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REMEDIATION TECHNOLOGY NEEDS AND APPLIED R&D INITIATIVES

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Abstract

The U.S. Department of Energy (DOE) recently consolidated its environmental restoration and waste management activities. Within that new organization, DOE has committed to support Research, Development, Demonstration, Testing and, Evaluation (RDDT&E) activities with the following objectives: rapidly advance beyond currently available technologies; provide solutions to key technical issues that will improve effectiveness, efficiency, and safety; and enhance DOE's ability to meet its 30-year compliance and cleanup goals.

Four general categories have been identified where R&D (and DT&E) efforts need to be focused. These include: waste minimization technologies, site characterization and assessment methods, waste treatment technologies, and remediation technologies with emphasis on in-situ methods. The DOE has already supported a number of R&D activities in these areas and plans to continue that support in the future. For technology development, the DOE is committed to forming cooperative partnerships and eliciting broad participation from qualified organizations who can contribute to RDDT&E activities. The new technologies resulting from these R&D initiatives will enhance DOE's ability to meet its 30-year cleanup goal, reduce environmental risk, and provide significant cost savings over existing technologies. Even modest investments in these emerging technologies now can be expected to generate a high rate of return.

Introduction

The Secretary of Energy established the Office of Environmental Restoration and Waste Management (EM) in November 1989 to effectively coordinate and manage the Department's activities to remediate the DOE Defense Complex and to properly manage waste generated from current operations. It is the EM goal to ensure that risks to human health and safety and to the environment from past, present, and future operations are either eliminated or reduced to prescribed, safe levels by the year 2019. To this end, EM seeks to establish and maintain an aggressive national program for applied RDDT&E to resolve major technical issues and rapidly advance beyond currently employed technologies for environmental restoration and waste management.

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The EM is divided into three major offices. The Office of Waste Operations (WO) is responsible for the treatment, storage, and final disposal of currently generated waste. The Office of Environmental Restoration (ER) is responsible for the remediation of sites no longer in use. The Office of Technology Development (OTD) is responsible for the Technology Development (TD) program to address the needs identified by three customers: Waste Operations, Environmental Restoration, and, in the case of waste minimization techniques, the Office of Defense Programs.

The TD program responsibilities include research and development (R&D) of new technologies, and demonstration, testing, and evaluation (DT&E) of the more promising technologies. Close coordination with Offices of Environmental Restoration and Waste Operations ensures that specific problems related to DOE sites or the DOE needs for new technologies are identified. The DOE has recognized the importance of resources available in various sectors and has elicited broad participation from national laboratories, DOE facilities, universities, research organizations, and the private sector in developing technologies that will allow environmental restoration efforts to proceed faster, safer, cheaper, and better.

The TD program is designed to make new, innovative, and effective technologies available and transfer these to the users. New technologies are sought to meet legal and regulatory requirements; to reduce risks, operating costs, operating time; and to minimize the generation of new waste. The R&D Division of OTD identifies innovative technologies and is responsible for the generation of data to support engineering decisions to proceed to the DT&E phase. The DT&E Division acts as the conduit to full-scale implementation through demonstration and testing of technologies. Program coordination offices have been established for Innovative Technology, Applied R&D, and DT&E programs at the DOE's Idaho, Chicago, and Oak Ridge Field Offices, respectively, to facilitate movement of technologies from conceptualization to implementation.

Remediation Technology Needs

In order to organize and prioritize the user needs, the EM is currently developing roadmaps for solution of many of the problems. Roadmaps are derived from a planning process that focuses on issue identification, root-cause analysis, and issue resolution (1). This process forms the basis for EM strategic planning to carry out waste management operations and environmental restoration in a manner that achieves regulatory compliance within budget and on schedule. Table 1 lists the major DOE sites and the related corrective actions and/or problems requiring remediation technologies at each site.

The roadmap process identifies and prioritizes specific technology needs to meet scheduled compliance milestones. Once these priorities are established, OTD requests internal and private sector institutions to submit technical task plans (TTPs) and proposals, respectively, to execute its program.

Table 1. Summary of Major Problems at DOE Facilities Requiring Innovative Solutions

Kansas City Plant
- VOCs (air emissions)
- PCBs (soil-groundwater)

Los Alamos National Laboratory
- USTs (replacement), Radioactive emissions (air/water), VOCs (air), PCBs (soil/groundwater)

Pantex and Pinellas Plants
- USTs (replacement),
- Volatile organics (soil/groundwater)

Sandia National Laboratory
- Mixed waste landfill (soil/groundwater contamination)

Argonne National Laboratory
Brookhaven National Laboratory
Fermi National Laboratory
- Soil/groundwater contamination

Brookhaven National Laboratory
- USTs (replacement, soil/ groundwater contamination)

Idaho National Engineering Laboratory
- Buried waste
- USTs (replacement, soil/groundwater contamination)

Lawrence Berkeley Laboratory
- USTs (soil/groundwater contamination - volatile organics)

Lawrence Livermore National Laboratory
- Sewer system leakage (soil/groundwater contamination)

Savannah River Site
- Volatile organics in soil (humid sites demo)
- Soil/groundwater contamination

Nevada Test Site
- Cleanup of Pu contaminated soils,
- Septic system soil cleanup

Oak Ridge National Laboratory
- USTs (soil/groundwater contamination)

Fernald (FEMP)
- U contaminated soils

Portsmouth Gaseous Diffusion Plant
- PCBs (soil/groundwater contamination)

Paducah Gaseous Diffusion Plant
- PCBs (soil/groundwater contamination)

Hanford
- Volatile organics in soil (arid sites-demo)
- USTs (replacements/cleanup)

Rocky Flats
- Radioactive and hazardous mixed waste (soil/groundwater contamination)

The OTD activities described here address technology needs in three broad areas (but, by no means all of the key needs which DOE foresees). The three areas include (1) characterization and assessment, (2) remediation, and (3) decontamination and decommissioning.

Present site characterization methods are imprecise, costly, time-consuming, and overly invasive. Improved site characterization methods will require better technologies for accurately describing the subsurface geohydrologic features of a site. For example, more efficient nonintrusive sampling strategies and practical methods are necessary for understanding and predicting subsurface contaminant transport. Also needed are more reliable procedures for interpreting characterization data, and understanding how clean is "clean."

Intrusive activities, such as sampling and excavation during remediation of a site, often involve immediate hazards to workers in the form of exposure to radioactive and/or toxic materials. Remote real-time analyses of ambient levels and rapid assessments of potential hazards in the air, water, and soil during characterization, as well as in the remedial action phase, would help ensure worker safety and allow continuous operation. Instrumentation capable of detecting low levels of broad classes of hazardous materials and specific compounds is needed to indicate cleanup status. Better characterization methods based on real-time analyses are especially important to confirm the most effective use of certain in situ remediation technologies. In the absence of real-time monitoring, excessive volumes of soil and water must be treated to guarantee compliance; otherwise, pockets of contamination may be missed.

Special characterization and remediation technologies are necessary for decontamination and decommissioning of inactive facilities, underground storage tanks, and wastewater lagoons. These facilities often contain significant quantities of radioactive wastes, in certain cases mixed with heavy metals and/or hazardous organic compounds that make personnel entry unacceptable. Thus, the development of advanced robotic samplers, smart probes, mobile and in-situ fiber-optic devices, and nonintrusive characterization instrumentation (based on electromagnetic, thermographic, and acoustic principles) is needed for sampling and chemically characterizing these sites. The development of such techniques will significantly reduce radiological exposure to workers and provide more assurance that the correct remedial technology has been selected.

Most DOE sites have some form of subsurface contamination ranging from buried concentrated waste forms, such as tanks or trenches, to dispersed contaminants in soil or water. Soils, sludges, sediments, soils mixed with buried waste, and mill tailings at DOE sites are contaminated with radionuclides, toxic metals, and hazardous organic compounds. Contamination resulted from a variety of operations, including the use of soil columns, ponds, liquid waste storage tanks, and subsurface disposal of waste. The potential for migration of radionuclides and heavy metals from contaminated soils necessitates technologies to treat the contaminated volume in a manner that effectively protects public health, public safety, and the environment.

In some instances, contamination is contained largely in the surface soils. In other cases, there is subsurface contamination by hazardous organics, nitrates, metals, inorganic salts, and radionuclides resulting from disposal of wastes in lagoons, shallow-land burial, or leaks from cribs, tanks, and pipes. Soil treatment strategies can be classified as (1) in-situ treatment and (2) retrieval and treatment.

Technologies are sought that can satisfy one or more of the following requirements:

- isolation and containment of radioactive constituents or heavy metals;
- long-term immobilization without migration of radioactive constituents or heavy metals;
- removal of radioactive constituents or heavy metals for treatment;
- degradation of organics or organometallics to innocuous products such as carbon dioxide and water;
- elimination or reduction to acceptable limits of chemical toxicity; or
- removal of chemical constituents for treatment.

Radionuclide, heavy metal, and/or inorganic chemical contamination occurs in groundwater at many DOE sites. This contamination results from a variety of operations, including the use of liquid waste storage tanks and disposal of liquid wastes to cribs (engineered leach fields), trenches, and ponds. Many contaminants are dispersed in the soil column (unsaturated zone) and in the groundwater. Because of the migration potential of these contaminants, technologies are needed to treat the contaminated groundwater in a manner that effectively protects the environment and human population.

Both extraction and in-situ technologies for treating these contaminants are sought that meet the following requirements:

- removal or destruction of organics in the presence of other wastes;
- isolation of heavy metal, radioactive, and/or inorganic constituents;
- removal of heavy metal, radioactive, and/or inorganic constituents;
- reduction of concentrations to Maximum Contaminant Levels for drinking water; or
- elimination of impacts to surrounding environment.

DOE's uranium enrichment and fabrication facilities, nuclear production reactors, and fuel reprocessing facilities all include massive structures that are contaminated with radionuclides and, in many cases, hazardous materials. These facilities present immense challenges for decontamination and decommissioning (D&D). Technologies are needed to ensure that D&D processes used are cost-effective and that they meet all health, safety, and environmental regulations. Many of the presently available decontamination processes are expensive, create too much waste, and require modification to satisfy current regulations.

To reduce worker exposure, D&D time, and minimize wastes, technologies must be developed that meet the following requirements:

- remotely characterize contamination in real time;
- perform decontamination of concrete, piping/equipment, and removal;
- reduce waste volume and facilitate recovery of recyclable materials;
- capable of addressing chemically contaminated as well as radioactively contaminated materials and waste.

Clearly, there are more technology development needs and more innovative ideas than there are resources to devote to these investigations. Priorities must be set and sufficient resources must be allocated to pursue those activities deemed most urgent.

RDDT&E Program Structure

The OTD has developed its Research, Development, Demonstration, Testing, and Evaluation (RDDT&E) Program to promote the resolution of major technical issues and the rapid advancement of the current technology beyond what is now available for environmental restoration and waste management operations. The RDDT&E Program has been designed to satisfy needs of the ultimate users: DOE Installations, the Office of Environmental Restoration, the Office of Waste Operations, and the Defense Programs.

Applied R&D activities constitute a major portion of the RDDT&E Program. Critical tasks are planned and conducted to provide a technical, regulatory, and economic base for the decision-making process to transfer technologies to the DT&E phase. Most tasks focus on the collection of experimental data to support the development of engineering specifications for full-scale technology implementation. Other activities concentrate on the identification of critical engineering issues for full-scale testing.

The DT&E staff is chartered to identify technologies that are promising for transition to the demonstration arena. Tasks are designed to develop cost-effective, efficient programs for demonstration, testing, and evaluation of promising technologies and to advance those technologies to full-scale implementation on schedule to meet compliance requirements. Promising technologies are organized into Integrated Programs and Integrated Demonstrations that focus technical activities toward the solution of critical DOE environmental problems. Integrated Programs and Demonstrations provide a means to move technology products from universities, industries, governmental agencies, international agencies, and DOE laboratories to the user.

An Integrated Program (IP) is a group of research, development, and/or demonstration tasks that relate to a single class of environmental restoration or waste management issues or functions. IPs were phased into the RDDT&E program to address cross-cutting technology issues and to sustain RDDT&E input into the Integrated Demonstration process.

The Integrated Demonstration (ID) is the cost-effective mechanism that assembles a group of related and synergistic technologies to evaluate performance individually or as a complete system in correcting environmental restoration and waste management problems. Currently identified IPs and IDs (Table 2) fall into three program areas: groundwater and soils characterization and cleanup, waste retrieval and waste processing, and waste minimization and waste avoidance.

Table 2. Proposed Integrated Demonstrations and Integrated Programs

Integrated Demos

Soil and Groundwater Remediation

- ID-A1 VOC in Saturated Soils
- ID-A2 Plutonium in Soils
- ID-A3 Uranium in Soils
- ID-A4 VOC in Unsaturated Soils
- ID-A5 Non Pu/U Metals in Soils
- ID-A6 Toxic Chemicals in Soils
- ID-A7 Non-VOC Unsaturated Soils
- ID-A8 Non-VOC Saturated Soils
- ID-A9 Mixed Waste Landfill

Waste Retrieval and Waste Processing

- ID-B1 Buried Waste
- ID-B2 Underground Storage Tanks
- ID-B3 Dry Storage
- ID-B4 Newly Generated Mixed Waste
- ID-B5 RCRA Waste
- ID-B6 Combustible Waste
- ID-B7 D&D/Concrete
- ID-B8 D&D/Metal
- ID-B9 In-Situ Vitrification
- ID-B10 Advanced Processing

Waste Minimization and Avoidance

- ID-C1 Depleted U Waste Minimization
- ID-C2 Pu Waste Minimization
- ID-C3 Envir. Conscious Manufacturing
- ID-C4 DP/EM MOU
- ID-C5 DOE/Air Force MOU
- ID-C6 Non-Rad Components
- ID-C7 General Waste Minimization

Integrated Programs

- IP-1 In Situ Remediation Tech. Dev.
- IP-2 Charact. and Sensor Tech. Dev.
- IP-3 Radioisotope Separation and Proc.
- IP-4 Mixed and Hazardous Wast Dest.
- IP-5 Pollution Prevention

R&D Initiatives

At the national laboratories and DOE facilities, the waste management R&D activities include process modification, waste minimization, recycling of materials, waste form development and testing, and container development. Environmental restoration R&D activities stress DOE's unique problems with radionuclides but also acknowledge the need to improve hazardous and mixed waste technologies. These activities include: site characterization methods, in-situ monitoring of chemical species, chemical analysis techniques, thermal destruction of organics, in-situ bioremediation, soil vitrification, chemical separation technologies, and application of robotics to characterization, excavation, handling, and treatment of hazardous materials. For FY91, the funds for activities in this regard are in excess of $50 million and for FY92, funding projections are approximately $140 million.

The private sector initiatives have included contracted R&D technology development. In FY 1990, on behalf of the OTD, the applied R&D PCO solicited proposals from private sector for applied R&D in technologies in the following general areas: soil remediation; groundwater remediation; characterization and sensing of buried objects, contamination, and/or geological/hydrological features; and containment of contamination at sites (2). Based on the recommendations arising from proposal evaluation by an independent peer review, contract negotiations were authorized by DOE with 15 offerors for a total of $6 million in funding; all contracts were in place by September 1990. The 15 selected projects listed by the technical areas addressed are as follows:

- Groundwater cleanup
    - Biodegradation of TCE and other chlorinated hydrocarbons in a vapor phase bioreactor
    - Removal of VOCs with a combined air stripping/ membrane vapor separation system
    - Removal of radionuclides, toxic metals and organics from contaminated groundwater using chemical binding/filtration cold vaporization techniques
    - Removal of radionuclides, heavy metals, inorganic and/or organic ions from groundwater using the Alga SORB biosorbent
- Soil cleanup
    - Volume reduction and stabilization of soil contaminated with radionuclides, heavy metals, and inorganic/organic ions using a combined soil washing/in-furnace vitrification system
    - Investigation of electrokinetic effects in the treatment of contaminated soils, sludges and lagoon sediments.

- Investigation of the effectiveness of composting to destroy explosives and other hazardous organic contaminants in soil, sediments, and sludges

• Site Characterization

- Investigation of high resolution shear wave seismic reflection profiling for hydrogeological surveying

- Development and testing of hydraulically installed multisampling lysimeter for use in the vadose (unsaturated) zone

- Development of the SEAMIST concept to deploy instrumentation and sampling systems down hole by pneumatically emplacing an everting and impermeable membrane liner carrying many instruments

- Development of a mobile fiber optic Raman spectrograph for in-situ characterization/monitoring

- Development of surface-acoustic-wave (SAW) microsensor arrays for detecting volatile organic compounds (VOCs)

- Development of a bulk soil assay system using a mobile sensor incorporating both capture-gamma ray (CGRS) and inelastic-gamma ray imaging and spectroscopy (IGRIS) techniques

- Development of hardware and software for three-dimensional site characterization using three minimally invasive measurement techniques -- cone penetrometer, synergistic electromagnetic mapping technology (SEMT) and reflection seismology

• Containment

- Investigation of the fixation of heavy metals (e.g. chromium) through in-situ reduction followed by injection of a silica solution to immobilize the resulting metal hydroxides.

In companion solicitations, the Innovative Technology Development Program announced the selection of seven awardees for a total of $1.5 million in funding in March 1991. The selected projects include the following: extraction and separation of actinides and lanthanides from waste streams and soils, application of synthetic membranes to remove volatile organics from water, use of fiber-optic TLDs to monitor soil or waste storage, isolating contaminated areas of aquifers through placement of subsurface barriers, using light as a catalyst to destroy organic contaminants, application of computer models to simulate flow of hazardous materials, and treatment of trichloroethylene (TCE) in contaminated air-stream. The Field Demonstration Program is now reviewing proposals for remediation technologies received in June 1991 for possible pilot field testing and evaluation. Technology areas include remediation of (1) groundwater, (2) soils contaminated with radionuclides, heavy metals, inorganic ions and organics, and (3) nonintrusive characterization and sensing of buried objects, contamination, and/or geological/hydrological features.

Other initiatives that have been undertaken involve DOE's participation through interagency agreements with the U.S. Environmental Protection Agency (EPA) in the Hazardous Substance Research Centers (HSRCs) Program (3), and the Superfund Innovative Technology Evaluation (SITE) Program. The five university-based HSRCs (each covering two EPA regions) that are geographically distributed across the country represent multi-university consortiums whose directors are located at the lead university or institute campus. The basic mission of the HSRCs is to study all aspects of the manufacture, use, transportation, disposal, and management of hazardous substances. The HSRC projects supported by DOE focus primarily on biotechnology. The projects supported in 1990 include the following:

- Contaminated groundwater treatment with bioreactors utilizing a white rot fungus
- Remediation of contaminated aquifers with surfactants: The effect of surfactant adsorption and desorption
- Phase equilibria and transport properties of surfactant systems of interest to soil remediation
- Biodetoxification of hazardous solid wastes by staged anaerobic fermentation conducted at separate redox and pH environments
- Optimal bioreactor design for biological removal of mercury
- Heavy metals removal from dilute aqueous solutions using biopolymers
- In-situ bioremediation of organic groundwater contaminants
- Innovative treatment of bank stabilization of metals-contaminated soils and tailings along Whitewood Creek, South Dakota
- Modeling of the use of plants in remediating soils and groundwater contaminated by hazardous organic substances
- Test-bed evaluation of in-situ bioremediation of chlorinated aliphatic compounds by toluene monooxygenase containing bacteria

- Dispersion modeling of volatile organic emission from ground-level treatment systems

- Dispersion modeling of volatile organic emissions from treatments of contaminated groundwater

For 1991, eight new projects have been selected for DOE support.

- Electrode emplacement geometries and electric field strengths for in-situ extraction of contaminants from hazardous waste sites by electroosmosis

- Use of pneumatic fracturing to enhance removal of VOCs from clay formations

- Remediation of contaminated aquifers with surfactants: The effect of surfactant adsorption and desorption

- Phase equilibria and transport properties of surfactant systems of interest to soil remediation

- Innovative treatment and bank stabilization of metals-contaminated soils and tailings along Whitewood Creek, South Dakota

- Modeling of the use of plants in remediating soils and groundwater

- Test-bed evaluation of in-situ bioremediation of chlorinated aliphatic compounds by toluene monooxygenase containing bacteria

- Dispersion modeling of volatile organic emissions from ground-level treatment systems

The purpose of the SITE program is to accelerate the development, demonstration, and use of alternative or innovative treatment technologies at superfund sites. One of the program components, the Emerging Technologies Program (ETP) fosters development of emerging technologies or approaches to ensure that a steady stream of appropriate technologies will be ready for demonstration. Since one of the OTD objectives is to tap the research expertise in nation's academic institutions and private enterprise, it was recognized that DOE participation in the HSRC and SITE programs provides an excellent opportunity for DOE to leverage research funds to provide an even greater return on its investment.

Opportunities for Participation

In eliciting broad participation from qualified organizations who can contribute to its RDDT&E activities, the OTD is aware of the wealth of technological talent and innovative ideas in all sectors. It has initiated steps during the past two years to increase participation of the private sector (academia and industry) through competitive solicitations and through funding of unsolicited proposals. The DOE also worked to increase participation by academia through interagency agreements for cooperative funding of research and through an establishment of a DOE educational consortium. Many significant technology development activities are also being conducted at DOE sites such as the national laboratories. The DOE is funding technology development and technology exchange activities beyond the United States through direct contracts, international agreements, and other mechanisms.

The DOE plans to continue this type of support for technology development in the coming years. Organizations interested in responding to Program Research and Development Announcements should contact Thomas Martin of the Morgantown Energy Technology Center (METC), P.O. Box 880, Morgantown, WV 26507-0880. Organizations wishing to submit unsolicited proposals or needing additional information should contact Stephen C.T. Lien, Director, Division of Research and Development (EM-54), Department of Energy, 12800 Middlebrook Road, Trevion II Building, Germantown, MD 20874, for information on submission format and procedures prior to preparation of a proposal.

Summary

The TD program and the supporting activities described here address some, but by no means all of the key needs for remediation technology developments. The technology development approach, which is designed to satisfy the regulatory requirements under which DOE's 30 year cleanup program must operate, has been discussed. The accelerated development of technologies can be facilitated by a variety of factors that include the integrated nature of the development process thereby enhancing the cross-fertilization of ideas and increasing the rate of transfer of technologies between DOE and the private sector and academia.

More efficient and cost-effective technologies will be developed through integrated programs and demonstrations. Implicit in the discussion of remediation needs is that once technologies are developed and evaluated, they must be implemented at DOE's facilities to yield benefit from the R&D investments. Success is implementation. Many technological challenges lie ahead in developing faster, better, safer, and cheaper remediation technologies but also tremendous opportunities for innovative approaches.

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