Subsurface Immobilization of Metal Contaminants by Amendment-Driven Mineral Precipitation

Idaho National Laboratory
Subsurface Science Scientific Focus Area (SFA)

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EXECUTIVE SUMMARY

Addressing persistent subsurface contamination by radioactive or toxic metals is a necessity at sites across the Department of Energy (DOE) complex. One important example is the Idaho Nuclear Technology and Engineering Center (INTEC) facility at Idaho National Laboratory (INL), where strontium-90 has migrated from the original release site and contaminated perched water in a geologically stratified vadose zone. Planned remedial actions to prevent aquifer contamination will require long-term monitoring and maintenance, which alone could extend to the year 2263 and cost an estimated $54M or more. No viable remediation options exist at this time for responding to transport behavior that exceeds current estimates.

For INTEC, as well as many other metal-contaminated DOE sites, *in situ* immobilization through induced contaminant precipitation, reactive barrier emplacement, contaminant encapsulation, and/or hydraulic isolation could provide significant reduction in programmatic risk and uncertainty. Approaches for *in situ* immobilization of metal contaminants involve stimulating the production of mineral phases that sequester or isolate the contaminants. The success of such approaches depends on understanding how the transport and mixing of reactants determines the spatial and temporal distributions of mineral nucleation and growth, and understanding the impact of the mineral precipitates on the mobility of metal contaminants. Field-scale applications also require the capability to accurately predict and sense the occurrence and distribution of the amendment-stimulated reactions.

The objective of the INL Subsurface Science Scientific Focus Area (SFA) research program is to advance the scientific understanding required for the development and application of field-scale *in situ* immobilization strategies for subsurface metal contaminants. The ^{90}Sr contamination under the INL INTEC facility will be used as one case study for the research program, but the outcomes of the INL SFA effort are expected to benefit DOE in addressing environmental challenges across the complex. The following principal hypotheses form the basis for the INL SFA research program plan:

- **The formation and distribution of mineral precipitates in heterogeneous subsurface matrices, and the subsequent impacts on metal contaminant mobility, can be predicted from knowledge of the spatial and temporal structure of mixing zones between mineral-forming reactants. Mixing zone structures are determined by how reactants are introduced and by the heterogeneous reactive transport properties of the subsurface system.**
- **Changes in macroscopic properties of subsurface systems due to mineral precipitation can be detected and quantified by measuring changes in electrical properties of the media.**

These and other more focused supporting hypotheses will be addressed using laboratory experiments supported by computer simulations and enhancements to existing numerical models. Calcium carbonate and phosphate minerals will be the model mineral phases in the experiments, and ^{90}Sr will serve as the model target contaminant.

The 5-year SFA research program plan is structured around four principal interdependent research elements: (1) Transport and precipitation coupling in porous media, (2) Basic processes and parameters, (3) Multi-scale model application, validation and improvement, and (4) Sensing methods for precipitation-related properties and processes.