydraulic shock to fragment the monoliths. The resulting fragmentation is comparable to that achieved by explosive charges without the hazard of "fly" rock or toxic fumes and without the precise positioning required for water jet cutters. The resulting fragment size varies with material. The current tool uses water as the working fluid, with only about 200 ml (one-half pint) per blast. The control console monitors the pressurization of the tool and controls the discharge of the tool through the control valve assembly. The end-effector can be fired repeatedly with 5-10 seconds between blasts. The end-effector is remotely operated, and the design incorporates several features to provide "fail safe" operation.

Development tasks are varied. The design can be refined to reduce the amount of additional processing required for the fragments. Alternative fluids are being evaluated which either vaporize or gel in the tank after discharge to limit the addition of water to the tank. Reduction of the poppet valve opening time will increase the shock energy rate. Fi-

nally, the end-effector is being radiation-hardened and will be capable of accommodating remote decontamination.

**TECHNOLOGY NEEDS**

Many DOE sites have stored high-level radioactive wastes in underground tanks. Interim stabilization activities have removed much of the liquid from the tanks, leaving waste deposits in the form of sludge and hard saltcake. Removal of this saltcake from the tank equipment requires breaking up monolithic or large pieces of the saltcake into smaller fragments that can be easily handled and removed by other end-effectors. The rubblizer requires a less complex and forgiving positioning system than waterjet technology, allowing for a simpler control system. The control system allows for either manual or automatic operation of the end-effector.

**ACCOMPLISHMENTS**

Tests involving charge pressure effects, stand off distance, effector angle, dilution level, cycle rate and interface loads have been successfully completed. The results have led to a refinement of the design. Many parameters are being optimized and, with that, failure modes are better understood, such that failure mode recovery methods can be developed.

## **COLLABORATION/TECHNOLOGY TRANSFER**

LLNL is working with Quest Integrated Inc. to develop this technology. Joint testing is underway at both facilities and Quest is involved in evaluating the alternate fluid studies. Once developed, Quest will be able to commercialize the resulting product for use at other storage tank sites as well as market the product in other areas.

**For more information,  
please contact:**

**R. C. Eschenbaum**  
Characterization and Retrieval  
Program Manager  
Westinghouse Hanford Company  
(509) 376-7439

**R. L. Gilchrist**  
Integrated Demonstration Coordinator  
Westinghouse Hanford Company  
(509) 376-5310

**Jaffer Mohiuddin**  
Program Manager  
U.S. Department of Energy  
(301) 903-7919

## 2.5

# DERIVATIVES OF NATURAL COMPLEXING AGENTS FOR THE REMOVAL OF PLUTONIUM FROM WASTE WATERS

### TASK DESCRIPTION

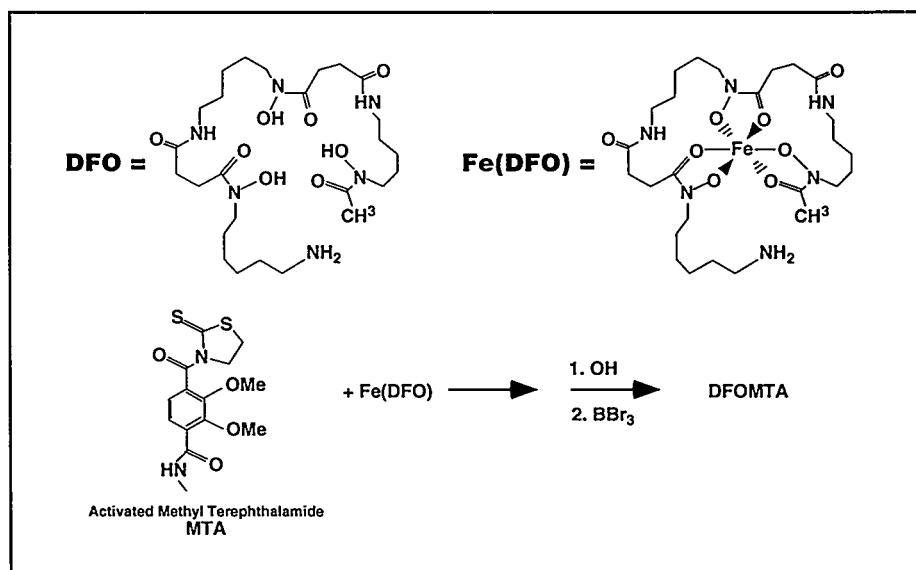
The objective of this task is to develop a separation system using a highly selective complexing agent derived from a natural material to remove plutonium (and perhaps other transuranic wastes (TRUs) from the high ionic strength waste waters which vary in pH depending on the exact flowsheet. In nature, bacteria and other microorganisms produce siderophores, low molecular weight multidentate iron chelators, to scavenge the ferric ion from their environments. One of the major siderophores is desferrioxamine B, and derivatives of this material show promise in fulfilling the requirements of a substance that binds plutonium in the presence of other metals and in solutions ranging from highly-acid to highly-basic (see Figure 2.5). This project will:

- determine or estimate the stability constants of the derivatives with Pu(IV);
- determine the speciation of the metal-ligand complex for a variety of pHs;
- determine the stability of the derivatives with Pu(IV) over the ionic strength range likely to be encountered in waste streams;

- attach appropriate ligands to solid supports and/or attach lipophilic side chains to the molecules to convert them into extracting agents; and
- test the engineered materials on simulated or actual waste.

### TECHNOLOGY NEEDS

Efficient chemical processes for the selective removal of actinide elements are needed for the treatment and minimization of wastes such as those found at the Hanford site. To accomplish this objective, new metal complexing agents capable of withstanding harsh chemical and radiation environments must first be developed and then modified for use in practical extraction systems.



## ACCOMPLISHMENTS

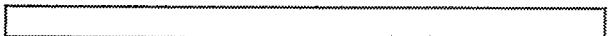
Desferrioxamine methylterethalamide (DFOMTA), Desferrioxamine-1,2-hydroxy-pyridonate (DFO-1,2-HOPO), and Desferrioxamine-3,4-hydroxy-pyridonate (DFO-3,4-HOPO) have been synthesized. The stability constant of the Pu(IV)/DFOMTA, Pu(IV)/DFO-1,2-HOPO, Th(IV)/DFOMTA, and Th(IV)/DFO-1,2-HOPO complexes have been determined.



## COLLABORATION/TECHNOLOGY TRANSFER

Glenn T. Seaborg Institute for  
Transactinium Science

University of California at Berkeley  
Ken Raymond  
(415) 642-7219



**For further information,  
please contact:**

**Darlene Hoffmann**

Principal Investigator  
Lawrence Livermore National Laboratory  
(510) 423-5031

**Ann Heywood**

Technical Project Manager  
Lawrence Livermore National Laboratory  
(510) 423-8203

**Teresa B. Fryberger**

Program Manager  
U.S. Department of Energy  
(301) 903-7962



## 2.6 REMOVAL AND RECOVERY OF TOXIC METAL IONS FROM AQUEOUS STREAMS BY UTILIZATION OF POLYMER PENDANT LIGANDS

### TASK DESCRIPTION

The purpose of this work is to investigate the use of polymer-supported pendant ligand technology in the removal of toxic metal ions from DOE waste streams. Polymer pendant ligands are organic ligands with metal-ion removal capabilities attached to the modified surfaces of 3, 10 or 20 percent cross-linked divinylbenzene-polystyrene beads. The metal-ion removal step usually occurs through an ion exchange or binding phenomena, and consequently regeneration and reuse of the beads is achievable. The research objectives of this project are to prepare the polymer supported ligands, to evaluate the ligands for selectivity with respect to the metal ions of interest, to study rates of removal of metal ions in order to determine residence times necessary for demonstration experiments, and to define regeneration and reuse procedures. The work will initially focus on the waters in the Berkeley Pit, and the metal ions targeted for removal from the pH ~2.6 solution are Cu, Zn, Mg, Mn, Al, Fe, Cd, Ni and Ca. The first six of these metals are of economic importance and represent ~\$720 million of projected recovery value.

### TECHNOLOGY NEEDS

The range of DOE remediation and waste management problems is so wide that no single technique can address them all. The separation and removal of metals is an obvious area demanding much attention in technology development. In addition to developing a wide range of technologies for specific applica-

tions, there is an advantage in having a generic base technology that can be customized to a wide range of applications with regard to both metal and type of matrix to be treated. The use of polymer pendant ligands would be a cost-effective alternative to cumbersome precipitation and bioremediation techniques.

### ACCOMPLISHMENTS

A report entitled "Berkeley Pit Separation Needs Using Polymer Pendant Ligands" co-authored by Richard Fish (LBL) and by Robert Albright and William Fries (Rohm and Haas) has been prepared and submitted. The basic premise of the report is that the development of an iron selective polymer pendant ligand (iron concentration in the Berkeley Pit is ~1,000 ppm) would facilitate removal of copper and zinc with a commercially available Rohm and Haas iminodiacetic acid polymer pendant ligand at pH~2.5.

Experimental studies on the development of such an iron selective polymer pendant ligand have started. The polymer pendant catechol derivatives, sulfonated catechol and sulfonated 3,4-LICAM, are ideal candidates since their structures are similar to moieties in bacteria that sequester iron.

## **COLLABORATION/TECHNOLOGY TRANSFER**

Robert Albright  
William Fries  
Rohm and Haas Company

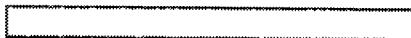


**For further information,  
please contact:**

**Richard Fish**  
Principal Investigator  
Lawrence Berkeley Laboratory  
(510) 486-4850

**Sally M. Benson**  
Technical Project Manager  
Lawrence Berkeley Laboratory  
(510) 486-5875

**Teresa B. Fryberger**  
Program Manager  
U.S. Department of Energy  
(301) 903-7962



## 2.7 CLEANABLE HIGH-EFFICIENCY PARTICULATE AIR FILTER DEVELOPMENT AND DEMONSTRATION

### TASK DESCRIPTION

Alternative methods/materials are being explored for High Efficiency Particulate Air Filters (HEPA) to produce low cost, low risk, reusable and reliable filters (see Figure 2.7a). Two separate projects are working to achieve this goal. Steel filter materials are being examined at LLNL, and inorganic membrane filters are being examined at the Oak Ridge K-25 site.

Plans for the steel filter production at LLNL include:

- fabrication of a 0.5 micron steel fiber filter;
- evaluation of new filter efficiency and pressure drop; and
- preparation of a report comparing the test results to standards.

Plans for the inorganic membrane filter production at Oak Ridge include:

- fabrication of an inorganic membrane filter using Oak Ridge K-25 technology;
- evaluation of new filter efficiency and pressure drop; and
- preparation of a report comparing test results to standards.

These task descriptions are similar and feasible, but future funding will depend upon the results of filter efficiency, pressure drop, reusability and cost savings between the two systems.

### TECHNOLOGY NEEDS

Current HEPA filters, made of glass and used to remove particles during the off-gas treatment, are expensive. Difficult generating conditions include high temperature and high pressure. The filters cannot be cleaned and are disposed of after use, contributing to high cost and more radioactive waste in the environment. Significant handling and maintenance occurs for the glass filters, which exposes workers to unsafe envi-

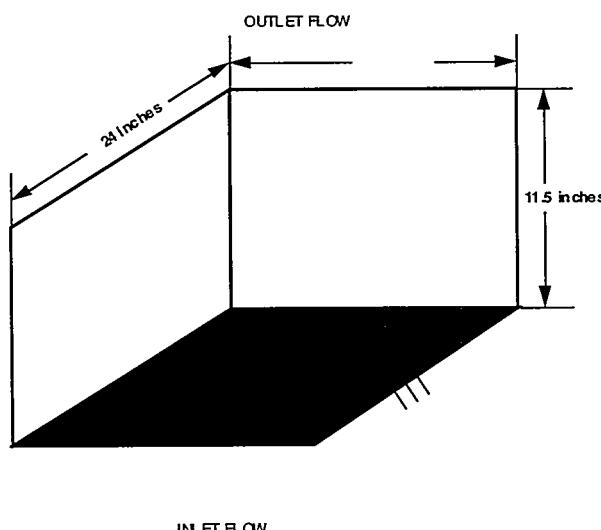


Figure 2.7a. Design of cleanable HEPA filter module.

ronmental conditions and increases person hours.

Alternative filter materials need to improve these conditions and pass efficiency and pressure drop requirements. HEPA filters need to capture 99.97 percent of 0.3 micron sized particles while maintaining less than 1 inch of water pressure drop (see Figure 2.7b).

## ACCOMPLISHMENTS

Filters of 2 micron steel fibers have been fabricated at LLNL that pass efficiency standards, and the lifespan is estimated at a minimum of 15 years.

Inorganic membrane filters fabricated at Oak Ridge have been successfully cleaned through reverse air pulsing.

## COLLABORATION/TECHNOLOGY TRANSFER

The optimum performing alternative HEPA filter will be used in the off-gas treatment of mixed waste in MWIP (see Figure 2.7c).

Pall Corporation in NY, which is jointly conducting the steel filter project with LLNL, will make this technology commercially available at the end of the project.

Golden Technologies Company, Incorporated, research and development subsidiary of Coors, has expressed interest in teaming with Oak Ridge to develop manufacturing of a cleanable inorganic membrane filter.

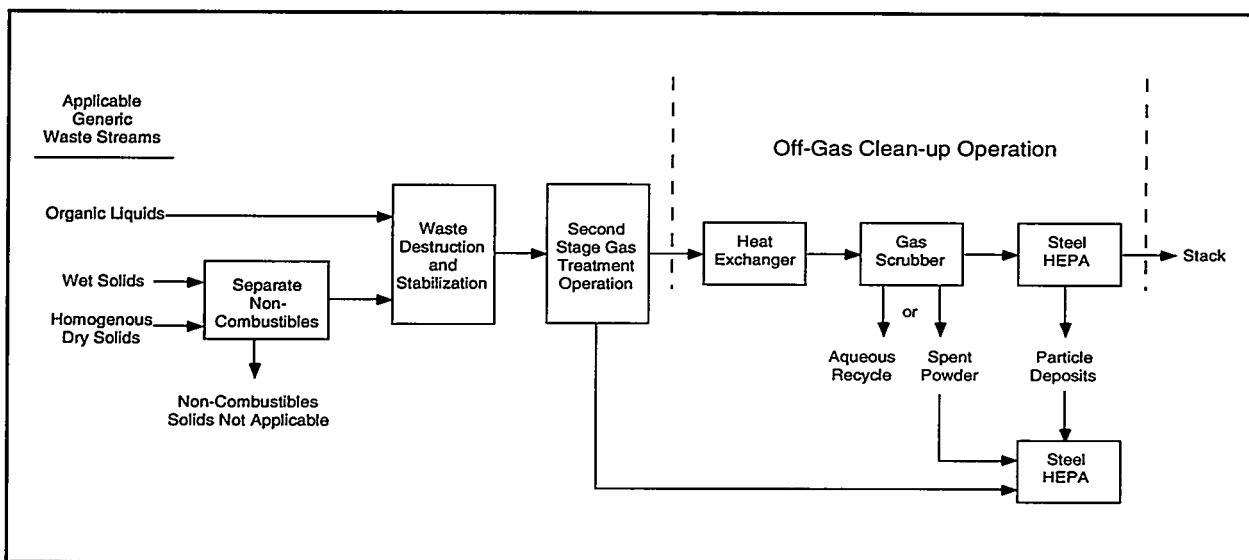


Figure 2.7b. Process Flow diagram.

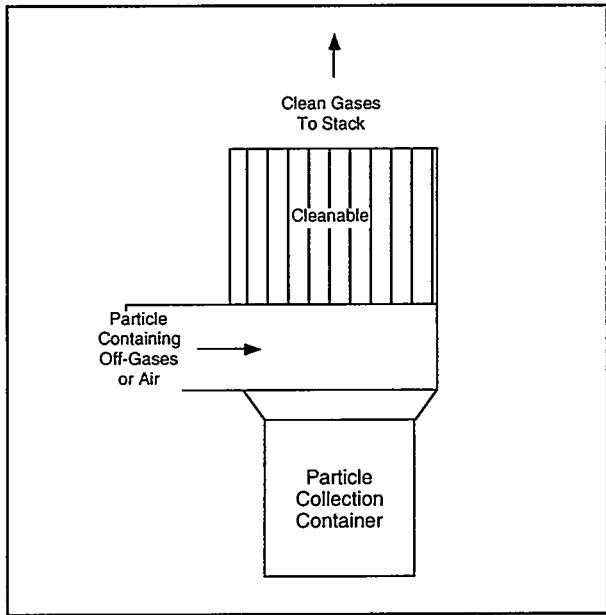


Figure 2.7c. Off-gas treatment.

**For further information,  
please contact:**

**Werner Bergman**

Steel Filters

Lawrence Livermore National Laboratory

(510) 422-5227

**D. E. Fain/G. S. Roettger**

Inorganic Membrane Filters

Martin Marietta Energy Systems

(615) 574-9932

**Paul W. Hart**

Program Manager

U.S. Department of Energy

(301) 903-7962

## 2.8

# SYSTEMS ANALYSIS FOR MIXED WASTE INTEGRATED PROGRAM

### TASK DESCRIPTION

The MWIP systems analysis coordinates potential alternatives to baseline technology (see Figure 2.8). Work focuses on safety risk assessment, performance systems analysis, and life-cycle costs for OTD-developed sub-systems. This includes an analysis of technology subsystems that have the potential to improve baseline technologies. The MWIP systems analysis group is developing alternative flowsheet models for baseline processes, which were developed by the Mixed Waste Treatment Project (EM-30). The alternative flowsheet processes involve mass and energy

balances, and could possibly improve baseline technology by analyzing replacement sub-systems of the master model.

The MWIP performance systems analysis group will model the innovative technologies in FLOW (to gain knowledge in the new technology) and in ASPEN software packages. The ASPEN models will be used by EM-30 to analyze the potential improvements of the innovative technologies with respect to their baseline process model. Evaluation will consider criteria such as implementability; maintainability; technical risk; environmental health and safety risk; and costs.

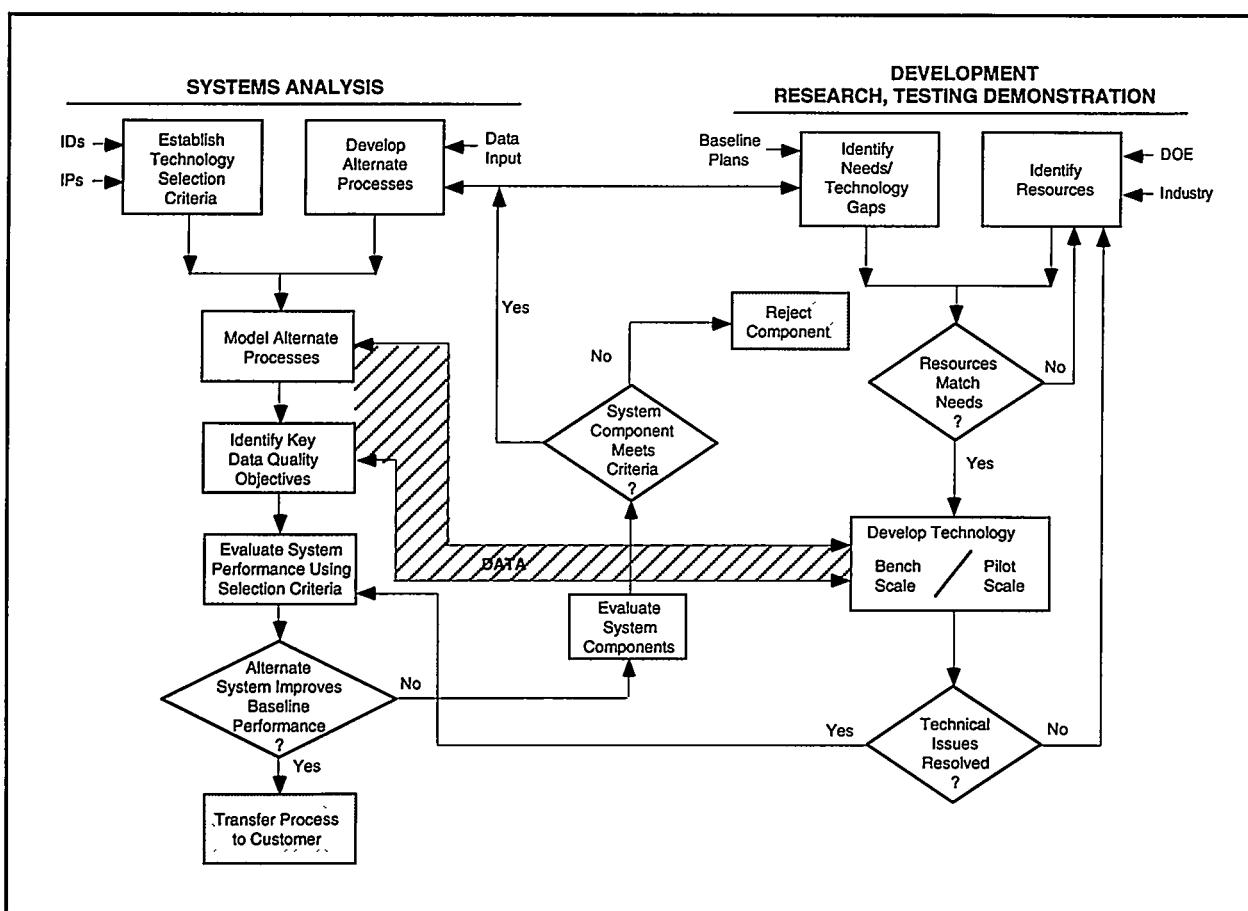


Figure 2.8. Systems analysis.

## **TECHNOLOGY NEEDS**

EM-30 requires that systems analysis be performed to assure that OTD-developed alternatives to baseline technologies are demonstrably superior to the original. MWIP is developing alternative technologies to fill technology gaps in mixed waste treatment plans, decrease characterization needs, and simplify treatment with versatile technologies.

## **ACCOMPLISHMENTS**

The systems analysis group completed a preliminary hazard analysis of the plasma hearth process, and found that there will be no significant risk if the waste inventory is maintained below 100 drums. An evaluation criteria report has been drafted, and includes technical and social elements. A performance analysis report has been drafted and includes tools development, preliminary performance results, and an uncertainty analysis that indicates the study needs for pilot plant experiments. A life-cycle cost analysis has been drafted, and includes a cost comparison between the baseline process and the first alternative flowsheet based on the plasma hearth process.

## **COLLABORATION/TECHNOLOGY TRANSFER**

Collaboration with Carnegie-Mellon University to perform uncertainty analysis has started. The computerized system being developed will run uncertainty analyses of innovative technologies. Actual work is directed to produce a computerized tool that works with the performance systems analysis tools to evaluate uncertainties in technology performance. Cost analysis has been developed by LANL, in conjunction with IT Corporation. The risk assessment has been conducted by LLNL in conjunction with Science Application International Corporation. Additional process engineering consultation is planned.

### **For further information, please contact:**

#### **Juan J. Ferrada**

Principal Investigator  
Oak Ridge National Laboratory  
(615) 574-4998

#### **Jeannette B. Berry**

Technical Program Manager  
Oak Ridge National Laboratory  
(615) 574-6907

#### **Paul W. Hart**

Program Manager  
U.S. Department of Energy  
(301) 903-7962

## 2.9

## INCINERATION ALTERNATIVES

Rocky Flats has generated a large quantity of mixed waste consisting of relatively common combustible items, such as rags, coveralls, paper products, shoe covers, and a variety of oils that have been exposed to the production environment. Similar waste streams are prevalent throughout the DOE Complex, as well as in other environments that work with radioactive materials. Although incineration has been identified as the best demonstrated available technology to treat the hazardous components of these mixed wastes and reduce the volume of the combustible materials, Rocky Flats Program (RFP) agreed to investigate non-thermal alternative technologies in the Comprehensive Treatment and Management Plan.

Work on alternatives to incineration involves several potential technologies which have been shown to destroy organic compounds in hazardous wastes. A series of lab-scale tests using non-radioactive surrogates have shown four technologies that may be appropriate for treatment of the Solvent Contaminated Wastes:

- *Catalytic Wet Chemical Oxidation;*
- *Mediated Electrolytic Oxidation;*
- *Packed Bed Reactor/Silent Discharge Plasma; and*
- *Supercritical Water Oxidation.*

These approaches provide treatment options for liquid and/or solid combustible waste streams in the event that incineration is not performed at RFP.

The Rocky Flats Compliance Program is continuing to evaluate these technologies in order to select a candidate technology for the demonstration of a complete incineration alternative system. Descriptions of the first three technologies are included in this section. The development of the fourth technology is the focus of the Supercritical Water Oxidation Program.

## 2.10 MEDIATED ELECTROCHEMICAL OXIDATION

### TASK DESCRIPTION

In the Mediated Electrochemical Oxidation process, an oxidizing metal ion (such as silver (II), cobalt (III) or cerium) is generated at the anode of an electrochemical cell containing an acidic solution (see Figure 2.10). The oxidizing metal then attacks and destroys the organic components of the waste.

Mediated Electrochemical Oxidation was originally developed to dissolve an insoluble form of plutonium oxide. Later, the ability to achieve high-destruction efficiencies for organic contaminants was demonstrated along with the effective dissolution of metals. The process operates at near-ambient temperatures and pressures using an acidic solution.

### TECHNOLOGY NEEDS

This technology has been extensively tested at the bench- and pilot-scale level both in the U.S. and in Europe. Work in DOE has demonstrated feasibility for treating organic liquids and some solids. Development work is focused on demonstration of required ancillary systems and on systems integration.

### ACCOMPLISHMENTS

- Completed lab-scale tests and determined destruction efficiencies for surrogate (non-radioactive) FBI oil (liquid chlorinated organics).
- Completed lab-scale tests and determined destruction efficiencies for surrogate solid combustibles (e.g., paper, plastic).
- Completed initial pilot-scale tests for surrogate liquid and solid organic wastes.

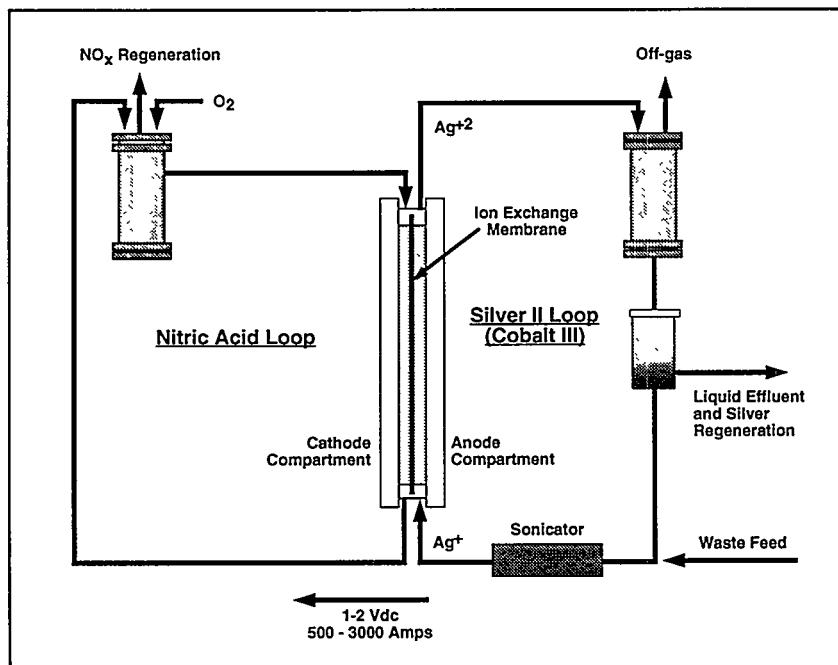


Figure 2.10. Mediated electrochemical oxidation.

## **COLLABORATION/TECHNOLOGY TRANSFER**

Evaluation of Mediated Electrochemical Oxidation for Rocky Flats is being conducted at LLNL and by PNL.

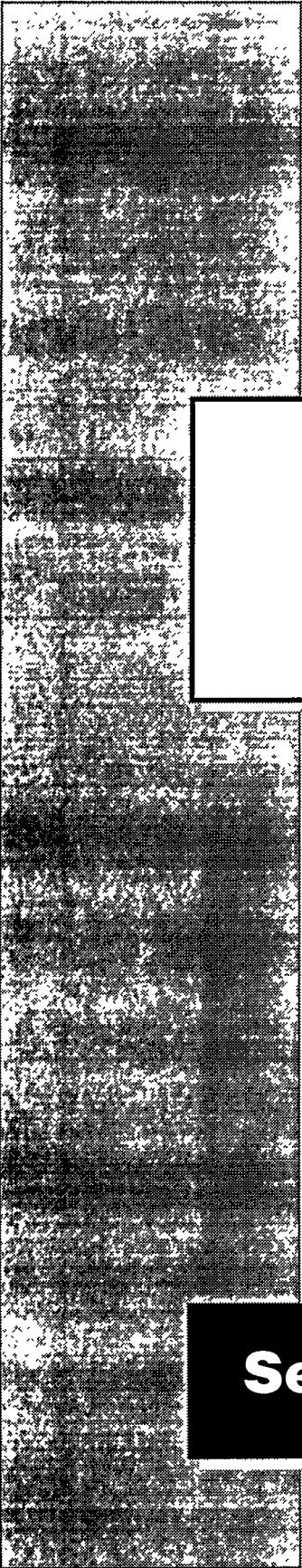
Rocky Flats also continues to evaluate published reports and data on other incineration alternative technologies and to follow the development of these technologies throughout the DOE Complex.

**For further information,  
please contact:**

**Zoher Chiba**  
Principal Investigator  
Livermore National Laboratory  
(510) 422-6124

**Alison B. Johnson**  
Program Manager  
U.S. Department of Energy  
(301) 903-7725





## **Innovation Investment Area**



**Section 3.0**



### **3.0**

### **INNOVATION INVESTMENT AREA OVERVIEW**

The mission of OTD's Innovation Investment Area is to identify and provide development support for 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.

The underlying strategy is to ensure that private industry, other Federal agencies, universities, and DOE National Laboratories are major participants in developing and deploying new and emerging technologies. This is accomplished through substantial funding set aside for building public and private-sector partnerships. Tools employed to achieve this include: Program Research and Development Announcements (PRDAs), Research Opportunity Announcements (ROAs), CRADAs, Financial Assistance Awards (Grants), Interagency Agreements (IAGs), and DOE National Laboratory Technical Task Plans (TTPs). Activities procured through these contracting devices can be promptly moved to other RDDT&E programs that identified the need for research and development, or to the private sector for commercialization.

### 3.1

## CLEANABLE STEEL HEPA FILTER

### TASK DESCRIPTION

The purpose of this task is to demonstrate the effectiveness of a replacement for currently used HEPA filters.

In the study, the experimental approach will focus on the development of a cost-effective cleanable HEPA filter, using sub-micron stainless steel filters, that will have the same performance as commercially available HEPA filters made from glass fibers (see Fig. 3.1). Five components make up this task: fiber size reduction, media development, filter design and fabrication, filter cleaning technique, and field evaluation.

Evaluation of the filter demonstration will take place at DOE's Oak Ridge Facility. Here, a series of runs will be made using the filter demonstration unit to treat a 100 cfm portion of the exhaust gas stream from the grit blaster. Samples obtained for the filter demonstration inlet and outlet gas streams and analyzed from mass loading values and particulate size distribution. Demonstration of the stainless steel filter considered successful since the filter demonstration unit can be shown to operate with a particulate removal more efficient than the current HEPA filter.

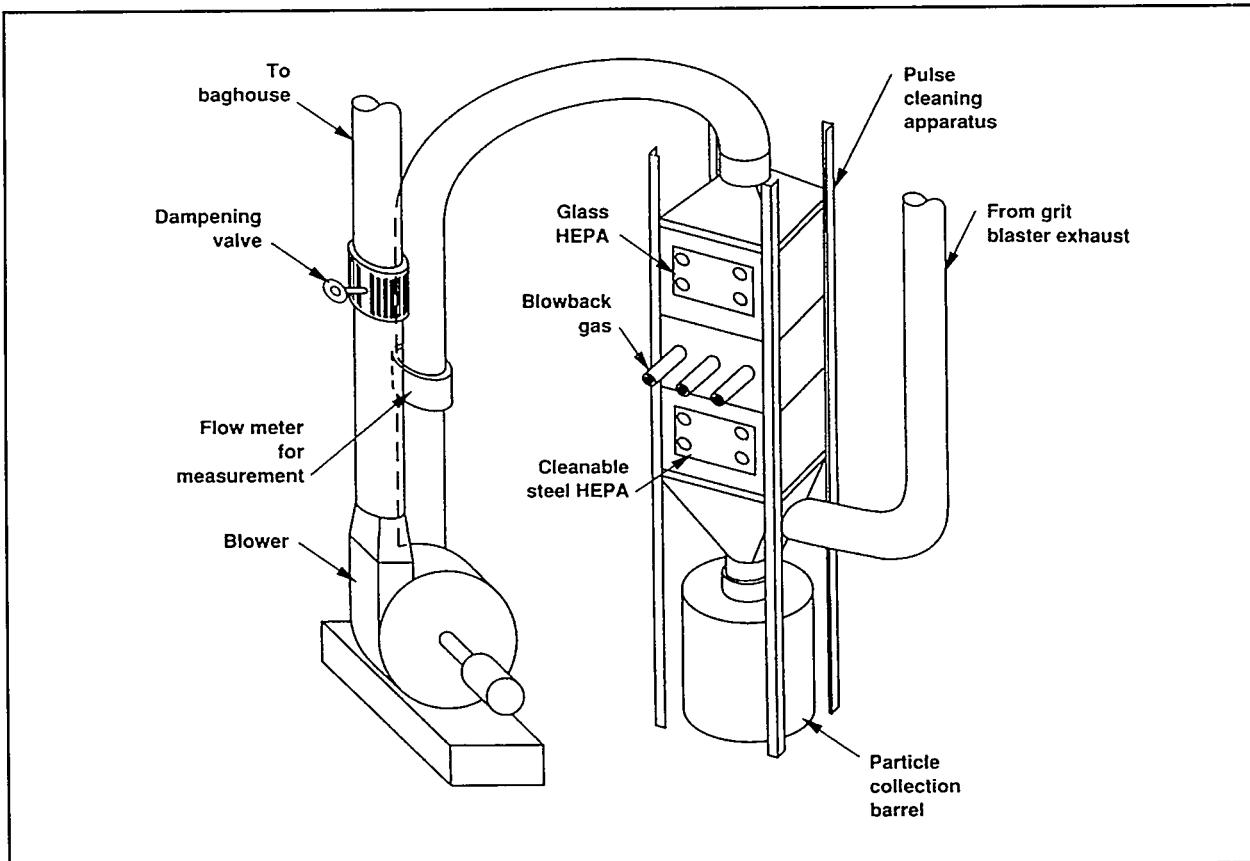


Figure 3.1. Initial design of demonstration unit for field test at the Y-12 Plant.

## TECHNOLOGY NEEDS

HEPA filters constitute the only acceptable method for absolute filtering of uranium contaminated air streams. The current regulatory requirement of 99.97 percent removal efficiency is based on a particle size of 0.3 mm, with a particle size of 0.1mm considered to be the most penetrating. Development of a cleanable steel HEPA filter might reduce the costs associated with meeting uranium environmental contamination regulations and industrial hygiene concerns.

Approximately 12,000 HEPA filters are used per year throughout the DOE Complex. At a cost of roughly \$4,500 per filter for disposal, \$55 million is spent per year on waste disposal costs. Replacement of the current HEPA filter with a cleanable, reusable stainless steel HEPA filter will reduce waste management costs and improve the reliability of the HEPA filtration system used extensively throughout the DOE Complex.

## ACCOMPLISHMENTS

- A prototype cleanable steel HEPA filter was developed and tested at DOE's Oak Ridge Y-12 Plant.
- Data from the filter evaluation was transferred to LLNL for analysis.
- A final report on the performance outcome of the experiments will be published shortly.
- Research on filter clogging and cleaning techniques is currently being negotiated.

## COLLABORATION/TECHNOLOGY TRANSFER

The project was funded by DOE under a contract to LLNL. Manufacturing of individual steel HEPA filter cartridges was contracted to the LLNL Corporation, with Memtec of America acting as a backup.

A formal communication system was established with DOE's Office of Environmental Management to keep them informed of progress being made and specific needs be incorporated.

### For further information, please contact:

#### **Werner Bergman**

Principal Investigator

Lawrence Livermore National Laboratory

(510) 423-9228

#### **Jesse L. Yow**

Technical Program Manager

Lawrence Livermore National Laboratory

(510) 422-3521

#### **Isiah Sewell**

Program Manager

U.S. Department of Energy

(301) 903-8459

### 3.2

## ENVIRONMENTAL REMEDIATION AND TREATMENT OF MIXED WASTES USING INTENSE PENETRATING BREMSSTRAHLUNG

### TASK DESCRIPTION

The purpose of this effort is to demonstrate a viable process for breaking down halogenated organic wastes into simpler, non-hazardous wastes using high-energy ionizing radiation.

Experimentally, the effort will focus on the efficacy of accelerator generated radiation to decompose chlorinated solvents and VOCs and to advance the radiolytic toxic waste processing technology to the point of industrial-scale development. Experiments will be performed using ionizing radiation to irradiate VOCs in groundwater in the vapor phase and in carbon filters.

Four different electron accelerators will be used to produce Bremsstrahlung radiation to destroy toxic substances. These accelerators will provide electrons ranging in energy from 1.6 to 9 MeV and produced Bremsstrahlung dose rates ranging from  $10^5$ - $10^{11}$  R/s. Additionally, toxic substances also exposed to cobalt-60 gamma radiation at a rate of 400 R/s; cobalt-60 gamma radiation has an energy of 1.25 MeV. The experimental parameters of the five radiation sources are listed in Table 3.2.

The project will be accomplished in two phases. In Phase I, the economic feasibility of the technology will be evaluated in the laboratory. In Phase II, the technology will move from the laboratory into the field for demonstration, testing, and evaluation.

### TECHNOLOGY NEEDS

Contamination of soils, sludges and groundwater with organics is a problem throughout the DOE Complex. The most common contaminants are VOCs, in particular, perchloroethylene (PCE), TCE, and carbon tetrachloride (CTET). Baseline technologies that are being used to treat these contaminants are pump-and-treat contaminated groundwater, and vapor vacuum extraction, and/or carbon-adsorption, followed by incineration to treat organically contaminated soils and sediments. There is a pressing need for cost-effective, innovative technologies to break down halogenated organics without generating a secondary waste.

### ACCOMPLISHMENTS

- Successfully demonstrated the use of Bremsstrahlung as an irradiation source for the decomposition of VOCs (see Figure 3.2).
- An absorbed dose of 450 kR was sufficient to decompose TCE vapor from an initial concentration of 10,000 ppm to a final concentration of 500 ppm.

Source	Energy (MeV)	Max Dose rate (R/s)
Pulseread	1.6	$5 \times 10^{11}$
Febetron	2.0	$5 \times 10^{10}$
ETA-11	2.0	$10^8$
Linatron	9.0	$10^5$
Cobalt-60	1.25	400

Table 3.2. Accelerator and Isotope Radiation Sources.

- The same applied dose was able to decompose TCE vapor from an initial concentration of 500 ppmv to less than 1 ppm.
- Bremsstrahlung treatment of TCE vapor is a factor 10 less expensive than TCE treatment by carbon filtration.
- Two patent disclosure documents resulted from the work and are in the process of patent application filing.

## COLLABORATION/TECHNOLOGY TRANSFER

This project was funded as a contract to LLNL. A similar activity, using spent fuel as the irradiation source to decompose halogenated organic waste, was funded at INEL. Collaborative comparisons of each form of ionizing radiation decomposition were made via sample analytical cross-checks and split sample irradiation by each laboratory.

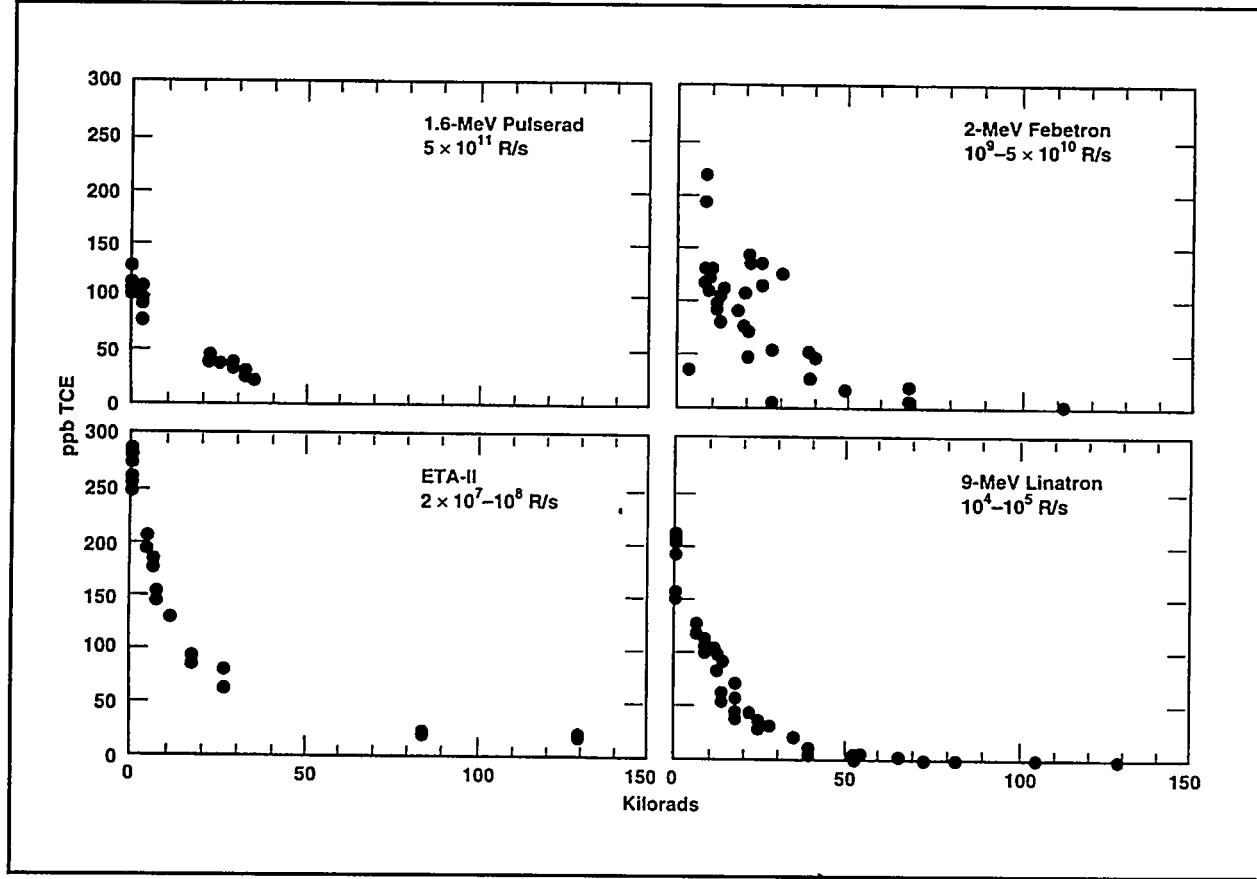


Figure 3.2. Radiolytically-induced reduction of TCE concentration in Well MW-222 groundwater as a function of radiation dose provided by four accelerators.

**For further information,  
please contact:**

**Stephen M. Matthews**

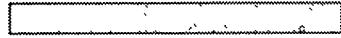
Principal Investigator  
Lawrence Livermore National Laboratories  
(510) 423-3052

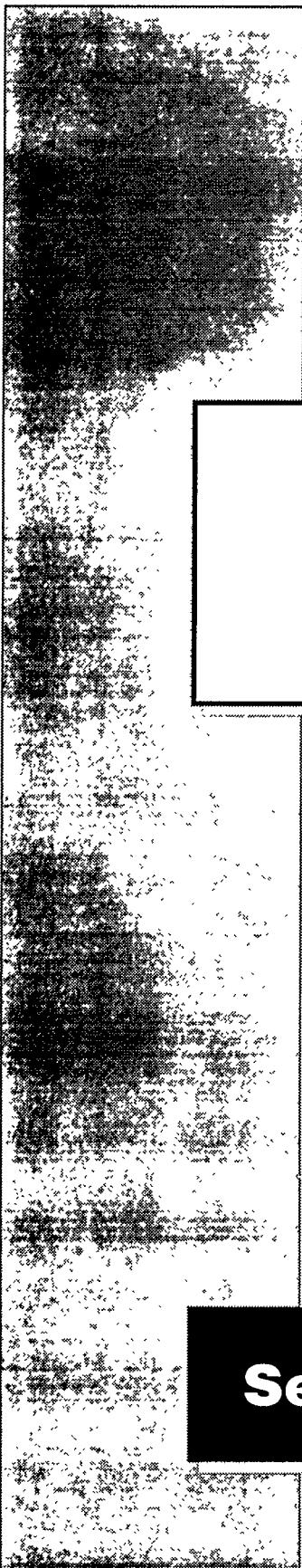
**Jesse L. Yow, Jr.**

Technical Program Manager  
Lawrence Livermore National Laboratories  
(510) 422-3521

**Isiah Sewell**

Program Manager  
U.S. Department of Energy  
(310) 903-8459





# **Robotics Technology Development Program**



## **Section 4.0**



## 4.0

## ROBOTICS TECHNOLOGY DEVELOPMENT PROGRAM OVERVIEW

The Robotics Technology Development Program (RTDP) is a “needs-driven” effort. A lengthy series of presentations and discussions at DOE sites considered critical to the Department’s Environmental Restoration and Waste Management (ER&WM) emphasis resulted in a clear understanding of needed robotics applications toward resolving definitive problems at the sites. A detailed analysis of the resulting robotics needs assessment revealed several common threads running through the sites: Tank Waste Retrieval (TWR), Contaminant Analysis Automation (CAA), Mixed Waste Operations (MWO), and Decontamination & Dismantlement (D&D). The RTDP Group realized that much of the technology development was common (Cross Cutting-CC) to each of these robotics application areas, for example, computer control and sensor interface protocols. Further, the OTD approach to the R&D process urged an additional organizational break-out between short-term (1-3 years) and long-term (3-5 years) efforts (Advanced Technology-AT). The RTDP is thus organized around these application areas - TWR, CAA, MWO, D&D and CC&AT - with the first four developing short-term applied robotics. An RTDP Five-Year Plan was developed for organizing the Program to meet the needs in these application areas.

Each application area is coordinated by a DOE contractor at a site/laboratory chosen for its unique expertise or its situation as paradigmatic of an ER&WM problem. The coordinator leads a team of experts chosen from throughout the DOE complex, private industry and universities: an integrated, multi-member, team approach.

The DOE Headquarters Robotics Program Manager, a DOE employee, is responsible for higher level management of the entire Program through consultations throughout ER&WM and frequent interactions with coordinators. Overall program direction, as reflected in fiscal emphasis, is a primary responsibility. Another is program integration between the several RTDP application areas, between the various OTD activities supported by the RTDP and between non-OTD offices in ER&WM. Program integration is critical for resource maximization in meeting needs. The Robotics Program Manager’s function can summarily be stated as directly managing the RTDP so as to develop and demonstrate efficacious robotics systems, defined as needed by the supported programs, through a complex-wide integrated approach.

The technology development and program management approach followed by the RTDP can be expressed as:

- 1) TEAMS - pull together the best from DOE National Laboratories, industries and universities.
- 2) BROAD APPLICABILITY - focused projects to solve complex-wide problems.
- 3) NEEDS-DRIVEN - direct contact with sites and supported programs to build required systems.
- 4) EXTERNAL INTEGRATION - each part of the RTDP is directly mapped onto DOE Headquarters organization.

5) INTERNAL INTEGRATION- emphasis on solutions to common problems within the RTDP for application to supported programs.

6) NATIONAL PERSPECTIVE - address complex-wide solutions through direct management by DOE Headquarters.

A brief description of each Technical Application Area appears below. For a more detailed description of the activities occurring in each of the Technical Application Areas, see the *Robotics Technology Development Program Technology Summary*, February 1994, DOE/EM-0127P.

### **Tank Waste Retrieval**

The TWR Team provides a cost-effective robotics technology base for retrieval of waste from underground storage tanks. Led by PNL, with contributions from ORNL and SNL, this three-laboratory Team works closely with industry and universities to meet program objectives.

The TWR Team provides enhanced research and development tools centered around a robotics test bed and a comprehensive computer-based simulation network shared among the three contributing laboratories. Retrieval-focused robotics technologies are developed by the Team and integrated as part of the test bed demonstration. The Team directly responds to technology needs identified by waste tank remediaters and provides robotics technology inputs for tank remediation planning and procurements.

### **Contaminant Analysis Automation**

LANL is the lead laboratory in the CAA coordination area. The other laboratories involved in the CAA effort include PNL, INEL, SNL, and ORNL. The CAA thrust is to address the development of technologies necessary for the automation of DOE and DOE-contract environmental laboratories. The CAA Team develops fully automated modules which perform a generic task common to analytical chemistry. The modules are chosen for their repeated use in DOE analysis methods and represent a significant fraction of sample load. The underlying theme is "plug-and-play", interface standardization, transportability, architectural openness and modularity. This effort is in response to the tremendous need for chemical characterization of soil samples, contents of storage tanks, and water samples that must take place before remediation can be initiated.

### **Mixed Waste Operations**

The MWO Team is composed of six DOE laboratories and sites working with industry and universities to develop state-of-the-art technology to store and treat low-level and transuranic mixed wastes. The Team, led by the Savannah River Technology Center (SRTC), works closely with the Mixed Waste Integrated Program in identifying and prioritizing needs and opportunities to cleanup over 24,000 cubic meters of low-level mixed waste at DOE sites. In addition to SRTC, participants of the MWO Team include Fernald Environmental Management Site (FEMP), INEL, LLNL, ORNL, and SNL. The Team develops systems for front-end handling and pre-processing of mixed waste containers and contents, plus handling of the final waste

forms after processing. Automated inspection of stored waste containers is also a major aspect of the MWO group. Graphical modeling and automation of operations with graphics viewing is a key approach to facilitating operations programming.

### **Decontamination and Dismantlement**

There are a large number of contaminated facilities including hot cells, canyons, glove boxes, and reactor facilities, at DOE sites that must eventually undergo some form of D&D. As facilities transition from operational use, facility deactivation, followed by a period of surveillance and maintenance pose many of the problems that will need to be addressed in ultimate D&D activities. Deactivation and S&M activities place emphasis on characterization, data capture, and selective D&D in order to define and minimize the risk and cost associated with possible long-term S&M activities required prior to final D&D. The overall emphasis of the D&D application area is the automation of the D&D process, from surveillance to facility characterization to surface decontamination to hot cell dismantlement to maximize efficiency while minimizing human exposure. The work centers around vehicular and crane deployed dual-arm systems using advanced sensors, control and operator interface technologies.

### **Cross Cutting & Advanced Technology**

Several program elements within RTDP have some degree of common technology needs. These common needs, plus the increasing need for technologies that can be directly applied to faster, safer, and more cost-effective robotics systems, are the main focus of the CC&AT Team. The CC&AT Team, coordinated by SNL, with participation by PNL, LANL, and ORNL, develops technologies used throughout the RTDP. Projects are directed toward a generic, graphics robot controller based on an integrated multisensory system plus systems analysis and modeling/simulation. Coupling of sensor-based modeling with automated programming of robot operations is a key approach to developing faster, safer, and less expensive waste clean-up systems.



**FY94 Activities Funded Through  
the Oakland Operations Office**

**Section 5.0**

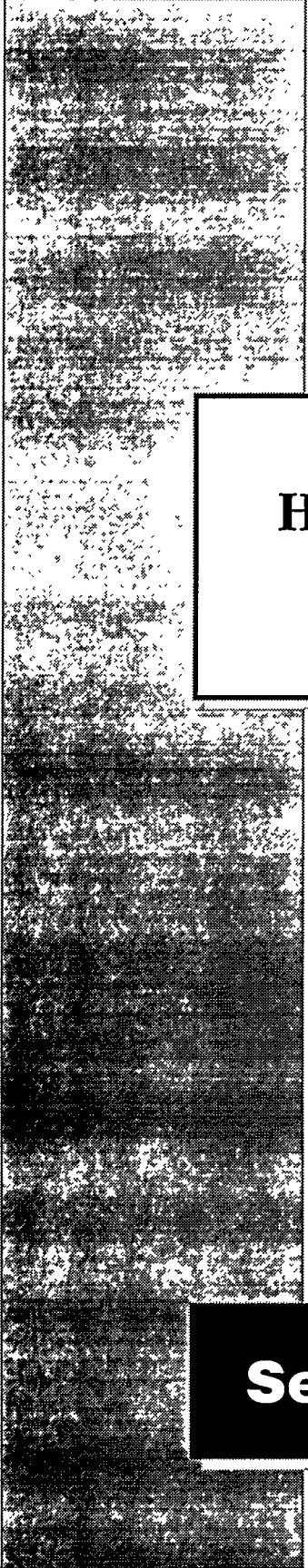


**OFFICE OF TECHNOLOGY DEVELOPMENT EM-50**  
**FY94 ACTIVITIES FUNDED THROUGH**  
**THE OAKLAND OPERATIONS OFFICE**  
**(By Program Element)**

TTP NUMBER	TITLE
<b>VOCS IN NON-ARID SOILS ID</b>	
SF221102	SAVANNAH RIVER INTEGRATED DEMONSTRATION TEST, MONITORING TASK - UNDERGROUND IMAGING
<b>VOCS IN ARID SOILS ID</b>	
SF241001	ARID ENHANCED PASSIVE SOIL VAPOR EXTRACTION
SR141002	ARID PASSIVE CONTROL OF VOCS USING VALVED WELLHEADS
<b>URANIUM IN SOILS ID</b>	
SF231003	INTEGRATED METHODOLOGY FOR DETERMINING CLEANUP LEVELS FOR URANIUM-CONTAMINATED SOILS
<b>CHARACTERIZATION, MONITORING &amp; SENSOR TECHNOLOGY IP</b>	
SF141001	ANALOG SITE FOR CHARACTERIZATION OF FRACTURED ROCK
SF141002	CONTAMINANT TRANSPORT MODELING STUDIES OF RUSSIAN SITES
SF231004	MULTI-ANALYTE, SINGLE FIBER OPTICAL SENSOR
SF241002	ELECTRICAL RESISTANCE TOMOGRAPHY FOR SUBSURFACE IMAGING
<b>IN-SITU REMEDIATION TECHNOLOGY DEVELOPMENT IP</b>	
SF131001	PHYSICAL BARRIERS FORMED FROM VISCOSUS LIQUIDS EMPLACED
SF201101	IN SITU MICROBIAL FILTERS
SF231001	OPTIMAL REMEDIATION DESIGN
SF231002	DEVELOPMENT OF SUBSURFACE MANIPULATION/PROCESS CONTROL SUB-PROGRAM
<b>OTHER TECHNOLOGIES - GROUNDWATER &amp; SOILS CLEANUP</b>	
SF341001	RESEARCH AND DEVELOPMENT ACTIVITIES - ETEC
<b>INTERNATIONAL TECHNOLOGY EXCHANGE</b>	
SF134301	CONTAMINANT TRANSPORT MODELING STUDIES OF RUSSIAN SITES
<b>PROGRAM DIRECTION</b>	
SF026001	PROGRAM DIRECTION - SALARIES AND OTHER EXPENSES
<b>PROGRAM SUPPORT</b>	
SF125001	TPM SUPPORT
SF225001	TPM SUPPORT
<b>ROBOTICS TECHNOLOGY DEVELOPMENT PROGRAM</b>	
SF213201	ROBOTICS WASTE MINIMIZATION (LLNL)
<b>TECHNOLOGY INTEGRATION</b>	
SF144103	CALIFORNIA ENVIRONMENTAL ENTERPRISE (LBL)
SF224101	TECHNICAL ASSISTANCE CALIFORNIA CENTERS FOR APPLIED COMPETITIVE TECHNOLOGIES
SF244101	MOU/INSTITUTE OF ENVIRONMENTAL SOLUTIONS
SF244102	ENVIRONMENTAL TECHNOLOGY TRANSFER DELIVERY SYSTEM
SF244103	CALIFORNIA ENVIRONMENTAL ENTERPRISE (LLNL)

**OFFICE OF TECHNOLOGY DEVELOPMENT EM-50**  
**FY94 ACTIVITIES FUNDED THROUGH**  
**THE OAKLAND OPERATIONS OFFICE**  
**(By Program Element)**

TTP NUMBER	TITLE
<hr/>	
<b>BURIED WASTE ID</b>	
SF221209	NDA CHARACTERIZATION OF TRU/LLW WASTE DRUMS
<b>UNDERGROUND STORAGE TANKS ID</b>	
SF211203	ADVANCED FIBER-OPTIC SPECTROSCOPY FOR INORGANIC CONTAMINANTS
SF242003	UST-ID SYSTEM INTEGRATION & TECH. ANALYSIS
<b>D&amp;D OF FACILITIES ID</b>	
SF342001	SAMPLING & TRITIUM MEASUREMENT FOR SAVANNAH RIVER SITE STEEL RECYCLING
<b>EFFICIENT SEPARATION AND PROCESSING IP</b>	
SF132001	REMOVAL & RECOVERY OF TOXIC METAL IONS/AQUEOUS WASTE STREAMS
SF232003	DERIVATIVES OF NATURAL COMPLEXING AGENTS/REMOVAL OF PLUTONIUM IN WASTES
<b>HAZARDOUS &amp; MIXED WASTE DESTRUCTION IP</b>	
SF221211	RISK ASSESSMENT-MIXED WASTE
SF242001	DEMONSTRATION PROOF OF CONCEPT STEEL HEPA
SF242002	TECHNICAL SUPPORT - PATRICK COYLE
<b>ROCKY FLATS COMPLIANCE PROGRAM</b>	
SF221207	INCINERATION ALTERNATIVES FOR ROCKY FLATS



## **How To Get Involved with DOE Environmental Management**



### **Section 6.0**



## 6.0

## HOW TO GET INVOLVED

### 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 and M&O 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**

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 RDD&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 ROA and PRDA. 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**

**David W. Geiser, Acting Director**  
International Technology Exchange Division  
EM-523  
Environmental Restoration and Waste  
Management Technology Development  
U.S. Department of Energy  
Washington, D.C. 20585  
(301) 903-7940

## **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 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:**

**Claire Sink, Director**  
Technology Integration Division  
EM-521  
Environmental Restoration and Waste  
Management Technology Development  
U.S. Department of Energy  
Washington, D.C. 20585  
(301) 903-7928

## **Acronyms**

## **Section 7.0**



## 7.0

## ACRONYMS

AT	Advanced Technology
CAA	Contaminant Analysis Automation
CC	Cross Cutting
CRADA	Cooperative Research and Development Agreement
CTE	carbon tetrachloride
CTMP	Comprehensive Treatment and Management Plan
D&D	Decontamination and Dismantlement
DNAPLs	dense non-aqueous phase liquids
DoD	U.S. Department of Defense
DOE	U.S. Department of Energy
DUVAS	Differential Ultraviolet Absorption Spectroscopy
EM	Office of Environmental Management
EPA	Environmental Protection Agency
ERT	Electrical Resistance Tomography
ESPIP	Efficient Separations Processing Integrated Program
FEMP	Fernald Environmental Management Site
HEPA	high efficiency particulate air (filters)
IAG	Interagency Agreement
ID	Integrated Demonstration
INEL	Idaho National Engineering Laboratory
IP	Integrated Program
ISR-IP	In Situ Remediation Integrated Program
LANL	Los Alamos National Laboratory
LLNL	Lawrence Livermore National Laboratory
MWIP	Mixed Waste Integrated Program
MWO	Mixed Waste Operations
NAPLs	non-aqueous phase liquids
NPL	National Priorities List
ORNL	Oak Ridge National Laboratory
OTD	Office of Technology Development
PCE	perchloroethylene
PNL	Pacific Northwest Laboratory
PRDA	Program Research and Development Announcements
RCRA	Resource Conservation and Recovery Act
RCS	Remote Characterization System
RDDT&E	Research, Development, Demonstration, Testing, and Evaluation
RFP	Rocky Flats Program
ROA	Research Opportunity Announcements
RTDP	Robotics Technology Development Program
SEE	Small Emplacement Excavator
SITE	Superfund Innovative Technology Evaluation

SNL	Sandia National Laboratory
SRTC	Savannah River Technology Center
SST	single-shell tanks
TCE	trichloroethylene
TRU	transuranic (waste)
TTPs	Technical Task Plans
TWR	Tank Waste Retrieval
UST	underground storage tanks
VOC	volatile organic compounds
VOC-Arid ID	Volatile Organic Compound in Arid Soils Integrated Demonstration
VOC-ID	Volatile Organic Compound in Non-Arid Soils Integrated Demonstration
WSRC	Westinghouse Savannah River Company