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LAND RESEARCH PROGRAM

METAL SPECIATION RESEARCH: PROVIDING EFFECTIVE REMEDIATION AND RISK INSIGHTS AT CONTAMINATED SITES

Issue

There are many complex remediation and risk management challenges for property that has been contaminated by metals. Risk assessors often evaluate these sites by measuring the total metal content. This approach is critical, but does not provide predictive insights on the bioavailability, mobility, and fate of the metal contaminants.

Metal speciation research is needed to improve the ability of decision makers to evaluate the risks of metal contamination and develop effective and economic remediation strategies.

The speciation, or chemical form, of metals governs its fate, toxicity, mobility, and bioavailability in contaminated soils, sediments and water. To assess these chemical properties and to accurately gauge their impact on human health and the environment, metals need to be characterized at the atomic level. An array of existing techniques can be used to elucidate metal speciation. In addition, researchers have used advanced synchrotron radiation methods.

Science Objective

The Land Research Program in EPA's Office of Research and Development is conducting cutting-edge metal speciation research to engineer effective and economic remediation strategies and to understand bioavailability of metals.

Researchers are solving fundamental problems regarding metal speciation in soils, sediments, and water by using advanced, molecular-level spectroscopic techniques coupled with macroscopic kinetic and thermodynamic laboratory studies and field research results. Their objective: to elucidate reaction mechanisms that influence fate, transport, reactivity, mobility, bioavailability, and toxicity of metals in the natural environment.

To attain in situ atomic level information on the speciation of metals, researchers have used high-energy synchrotron x-rays to probe the chemical environment of metals at the Advanced Photon Source at Argonne National Laboratory in Illinois. They have incorporated x-ray absorption (XAS), x-ray fluorescence (XRF), and micro-tomography spectroscopies to analyze environmental samples to determine the true, in situ speciation of metal contaminants.

These innovative research tools are expanding the ability to directly identify the role of metal speciation on many dynamic processes that influence risk at contaminated sites.

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Research Goals:

- Demonstrate that spectroscopic metal speciation enhances site evaluation and remedy selection
- Use metal speciation to improve remediation and reduce bioavailability
- Employ speciation results to enhance conventional methods to assess risk
- Develop an approach to understand exposure situations that alter bioavailability
- Demonstrate the relationship of metal speciation and bioavailability
- Reduce metal bioavailability in contaminated systems
- Confirm the effectiveness of in-situ remediation with speciation and bioavailability studies

Application and Impact

The importance of metal speciation and bioavailability research to the development of pollution law and control technologies is increasingly evident. Research on the chemical, biological, toxicological, and ecological effects of chemical species in the environment and methodology for the determination of chemical species and their bioavailability are providing new insights on previously hard-to-understand problems.

Studies conducted by the Land Research Program have enabled EPA to better predict the mobility, bioavailability, and fate of contaminant metals in environmental systems and develop effective and economic remediation strategies in response.

Research accomplishments:

- Speciation research has identified links between the effectiveness of in-situ site remediation and reduced metal bioavailability. Results indicate speciation can better predict fate and transport of contaminants, which improves remedy selection.

- Research efforts have resulted in new approaches to alter and measure metal bioavailability

- Numerous metal contaminated sites have used these new bioavailability measures to adjust cleanup standards
- Research indicates that in-situ remediation can be effectively used to reduce metal bioavailability and increase long-term stability
- Studies have demonstrated that metal speciation by advanced spectroscopic techniques is critical to understanding the mechanisms of metal bioavailability

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