Environmental Management Engineering and Technology – Making A Difference

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New Technologies Being Developed to Protect the Columbia River at the Hanford Site

Twelve projects are currently under way at DOE's Hanford Site to address the U.S. Congress's concern about contamination reaching the Columbia River. In H.R. 2419, the Energy and Water Development Appropriations Act passed by Congress in 2006, conferees expressed their concern about DOE's efforts to protect contaminants from reaching the Columbia River, adjacent to the Hanford Site in Washington State. They stated that "technology used in several remedies is not performing satisfactorily, and there is a lack of new technologies to address contamination issues." As such, they provided $10 million for analyzing contaminant migration to the Columbia River and for the introduction of new technology approaches to solving contaminant migration issues. In response, DOE requested proposals from Pacific Northwest National Laboratory, located at the Hanford Site, and Fluor Hanford, the site contractor responsible for groundwater cleanup, to address the Congressional concerns. In 2007, DOE EM provided $2 million additional funding. Through a robust peer review process, projects were selected and initiated. Two of the selected projects are highlighted below to show progress.

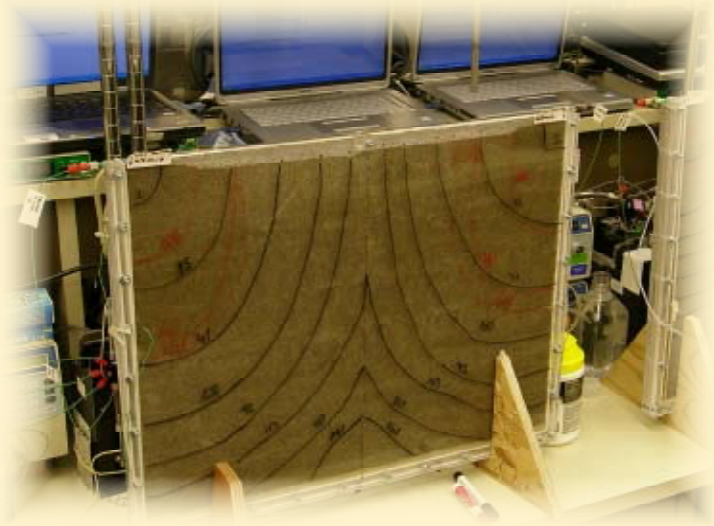
Polyphosphate to Treat Uranium in the 300-Area

In the 300 Area of the Hanford Site, an innovative polyphosphate material is being tested for its ability to reduce uranium concentrations in the groundwater, with promising initial results. Uranium in groundwater is of concern immediately adjacent to the Columbia River. Elevated uranium concentrations have been measured in seeps along the shoreline and in plant and animal life along the river bank. The project is testing and demonstrating whether this innovative material can be injected into the subsurface to sequester the uranium in place as an insoluble uranium phosphate mineral, thus reducing the uranium concentrations in groundwater. Laboratory tests were conducted to optimize the formulation and design of the field test, which was conducted in May 2007. Initial results of the field test were promising, as uranium concentrations were significantly reduced to below the drinking water standard within 23 meters of the injection well. The polyphosphate is also being tested as a treatment for the unsaturated (vadose) zone immediately above the contaminated aquifer where uranium is continually released to the aquifer. Much more work remains to be done before this technology can be applied full-scale, but the promising results call for further technology development.

Apatite to Treat Strontium-90 in the 100-N Area

Hanford 100-N Area, Apatite Injection Project Location

Researchers are testing an innovative strategy for effective injection of solutions to immobilize strontium-90 in the subsurface, preventing its migration into the groundwater near the Columbia River. In the 100-N Area of the Hanford Site, strontium-90 has been detected in the groundwater immediately adjacent to the river and in plant and animal life on the river bank. A pump-and-treat system located further from the river is effectively removing a significant portion of the strontium-90, but is not addressing the contamination near the river. A pilot-scale permeable reactive barrier containing the mineral apatite has recently been installed near the river to sequester the strontium in the groundwater. However, significant strontium remains in the unsaturated (vadose) zone immediately above the aquifer and is continually migrating to the aquifer. This project is developing an infiltration strategy for injection of calcium-citrate-phosphate solutions in the unsaturated zone. One and two-dimensional laboratory tests were run to determine the geometry of infiltration and the spatial distribution of the apatite, which will form after injection of the phosphate solutions. Results of the laboratory testing will be used to design the field test to ensure an effective and efficient infiltration strategy.



Laboratory Testing of Apatite Infiltration

EM and Office of Science Collaborating to Apply Scientific Advances to DOE Site Problems

DOE EM's Office of Engineering and Technology (EM-20) and DOE's Office of Science, Office of Biological and Environmental Research (BER) are effectively collaborating to bring advances in BER's discovery and use-inspired basic research directly to EM's applied research and technology development projects that are focused on specific DOE site problems. As an example, Lawrence Berkeley National Laboratory (LBNL) is collaborating with Savannah River National Laboratory (SRNL) to further understanding of natural attenuation processes for treatment of metals and radionuclides in groundwater. This collaboration is being funded by EM-20's new project entitled "Attenuation Based Remedies for Metal and Radionuclide Contaminated Groundwater" as well as BER funding to LBNL under the Environmental Remediation Sciences Program.

The overall goal of the EM-BER collaboration is to provide a combination of scientific and policy support to facilitate implementation of appropriate cleanup strategies that rely on natural attenuation processes at the F-Area of DOE's Savannah River Site and at other DOE sites. There is currently insufficient scientific understanding of the full range of natural processes and how they could be used to augment and polish active treatment systems. However, this concept has great potential to save millions of dollars at DOE sites with metal and radionuclide-contaminated groundwater.

For monitored natural attenuation to be a viable strategy at the F-Area, understanding of the site's natural capacity to attenuate these contaminants and how the plume changes over space and time is needed. The fate and transport of the contaminants may be changed over time by natural mechanisms within the subsurface.

SRS F-Area Seepage Basin, focus of collaborative study by SRNL and LBNL

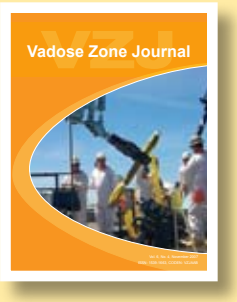
Many questions regarding the types, rates, and scales of these reactions remain to be answered.

The SRNL-LBNL collaboration is 1) investigating better methods for characterizing aquifers, 2) improving understanding of biogeochemical processes that control the fate and transport of these contaminants, and 3) incorporating these findings into reactive transport modeling to make sound scientific predictions of future conditions.

Scientists from both laboratories are working together at the F-Area, where a groundwater plume containing radionuclides has been characterized and remediated since 1997, using a pump and treat system for seven years and subsequently replaced with a more passive funnel-and-gate treatment system.

As part of the collaboration, LBNL will conduct basic science research to further understanding of contaminant-specific natural attenuation mechanisms and will develop innovative tools for site characterization, whereas SRNL will field test and verify the tools developed by LBNL as well as others, and will also develop a technical and regulatory framework for application of natural attenuation strategies at DOE sites.

Significant Research on Hanford Site Vadose Zone Published in Special Issue of the *Vadose Zone Journal*



The *Vadose Zone Journal*, a widely-read publication of the Soil Science Society of America, published a special issue edition in November 2007 on the scientific progress and understanding related to the vadose zone at the DOE Hanford site. The journal is focused on interdisciplinary research and assessment of the vadose zone, the mostly unsaturated zone between the ground surface and the shallowest aquifer.

At the Hanford site, as well as most locations in the West, the vadose zone represents a significant thickness that potentially may contain contaminant sources, which either have or may migrate to the groundwater. Improved understanding of Hanford's vadose zone will provide critical information for the site's cleanup program. Because the Hanford vadose zone is known to be very heterogeneous, understanding of how contaminants introduced at or near the surface may have migrated to the water table is a challenging problem. It is well known that some contaminants (particularly certain radionuclides) are immobilized by Hanford sediments in the shallow subsurface as a result of geochemical reactions, whereas other radionuclides are extremely mobile and have moved through the vadose zone into the groundwater. The specifics of the current location and potential for further migration of contaminants of concern need to be established to design effective groundwater remediation systems.

Over the past ten years, a large body of work to improve our understanding of contaminant transport at the Hanford site has been completed. The papers presented in this issue summarize a portion of that work. This research was funded by DOE EM through site-directed research, the EM Hanford Groundwater Remediation Project, the Groundwater Vadose Zone Integration Project, as well as through the DOE EM Engineering and Technology Program and Office of Science Environmental Remediation Sciences Program. The papers are authored by scientists from PNNL, other DOE national laboratories, CH2M HILL Hanford Group, Fluor Hanford, Fluor Government Group, and a private consultant, hydroGeophysics, Inc.; reviewed by DOE and contractor personnel familiar with the projects; and peer reviewed by the *Vadose Zone Journal* to assure that they met the journal's scientific standards.

Past issues of the *Vadose Zone Journal* have focused on the vadose zone at the Idaho National Laboratory and the Los Alamos National Laboratory.

Prediction Tools for Evaluating Cementitious Barriers and Materials

EM has begun work on a five-year project to develop a set of tools to predict the long-term performance of cement, which is frequently used in nuclear applications, including use as a waste form, as construction material for waste disposal facilities, and in decontamination and decommissioning activities. The simulation tools and data developed under this project will be used to evaluate and predict how cement changes physically, chemically, and structurally over the long term (meaning >100 years for operating facilities and >1,000 years for waste management).

This effort grows out of an EM-sponsored workshop on Cementitious Materials for Waste Treatment, Disposal, Remediation and Decommissioning, in which participants defined DOE's needs, the state of the art, and the state of practice by DOE EM. The outcome of the workshop was the formation of a multidisciplinary team, the Cementitious Barriers Partnership (CBP), consisting of experts from the public, private, academic and international arenas. It includes representatives from EM, the National Institute of Science and Technology, the Nuclear Regulatory Commission, Vanderbilt University, Savannah River National Laboratory, Energy Research Centre of the Netherlands, and SIMCO Inc. The objective of the CBP is to identify and develop tools necessary to address performance of cementitious materials in the near surface disposal of low-level radioactive waste.

In addition to the low-level waste environment, which includes waste forms, containment structures, entombments and environmental remediation; the tools developed will also support analysis of structural concrete components of other nuclear facilities such as spent fuel pools, dry spent fuel storage units, and recycling facilities.

The project focuses on reducing uncertainties associated with current methodologies for assessing cementitious barrier performance and increasing the consistency of the assessment process. The results of this project will enable improved, risk-informed, performance-based decision making, and support several of the strategic initiatives in the DOE-EM Engineering & Technology Roadmap. Additional benefits include more efficient use of materials and designs and reduced potential for human error through integration of process steps.

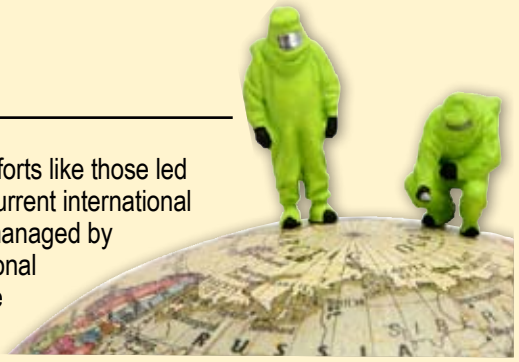
These new simulation tools will improve the ability to assess these facilities' projected performance by providing the means to more fully predict how the cement components will perform over time. This will allow the performance assessments to more fully incorporate the effectiveness of the barriers, the inventory of radionuclides that may be safely disposed of in shallow land disposal, and the predicted service life of operating nuclear facilities.

International Collaboration Brings Unique Radioactive Waste Expertise to DOE

DOE-EM uses international collaborations as one way of identifying innovative ways to reduce risks and accelerate cleanup at DOE sites across the country. Through this initiative, EM works with international government organizations, educational institutions, and private industry to identify and develop technologies that can address the cleanup needs shared by DOE and other nations.

Currently, DOE-EM is performing collaborative work with researchers at the Khlopin Radium Institute and the SIA Radon Institute in Russia and the Ukraine's International Radioecology Laboratory to explore issues related to high-level waste and to investigate experience and technologies that could support DOE-EM site cleanup needs. These programs are outlined in the three articles below.

DOE-EM has been collaborating with international governments and educational institutions through a variety of international agreements since the mid-1990s. In 1996, an International Agreement was set up under the auspices of a Government-to-Government Memorandum of Understanding to transfer technologies and methodologies that had been successful in the U.K. into the U.S. cleanup program. Through this Agreement, EM has used contractors such as NuVision Engineering (formerly AEA Technology) to identify, demonstrate and implement innovative approaches and technologies to address challenges in tank waste retrieval, tank closure, remote handling, D&D and groundwater sampling at a number of DOE sites including Oak Ridge, Los Alamos, Idaho Falls, Savannah River, Fernald and Hanford. For example, technologies obtained through the International Agreement were successfully used to retrieve waste from storage tanks at Oak Ridge and Fernald.



Early successes in efforts like those led EM to establish the current international effort, which is now managed by Savannah River National Laboratory, to explore ways that DOE could benefit from joint research with Russia and other countries in areas like soil remediation, separations and waste immobilization.

As EM continues with its complex-wide effort to identify technical needs in its three strategic areas (waste processing, groundwater and soil remediation, and deactivation and decommissioning), then to implement targeted R&D to address those needs, international collaborations will play an important role. Current international partnerships will be leveraged to apply international expertise to meeting those needs, and additional international partners will be identified.

Already, a Statement of Intent has been signed between DOE-EM and the U.K. Nuclear Decommissioning Authority (NDA) to work cooperatively on areas of mutual interest. Collaborative research opportunities will be identified in the future when the DOE-EM Engineering and Technology road map and multi-year program planning efforts are finalized.

Russian Cold Crucible Induction Melter Technology

Khlopin Radium Institute, Russia:

Improved Solubility and Retention of Troublesome Components in SRS And Hanford HLW Glasses

Pacific Northwest National Laboratory (PNNL) and Savannah River National Laboratory (SRNL) are working with Khlopin Radium Institute (KRI) to identify formulas for improving the treatment of high-level radioactive wastes that contain troublesome components, such as wastes with high aluminum oxide (Al_2O_3) concentrations.

The Savannah River Site (SRS) is currently using its Defense Waste Processing Facility (DWPF) to convert its high-level liquid waste to a stable glass form by mixing it with glass-forming materials, melting the mixture and pouring it into large canisters to cool and harden for permanent disposal; Hanford plans to process its waste in a similar manner. Some of the waste streams, however, contain high levels of Al_2O_3 or other troublesome components that can affect how much waste can be loaded into a quantity of glass and the durability of the resulting glass waste form.

This international team is developing glass formulas for specific DOE waste streams with high Al_2O_3 concentrations. The goal is to produce glasses that meet or exceed waste loading and/or waste throughput expectations as well as satisfying critical process and product performance requirements. The team is also working to assess the melting rate for various glass frits for the DWPF composition, and settling of spinel – a certain type of crystal formation in the glass – for the Hanford composition. Last fiscal year, the team used a combination of small-scale (crucible) testing and melter testing to identify optimal glass compositions with high waste loadings and high melting rates. The crucible tests were used to screen for suitable glass compositions and the melter tests were then used to evaluate the crystallization behavior and melting rates of the glass compositions to identify preferred compositions.

Scientific and Industrial Association (SIA) Radon Institute:

Application of the Cold Crucible Induction Heated Melter to DOE Wastes

As described in the October 2007 issue of *Environmental Management Engineering & Technology—Making a Difference*, Russia's SIA Radon Institute and SRNL are working on a project to evaluate and adapt Russian cold crucible induction heated melter (CCIM) technology to enhance the operations of the SRS DWPF to disposition the high-level waste currently stored at the site. Specific attention in FY07 was given to processing of high alumina content feeds. Using a glass-forming frit especially adapted for the purpose by SRNL researchers, a simulated version of one of SRS' high-alumina waste streams was converted to glass using lab-scale, pilot-scale, and finally production-scale melters. These tests showed that an SRS waste stream with high alumina content could be successfully converted to glass in the CCIM, achieving a waste loading of at least 50%, producing a glass with excellent durability (an order of magnitude better than the Environmental Assessment glass, which is used as the benchmark for repository qualification in the U.S.).

International Radioecology Laboratory:

Long-Term Impacts from Radiation/Contamination within the Chernobyl Exclusion Zone

The International Radioecology Laboratory (IRL) in Slavutych, Ukraine and SRNL are conducting a project to understand the long-term impacts to the environment from radiation exposure within the Chernobyl Exclusion Zone (ChEZ). This project also includes recommendations for the development and testing of effective cleanup technologies to reduce environmental and health risks.

This fiscal year, among other tasks, the team will evaluate the potential application of the vast amounts of information contained in the results of these studies to DOE sites in the U.S.

In the past year, the team completed an assessment of the environmental monitoring methods used during and after decommissioning of the Chernobyl nuclear plant, along with recommendations for improving monitoring methods to meet the requirements of environmental remediation. Three reports completed by the team look at the movement of contaminants through the environment. One of these examines the ways that radioactive contamination that had settled on the ground is re-suspended in the air as the result of natural forces, such as wind, or human activities like agriculture and construction. Another examines the effect of microbiological processes on the movement of contamination through soils, including the ways that fungal species in soils can act as indicators of radioactive contamination. The third looks at existing models for understanding the vertical migration of contamination through soil. As part of a task to evaluate risk assessment methods, the team has begun by documenting the methods used to assess radiation dose to humans and other species.

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