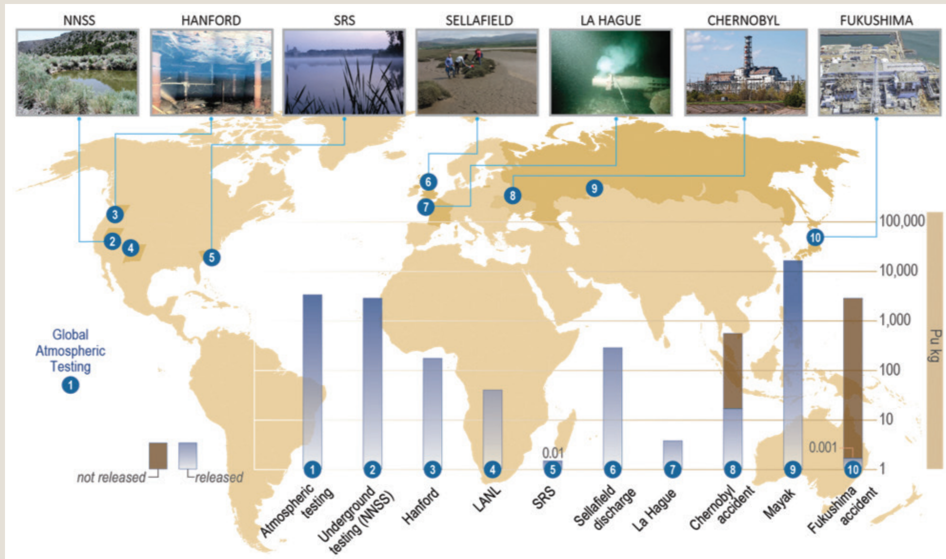
BioGeoChemistry of Actinides Scientific Focus Area

https://seaborg.llnl.gov/research/environmental-radiochemistry

Identifying biological processes that control actinide mobility in the environment

All the actinides, which are radioactive, can pose a risk to human health and the environment. However, plutonium (Pu) is the most abundant and chemically complex anthropogenic actinide. Since the dawn of the nuclear era, the global Pu inventory has increased from ~2 kg to 2,700,000 kg, with ~70,000 kg added to this inventory each year from spent nuclear fuel.

A fraction of this Pu inventory has been released into the environment as a result of nuclear weapons production, weapons testing, poor waste management, and nuclear accidents. Surface and subsurface transport of low concentrations of Pu from these releases has been documented on the scale of kilometers. This large Pu inventory, along with its long half-life (~24,000 years), high toxicity, and known ability to migrate, represents significant long-term environmental and public health risks.



Global Plutonium (Pu) Inventory. *The worldwide plutonium inventory is estimated at 2,700 metric tons. Approximately 1% of this inventory has been released to the environment, which means that actinides will be present in the environment for the foreseeable future. Consequently, the impact both locally and globally must be understood. The particularly high toxicity and long half-life of Pu and other actinides require understanding and predicting their behavior over exceedingly long timescales. Key: NNSS, Nevada National Security Site; SRS, Savannah River Site; LANL, Los Alamos National Laboratory.*

Reliable predictions of how actinides such as Pu and neptunium will migrate in the subsurface are not currently possible, preventing accurate assessments of risk to human health and the environment. The BioGeoChemistry of Actinides Scientific Focus Area (SFA) led by Lawrence Livermore National Laboratory (LLNL) is addressing this challenge. By identifying the dominant biogeochemical processes and underlying mechanisms that control actinide mobilization in surface water and groundwater (focusing on Pu), the SFA is advancing efforts to reliably predict and control actinide cycling and mobility in the environment. The project is supported by the Department of Energy's (DOE) Office of Biological and Environmental Research (BER), within DOE's Office of Science, as part of BER's Subsurface Biogeochemical Research (SBR) program.

Key Knowledge Gaps

The LLNL SFA is focused on advancing understanding of surface and subsurface actinide behavior to provide a scientific basis for remediation and long-term stewardship of DOE legacy sites and, more broadly, increase understanding of transport phenomena in environmental system science.

Key knowledge gaps addressed by the LLNL SFA include:

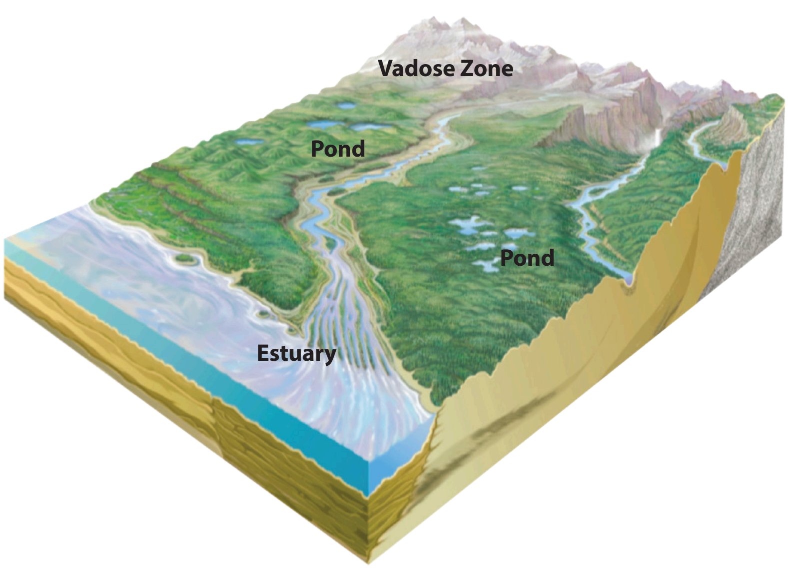
- Factors affecting long-term stabilization of actinides in sediments.
- Actinide incorporation into secondary mineral phases in sediments.
- Actinide stabilization on surfaces when coupled to redox cycles.
- Role of microbes and their exudates in actinide mobilization and stabilization.

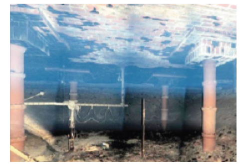
Linking Laboratory Experiments, Modeling, and Field Observations

Predicting long-term actinide behavior in the environment necessitates an approach that integrates research across multiple scales, linking laboratory experiments and computational models with field observations.

Laboratory experiments provide quantitative data on the affinities, kinetics, and morphology of actinide associations with mineral surfaces, organic matter, and microbes. Field observations provide direct evidence for long-term behavior of actinides in the environment as well as a foundation for conceptual understanding of actinide migration.

This integrated laboratory, modeling, and field observation approach to actinide biogeochemistry is being used to quantify actinide transport at four unique contaminated sites: the Nevada National Security Site (NNSS), Hanford Site (Richland, Washington), Savannah River Site





HANFORD
Vadose zone actinide contaminant transport

RAVENGLASS
Actinide mobilization from estuary sediments

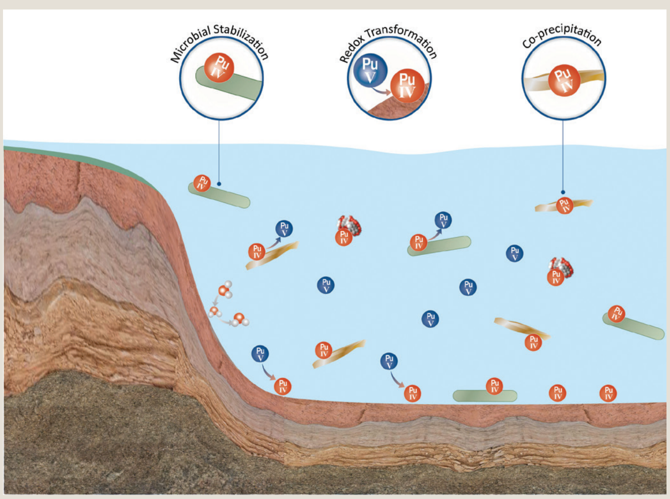
NNSS
Adventive colloid facilitated actinide transport in pond sediments

SRS
Actinide cycling from seasonal anoxia in ponds

Hydrologically Diverse Field Sites. *The four SFA field sites enable testing of specific processes that influence the long-term evolution of actinide mobility in the environment. Field sites include a vadose zone waste site (Hanford Site), perched water drainage ponds from a nuclear testing site (Nevada National Security Site [NNSS]), reactor cooling ponds linked to the Savannah River system (SRS), and an estuary (Ravenglass) located near a reprocessing facility (Sellafield, U.K.). These sites were chosen based on their known variations in contamination history, contaminant loading, location within the watershed, processes believed to control actinide transport, and long history of actinide contamination.*

(SRS; Aiken, South Carolina), and Ravenglass site (Sellafield, U.K.). Field studies capture actinide behavior on the timescale of decades. The diverse range of conditions at these four sites provides an opportunity to expand current conceptual understanding of actinide migration within specific components of a watershed system.

Fundamental laboratory studies can isolate specific biogeochemical processes and mechanisms that are observed in the field and impact long-term fate and transport of actinides. These processes include mineral co-precipitation with actinides, the role of mineral redox cycling on actinide stabilization on mineral surfaces, and the role of microorganisms in actinide mobilization and immobilization.



Actinide Stabilization and Mobilization Processes at the Intersection of Sediment, Microbiome, and Mineral Surfaces. *Microbial exudates play an important role in actinide mobilization in surface and groundwater, and biologically mediated iron oxide mineral transformations also lead to microbially derived long-term stabilization of actinides in sediments. At the same time, abiotic mineral transformations, iron redox cycling in particular, play an important role in irreversible sequestration of actinides in sediments and minimize actinide migration in the environment.*

Research Across Multiple Scales

The BioGeoChemistry of Actinides SFA is building an understanding of long-term actinide migration behavior in the environment. Findings from both field and laboratory studies identify key processes across spatial and temporal scales that are used to develop conceptual and numerical models and improve prediction of actinide migration in the environment.

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