Providing the Scientific Foundations for Environmental Management

Pacific Northwest
NATIONAL LABORATORY

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The U.S. Department of Energy's (DOE) national laboratories deliver the scientific foundations for DOE Environmental Management (EM) to enable legacy waste cleanup, reduce costs, and minimize long-term risk to human health and the environment.

National laboratories represent enduring institutions, many of which are co-located at major cleanup sites—Hanford, Savannah River, Oak Ridge and Idaho. Researchers at these laboratories have advanced the science and processes used to create and safely store legacy waste, as well as the treatment baselines currently being executed in the cleanup mission.

Additionally, the efforts of DOE's offices of Science (SC), Nuclear Energy (NE), Civilian Radioactive Waste Management, and Legacy Waste Management are also being leveraged to maximize the nation's cleanup mission.

Advancements in scientific understanding and the development of technological solutions have enabled the nation to address the cleanup challenges to date. The Pacific Northwest National Laboratory (PNNL) has identified opportunities for further advancement in the following areas:

- **Predictive Process Science**. Advancements in predictive process science to ensure the safe processing and long-term disposition of legacy waste streams.
- **Subsurface Science.** Advancements in science and technology to mitigate the impacts of persistent metals and radionuclides within the subsurface.
- **Computational Science.** Next-generation computational tools and methods to accelerate outcomes and minimize risk.

Predictive Process Science to Enable Design, Operation and Optimization

Achieving predictive understanding for radioactive processing is now possible through advances in solution and interfacial chemistry, rheology, and fluid dynamics in dynamic non-equilibrium chemical systems. Increased application of scientific understanding and advanced computational tools to predict process behavior under widely varying waste and process conditions enables decisions around new treatment operations. These decisions could improve safety and reduce cost.

Both independently and through strategic collaborations, PNNL is pioneering predictive process science. Highlights of our recent advancements in this field include:

- **Waste Formulation**. Collaboration between PNNL, Idaho National Laboratory, Savannah River National Laboratory and Khoplin Radium Institute produced a new method for high-sulfur low-activity waste (LAW) glass formulation. This new method increases target sulfur loading, which enables the reduction of LAW glass volume at Hanford by roughly 45% and saves billions of dollars in lifecycle costs.
- **Integrated Scaled Testing**. PNNL scientists and engineers, in collaboration with the site contractors and field office, have resolved many of the issues that will challenge caustic leaching of 53 million gallons of highly radioactive waste at Hanford's Waste Treatment Plant (WTP). Using a combination of bench-, engineering-, and pilot-scale systems with both radioactive and simulated waste testing, we have developed new methods and models to understand the complex behavior of mixed metal oxide and hydroxide slurry behavior.

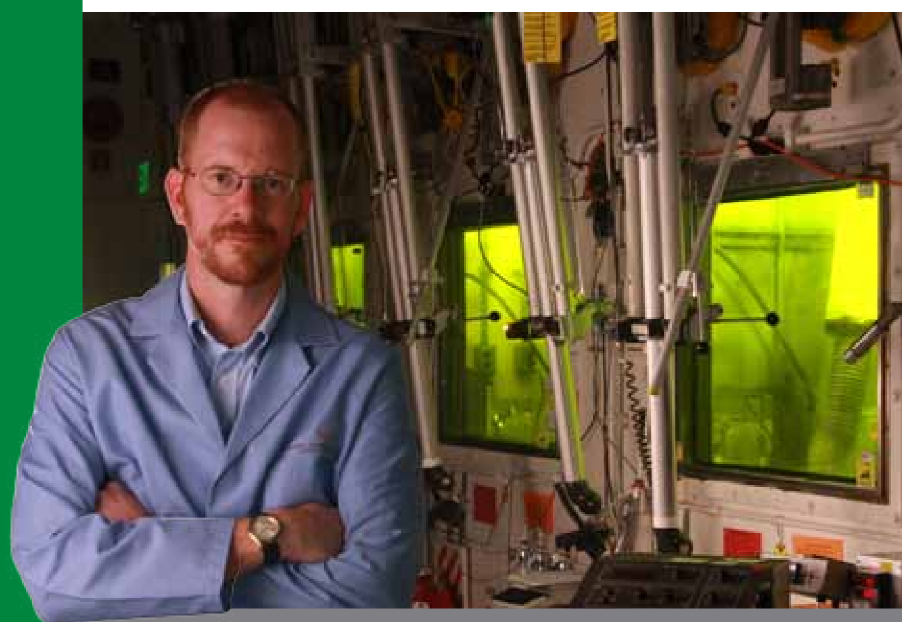
Subsurface Science to Mitigate Contamination

The subsurface environment is a complex heterogeneous domain governed by numerous coupled processes (e.g., biological, geochemical, hydrologic) that have spatial and temporal variability. Characterizing and understanding contaminant migration and fate will address many of EM's remaining subsurface challenges.

Innovative tools and approaches that translate basic science advances into applied solutions are being developed to better understand the migration of subsurface contaminants and treat the remaining persistent waste sources. An approach that systematically links scientific knowledge and capabilities from EM and SC to site cleanup activities will significantly accelerate cleanup and closure.

PNNL is a recognized leader in subsurface science and linking discovery to application. Notable examples include:

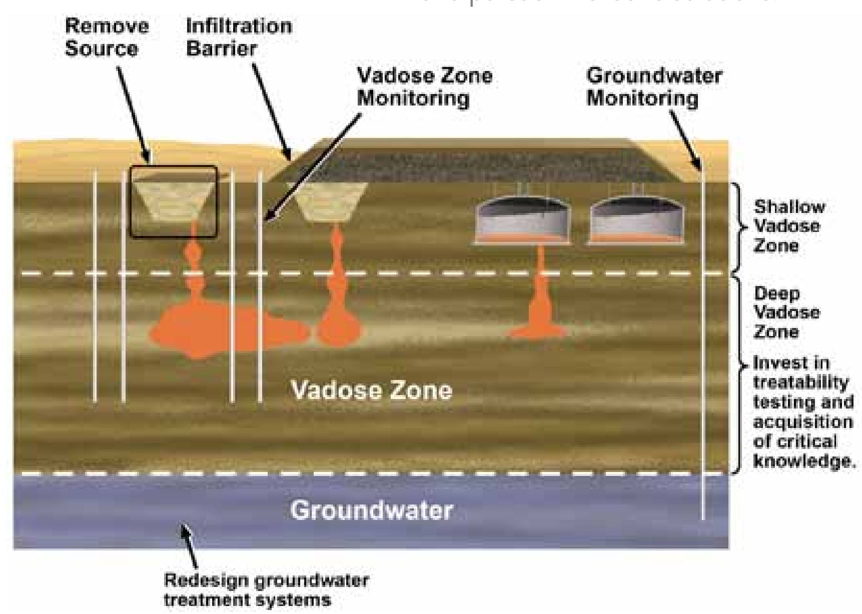
- **Deep Vadose Zone**. PNNL is leading a national collaborative applied field research initiative at Hanford. This initiative is making advances toward solving the problem of remediating the deep vadose zone by integrating basic research in hydrology, geochemistry, and biogeochemistry to support economical and sustainable strategies to characterize, monitor, model, and remediate contamination deep within the subsurface above the water table. Fundamental research conducted in the Subsurface Flow and Transport Laboratory at the Environmental Molecular Sciences Laboratory (EMSL) is being used to develop an approach to desiccate, or dry, the deep vadose zone and slow contaminant migration to groundwater.
- **Uranium**. Leveraging SC and EM investments, PNNL researchers conducted first-of-a-kind analyses that unraveled the fate of uranium released from one of the largest, single-point leaks at Hanford and now resides in the deep vadose zone. Results have led to an understanding of the mechanisms of uranium transport from unsaturated low-permeability zones via mass transfer and diffusion processes. This fundamental understanding is being used to identify effective in-situ approaches for vadose zone remediation.



Researchers at PNNL's Radiochemical Processing Laboratory, a Hazard Category 2 non-reactor nuclear facility, are advancing solutions in radioactive and hazardous waste cleanup, nuclear fuel processing and disposal, and medical isotope production.

PNNL provides the scientific foundations for reducing legacy waste costs and long-term risk to human health and the environment.

The Deep Vadose Zone Applied Field Research Center, led by PNNL, will examine and address the complexities of deep vadose zone contamination and pursue innovative solutions.



PNNL researchers are working to exploit the unique chemistry of Goethite, an iron bearing oxide mineral found in soil that could be a key to processing Tc-99 or stabilizing it in waste forms.

Computational Science to Enable Real-Time Remediation Decisions

The National Research Council has noted the importance of sophisticated computational methods that incorporate better scientific understanding of subsurface processes, as well as advanced computational fluid dynamics for waste processing.

DOE investments have advanced subsurface knowledge and research calculations. The Advanced Simulation Capability for Environmental Management Initiative (ASCEM) makes the data generated from those investments available to enable effective remediation decisions. ASCEM significantly leverages SC basic science and computational approaches.

The development of new subsurface modeling approaches by EM can also be leveraged to address the nation's energy needs by applying these tools to activities such as CO_2 sequestration in fractured/porous rock (e.g., basalts). EM-developed capabilities are already paying dividends with Fossil Energy field research on sequestration. Concepts developed for a modeling interface known as GS3 which supports CO_2 sequestration are being applied in the ASCEM Platform. Recent advancements in computational science include:

- **Process Modeling.** PNNL is developing an advanced computational model (ParaFlow) based on a new lattice kinetics algorithm incorporating highly complex physical relationships such as multi-phase flow that scales efficiently on massively parallel computers, enabling predictive process science in complex chemical and engineered systems.
- **Subsurface Modeling.** Predicting the fate and transport of contaminants in heterogeneous subsurface systems requires incorporation of key hydrogeologic and biogeochemical properties and processes at varying scales into numerical codes. PNNL has developed, and recently updated to run on high performance computers, the Subsurface Transport Over Multiple Phases (STOMP) code to capture process level details at varying scales and provide input to remedial approaches.
- **Subsurface Imaging.** Monitoring subsurface processes and environments is often limited to sparsely spaced access boreholes, leading to high uncertainty in remedial performance and understanding of contaminant transport and fate. PNNL is advancing the computational models, Finite Element Resistivity in 3D (FERM3D) and Finite element Spectral Induced Polarization (FSIP3D), to provide near real-time, geophysical imaging of subsurface processes and contaminant fate. This will reduce uncertainty in 1) estimating 3D distribution of parameters that govern flow and transport, 2) contaminant transport and fate, and 3) remediation performance, including contaminant mobility.

About Pacific Northwest National Laboratory

PNNL is located in Richland, Wash., has approximately 4,900 staff, and $1.1 billion in business volume in fiscal year 2010. In the quest for knowledge discovery, PNNL marshals interdisciplinary research teams, collaborates with a range of partners, and leverages research funding to maximize results. Our staff, facilities, capabilities, and approach to inquiry and innovation have established PNNL as a premier science and technology enterprise.

For more information about the science you see here, please contact:

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