

**U.S. DEPARTMENT OF ENERGY, OFFICE OF ENVIRONMENTAL MANAGEMENT
INTERNATIONAL PROGRAMS**

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ABSTRACT

The Department of Energy's Office of Environmental Management (DOE/EM) has the monumental task of cleaning up the legacy of over six decades of nuclear weapons research, development, and production. Because many other countries face a similar environmental legacy, DOE/EM is working collaboratively with the environmental management communities of several countries to identify and investigate promising technologies for potential application in the United States. DOE/EM currently has international programs with Russia, Poland, Argentina, the United Kingdom, Canada, the Czech Republic, and Ukraine. These programs have identified relevant and useful technologies that DOE/EM has employed throughout its domestic cleanup mission.

INTRODUCTION

As a result of the nuclear arms race during the forty-five year Cold War, the United States (U.S.) created one of the world's largest inventories of radioactive and hazardous waste. Although the U.S. instituted waste management systems to convert and store waste, significant discharges into the environment occurred. Among the many dangers posed by past waste management practices are widespread contamination of soil and groundwater, leaking or deteriorating containment vessels seeping radioactive waste and/or chemical wastes into the soil and groundwater, and the escape and transport of airborne contaminants. These and related issues demanded attention and illustrated the need to redirect resources from weapons production to environmental restoration and waste management.

In 1989, the U.S. Department of Energy (DOE) responded to these concerns by establishing the Office of Environmental Management (EM) and delegated this office with the responsibility of cleaning up the U.S. nuclear weapons complex. Now in its twelfth year, EM's mission has three primary objectives: 1) to assess, remediate, and monitor contaminated sites and facilities; 2) to store, treat, and dispose of waste from past and current operations; and 3) to develop and implement innovative technologies for environmental cleanup.

The Office of Environmental Management faces a challenging job. A 1997 DOE report entitled *Linking Legacies* stated that DOE manages 36 million cubic meters of waste comprised of seven fundamental waste categories: high-level, low-level, transuranic, and mixed low-level radioactive waste as well as hazardous, byproduct material, and "other" waste. In addition, EM has oversight of more than 5,100 contaminated buildings and facilities awaiting decontamination, decommissioning, and dismantling. This challenge requires the identification of technologies and scientific expertise from a variety of sources including industry, academia, national laboratories, and the international community.

The Office of Environmental Management established the Office of Science and Technology (OST) to conduct an aggressive program for the deployment of innovative solutions to address DOE's environmental remediation needs. OST investments provide the scientific foundation for new approaches and technologies that bring about significant reduction in risk, cost, and schedule for EM mission completion.

The mission of OST is to provide the full range of science and technology resources needed to deliver and support fully developed deployable technological solutions to the environmental remediation problems faced by EM. These resources include providing basic and applied research, technology demonstrations, and technical assistance for deploying technologies.

OST programs establish, direct, and manage targeted intermediate-term research bridging the gap between broad fundamental research that has wide-ranging applications and needs-driven applied technology development. Through the integration of basic research and applied research and development (R&D), as conducted by the Focus Areas, Crosscutting Programs, University Programs, and the Technology Integration Program, OST expects to produce and deliver technology solutions for the major needs of its EM customers.

Within OST, the Office of International Programs (IP) is responsible for the identification, evaluation, acquisition, and demonstration of international technologies that can accelerate DOE cleanup operations in conjunction with Focus Area activities. The goal of IP is to pursue collaborations among foreign government organizations, educational institutions, and private industry to identify technologies that can address the environmental remediation needs of DOE. Through international agreements, OST engages in cooperative exchanges of information, technology, and data on technology development and demonstrations IP also supports scientist exchanges between DOE and foreign organizations.

IP seeks out and leverages foreign technology, data, and resources in keeping with EM's mandate to protect public health and the environment through the safe and cost effective remediation of the DOE's nuclear weapons sites. These international resources are used to manage the more urgent risks at DOE sites, secure a safe workplace, help build consensus on critical issues, and strengthen DOE's science and technology program.

DOE/EM currently has international programs with Russia, Poland, Argentina, the United Kingdom, Canada, the Czech Republic, and Ukraine. These programs have identified relevant and useful technologies that DOE/EM has employed in remediation projects, and they continue to support the research and development mission of EM.

RUSSIA PROGRAMS

Joint Coordinating Committee for Environmental Restoration and Waste Management (JCCEM)

In 1990, DOE and the Ministry of Atomic Energy for the Russian Federation (MINATOM) signed a Memorandum of Cooperation (MOC) in the area of Environmental Restoration and

Waste Management. The MOC is managed by the Joint Coordinating Committee for Environmental Restoration and Waste Management (JCCEM), which meets annually to determine projects of mutual interest and benefit. Through direct technical exchange with MINATOM institutes, DOE benefits from the expertise of the Russian scientific community at a dramatic cost-saving ratio compared to U.S. labor. Under the auspices of the JCCEM, the best scientists in both countries share experiences and develop innovative technologies jointly in six areas of cooperation: Efficient Separations, Contaminant Transport Migration and Site Characterization, High-Level Waste (HLW) Tanks, Deactivation and Decommissioning (D&D), Transuranic (TRU) Stabilization, and Vadose Zone issues.

Recent successes include the initiation of the first JCCEM deployment, a Russian-developed high capacity pulsating pump and monitor which allows dense radioactive sludge to be removed from high-level waste tanks. This technology was deployed into tanks at the Oak Ridge site in October 2000. In addition, the jointly-developed Universal Extractant (UNEX) Cobalt Dicarbolide Separations technology is included in the Idaho Environmental Impact Statement as an alternative to baseline technologies. Further, in the area of Deactivation and Decommissioning, it is expected that Russian technologies will be demonstrated over the next two years as part of the Large Scale Demonstration and Deployment Project. Four Russian D&D technologies are being considered for U.S. demonstration in 2001.

Other successes from the JCCEM include four pending U.S. patents for technology in addition to four that have already been granted. In 1999, a U.S. patent was granted for a Russian-developed technology designed for the immobilization of mixed waste streams, the Plasma Induced Cold Crucible Method (PICCM). Earlier patents include one for actinide chemistry work and two patents related to PICCM technology. Additionally, the patent application process was initiated for two other technologies, UNEX and Gubka (see below) with filing dates of February and November 2000, respectively.

Currently, the JCCEM includes thirteen technical projects in six areas of cooperation. Each of these projects is designed to meet a specific need within DOE and employs Russian scientists in an area where they have extensive expertise.

One of the largest projects under the JCCEM program is the development of Gubka technology. Gubka, which means 'sponge' in Russian, is being developed under the JCCEM as a porous, crystalline matrix for stabilizing actinide solutions. Although further tests on the project are scheduled, the technology should be available soon for deployment at DOE sites.

Another important project developed under the auspices of the JCCEM is a Russian cleaning 'recipe' for decontamination of high-level waste (HLW) tanks after bulk sludge has been removed. During the normal process of cleaning a HLW tank, certain heavier wastes form a heel at the bottom of the tank that must be removed to complete the process. A removal recipe developed under the JCCEM is being tested at Savannah River Site and preparations have begun to test that recipe at other locations as well.

Also developed under the JCCEM is a three-dimensional modeling technology for predicting long-term groundwater plume migration based on historical plume development. In conjunction

with Pacific Northwest National Laboratory, scientists working under the JCCEM have assisted the laboratory in creating an inverse transient model in compliance with the regulatory deadline of 2001.

These are only a few of the thirteen current projects being conducted under the auspices of the JCCEM. The details of the JCCEM projects are available in the DOE publication, *Environmental Management Activities: United States-Russia*. The newest version of this publication will be available in Summer 2001.

Joint Coordinating Committee for Science and Technology

A Memorandum of Understanding (MOU) designed to promote cooperation in science and technology was signed by DOE and the Russian Academy of Sciences on March 4, 1999. This MOU is being conducted under the auspices of the U.S./Russian Federation Science and Technology Agreement that has been in effect since December 16, 1993. The managing body for the MOU is the Joint Coordinating Committee for Science and Technology (JCCST).

Two Implementing Arrangements were signed at the first JCC meeting on May 15, 2000. The two-signed Implementing Arrangements include "Geologic Analogues, Migration and Accumulation of Radionuclides in Geologic Media" and "Risk Assessment and Advanced Modeling Regarding Geologic Disposal." A third Implementing Arrangement is currently being negotiated in the area of Fuel Cells.

There are three Office of Science and Technology projects currently operating under the JCCST agreement. The first program, Uranium Transfer Phenomena in Welded Tufts, is a study of the conditions for uranium migration and accumulation in horizons of welded tufts (ignimbrites) and felsites of the Streltsovsky ore field in southern Siberia. The results of this study will give DOE an increased understanding of vadose-zone migration of uranium and will benefit EM programs involving contaminant radionuclide transport within the DOE weapons complex, especially through fractured bedrock. The second program involves characterization of contaminated territories, monitoring network optimization, and cost minimization. This program, which will develop capabilities for detailed mapping and characterization of contaminated areas, will allow DOE to show that the amount of contaminated soil that requires remediation has been overestimated. The final program is Uncertainty Assessment through Incorporation of Mathematical Geology in Development of Inverse Flow and Transport Models. Under this program, scientists will incorporate geostatistical methods from the evolving field of mathematical geology with inverse modeling methods that already incorporate historical observational records to better address uncertainty arising from spatial variability, assisting the groundwater modeling initiative at the Hanford Site.

POLAND PROGRAM

In 1995, DOE and the Institute for the Ecology of Industrial Areas (IETU) signed a cooperative agreement on environmental restoration and hazardous waste management. This agreement is managed by the Joint Coordinating Committee for Environmental Systems (JCCES) which meets annually to review and approve proposals, assess program progress, evaluate potential future

activities, share experiences, and develop innovative technologies jointly in two areas of environmental management, organic and inorganic remediation.

This program has had notable successes with organic remediation including work with petroleum contaminated soils (PCS) and in development of a portable bioreactor. At the Czechowice Oil Refinery in Poland, scientists working under the JCCES began investigating methods for breaking down petroleum-based sludge that had been dumped in unlined lagoons around the refining plant. Using the newly developed Biopile, PCS is remediated by stimulating the organisms that would naturally process these petroleum-based contaminants. This *in situ* process also uses a DOE-developed technology, Baroballs, which take advantage of changes in atmospheric pressure to circulate air through the system. In addition, scientists working under the JCCES are developing a portable bioreactor that utilizes the same process for remediating smaller areas of organic contamination.

As a part of this project, scientists from IETU have identified several unique petroleum hydrocarbon-degrading microbes that are adapted to conditions of extremely low pH (2.5 and lower). These uniquely adapted organisms have potential application to sites within the DOE complex as well as in industrial settings throughout the United States. Due to their unique characteristics, DOE is investigating the patentability of these microbes.

Along with organic remediation, current JCCES projects include the remediation of inorganic contaminants, especially lead and mercury. Phytoremediation, or the use of plants to absorb contaminants, has been the subject of numerous JCCES projects. Laboratory tests have shown that phytoremediation of heavy metals is possible; therefore, are investigating increasing the cost-effectiveness and efficiency of this technology on a wider scale. The most recent projects in this field involve a full-field optimization for remediation of lead contaminated soils through use of amendment applications and a chlorophyll fluorometer for measuring plant stress, as well as investigating the possibilities for *in situ* stabilization of mercury to reduce its bioavailability.

The details of JCCES projects are available in the DOE publication, *Environmental Management Activities: Central and Eastern Europe*. The newest version of this publication will be available in June 2001.

ARGENTINA PROGRAM

In 1996, DOE and the National Atomic Energy Commission of the Argentine Republic (CNEA) signed a cooperative arrangement in the area of radioactive and mixed waste. The Agreement is managed by the Joint Coordinating Committee for Radioactive and Mixed Waste Management (JCCRM). The JCCRM meets annually to review and approve proposals, assess program progress, and evaluate potential future activities.

One of the most significant programs under the JCCRM deals with the radioactive isotope, Molybdenum 99 (Mo-99). Because of its prevalence in nuclear medicine, Mo-99 is a valuable waste product of nuclear reactions. The U.S. has not produced Mo-99 since 1989; however, considerable interest exists for restarting production. Under the JCCRM, U.S. and Argentine scientists have been experimenting with Crystalline Silicotitanate (CST) as a tool for filtering

out cesium and strontium from Mo-99 waste streams, making the process of Mo-99 extraction more efficient. As a part of this project, an evaluation of the suitability of crown ethers or other absorbers that may accomplish this objective will also be conducted. Benefits to DOE include obtaining information on the performance of new ion exchange materials in actual waste treatment operations, and demonstrating the effectiveness of a new ion exchange material developed, in part, with funding provided by DOE.

Another project being investigated under the JCCRM is the vitrification of spent ion exchange resins. These resins, used by Argentina to decontaminate heavy water systems, had been stored in tanks because currently available solidification processes were not space efficient. Vitrification offers a stable, space-conservative approach for storing these wastes and an opportunity for DOE to test a portable vitrification unit. Recent tests have involved testing the vitrification process with spent resins from Embalse Nuclear plant and the long-term durability of this waste form.

The details of JCCRM projects are available in the DOE publication, *Environmental Management Activities: Argentina*. The newest version of this publication will be available in June 2001.

OTHER INTERNATIONAL PROGRAMS

In addition to the four joint coordinating committees, DOE/EM supports several partnerships with other countries covering a variety of EM issues and projects. These arrangements range from technical exchanges among scientists to the full-scale deployment of innovative technologies. The most significant international programs in DOE/EM are with the United Kingdom, Canada, the Czech Republic, and Ukraine.

The Office of Science and Technology has contracted through the United Kingdom Atomic Energy Authority (UKAEA), with AEA Technology, Inc. to identify, modify, and demonstrate technology and processes jointly in the United States. Utilizing their broad experience in nuclear waste programs, AEA Technology and OST have successfully identified and deployed several technologies supporting high-level waste tanks as well as deactivation and decommissioning. These projects include the fluidic jet pulse mixer, salt kinetics, the SRS pump tank mixer, immobilization options, and the nested fluidic sampler.

Also developed in the United Kingdom and deployed in the U.S. is the IonSens Monitor, which allows measurements of alpha particles in inaccessible areas by measuring air ionization. These measurements allow scientists to determine if an object emits no alpha radiation, and therefore, need not be classified as low-level radioactive waste.

In partnership with a Canadian firm, Spar Aerospace Limited, DOE has developed the Light Duty Utility Arm (LDUA), which assists in the characterization, surveillance, and retrieval activities at high-level waste tank sites. The ability of the LDUA to retrieve waste and clean sludge in high level waste tanks has made it very useful for obtaining data and cleaning tanks in preparation for decommissioning. Also in Canada, DOE signed a statement of intent with the Ontario Ministry of the Environment to pursue the development, evaluation and dissemination of

information about more cost-effective characterization and remediation techniques of fractured bedrock sites.

DOE/EM is continuing a project with the Czech Technical University in Prague to evaluate the radiation and chemical stability as well as the performance of Polyacrylonitrile (PAN) as a binder material for inorganic ion exchange materials such as Ammonium Molybdophosphate (AMP). This material has been tested to remove cesium from acid wastes at Idaho National Engineering and Environmental Laboratory (INEEL) and showed exceptional removal efficiencies and capabilities. The most recent experiments with this technology involve testing to determine the optimization for the degradation process. INEEL is completing an environmental impact study that will define the most promising approaches to their tank problems that will receive further development; AMP-PAN is included in the study. Under a separate contract with EM, the Czech Nuclear Research Institute conducted a project entitled *Review of Advance Separations Technologies in the Czech Republic*. The review covers technologies in use or under development that deal with solvent extraction, ion exchange, and adsorption.

Pioneer, a state-of-the-art robot based on a design developed with funding from OST, began work at the Chernobyl accident site in Ukraine in early spring 1998. The robot is based on a design by RedZone Robotics named Houdini, which was funded through the Federal Energy Technology Center's Industry Program, and is currently being used at Oak Ridge National Laboratory to retrieve radioactive sludge and debris from an underground storage tank. Pioneer will be commissioned to assess structural damage to the concrete shell, called the shelter, which was hurriedly built around the reactor after the Chernobyl accident, which occurred in 1986. The shelter is now cracked. Information on radioactive hot spots and structural damage gathered by Pioneer will be used to determine cleanup strategies.

WORK FOR OTHERS

Due to the technical expertise and available facilities at the national laboratories, DOE initiated the Work for Others (WFO) program whereby outside entities can contract with DOE laboratories for scientific research. WFO agreements benefit DOE because the work is financed by outside sources, and DOE scientists expand their technical expertise while engaging in these projects. Under the WFO program, DOE laboratories have contracts to perform work for the United Kingdom Atomic Energy Authority and the Japan Nuclear Cycle Development Institute.

As a WFO project, the United Kingdom Atomic Energy Authority has requested a demonstration of the Idaho National Engineering and Environmental Laboratory Remedial Action Monitoring System (RAMS) at the UKAEA Dounreay and Harwell sites. The RAMS consists of enhanced sensor technology, measurement modeling and interpretation techniques, and a suite of deployment platforms to obtain real-time, densely spaced, in situ characterization data of various radionuclides and contaminants. INEEL will operate its RAMS on-site with the most appropriate radiological sensor(s) for the selected sites. While the RAMS is performing its non-intrusive, in situ mapping routine, UKAEA representatives will be able to view, in real-time, the data collected in the area of investigation on a monitor at the remote workstation. The INEEL will generate post-processed distribution maps within minutes after the data collection process is complete.

A cooperative agreement with Japan, signed in 1986, involves three WFO annexes dealing with radioactive waste. More specifically, these annexes deal with Mass Transport: Characterization and Predictive Technologies, Thermochemical and Adsorption Data, and Performance Assessment and Experimental Studies. These three projects are investigating handling, transportation, and prediction of high and low level radioactive waste as it relates to the surrounding environment. Sandia National Laboratory is also investigating additional WFO projects with two private firms in Japan.

INTERNATIONAL TECHNOLOGY DEPLOYMENTS

As the mission of EM/OST is to bridge the gap between research and application, technology deployment becomes the ultimate goal of nearly all international programs. EM defines a technology deployment as “the use of a technology or technology system toward accomplishment of one or more site-specific DOE Environmental Management program cleanup objectives as applied to the actual waste requiring management at the site” (*Deployment Summary, Fiscal Years 1995-2000, DOE/EM-0544*). These deployments include both U.S. technologies deployed abroad as well as internationally developed technologies that have been deployed in the U.S. Technology deployments under the agreements detailed above include the high capacity pulsating pump (Russia), the Biopile (Poland), Baroballs (Poland), inorganic phytoremediation (Poland), the power fluidic sampler (U.K.), the fluidic pulse jet mixer (U.K.), the light duty utility arm (Canada).

Other deployments not detailed above include several technologies for deactivation and decommissioning as well as site characterization. One of those technologies is the oxy-gasoline torch developed by DOE. This new torch, which has been deployed in Kazakhstan and Russia, works well in adverse conditions like on rusting metal or steel with cement coatings as found on many old waste tanks. Other international technology deployments include the GammaCam Radiation imaging system, which was deployed in Estonia. This technology detects gamma radiation and then imposes that data on a two dimensional image of a contaminated area, which allows for a radiological survey of a site without requiring a tedious manual survey. This is not an exhaustive list of international technology deployments, and more information on these programs can be found in the DOE publication, *Deployment Summary, Fiscal Years 1995-2000*.

CONCLUSION

Due to the size and complexities of DOE's environmental legacy, DOE/EM will need to address these environmental problems for the next several decades. The scope of this task will require DOE/EM to identify and investigate promising technologies developed internationally in addition to those developed domestically. By identifying promising technologies developed abroad and collaborating with scientists from around the world, DOE/EM can accomplish its remediation mission more effectively, efficiently, and with less environmental and human health risks.