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Microbial Mineral Transformations at the Fe(II)/Fe(III) Redox Boundary for Solid Phase Capture of Strontium and Other Metal/Radionuclide Contaminants

F. Grant Ferris
University of Toronto
22 Russell Street
Toronto, Ontario M5S 3B1
Phone: 416-978-3022
E-mail: ferris@quartz.geology.utoronto.ca

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Research Objective

Determine microbiological and geochemical controls on carbonate mineral precipitation reactions, and identify contributions of these processes to the solid phase capture of strontium and other metal/radionuclide contaminants. The study is relevant to the development of new clean-up strategies for DOE sites where strontium and other metal/radionuclides exist as ubiquitous and often mobile contaminants.

Research Progress and Implications

The work summarized in this report encompasses two years of a three-year project investigating the use of bacteria to concentrate and immobilize strontium, as well as other metal/radionuclide, contaminants. Major accomplishments to date include completion of metal sorption studies with bacteria and hydrous ferric oxides (HFO), assessment of the impact of strontium on bacterial Fe(III)-reduction, induction of carbonate mineral precipitation and solid phase capture of strontium under Fe(III)-reducing conditions, and discovery of a procedure to attain rapid high-level concentration of strontium in microbiologically produced calcite.

Applying principles of surface complexation theory to the strontium sorption studies has yielded equilibrium sorption constants and maximum binding capacities for HFO, and bacteria. Bacterial and HFO sorption of uranium, copper, and cadmium has also been measured. These results have revealed pronounced differences not only in the pH and time dependence of metal retention by HFO and bacteria, but also significant variations in sorption constants and sorption capacities. This information argues strongly for a paradigm shift in geochemical modeling to incorporate the influence of bacteria into studies focused on the reactive transport of metals in contaminated groundwater.

The rate and extent of bacterial Fe(III)-reduction were not negatively influenced by elevated concentrations of strontium (1.0 mM) in culture media. Similarly, strontium did not alter the pH increase that accompanies the reduction of HFO during bacterial growth. The benign impact of strontium on bacterial activity implies that toxicity is not a major concern for potential bioremediation applications. At the same time, bacterial Fe(III)-reduction contributed to substantial mineralogical transformation of substrate HFO, including formation of the Fe(II)-carbonate, siderite. When present, the solid phase partitioning of strontium was enhanced by these mineral transformation reactions. Dissolved strontium levels decreased by 10 percent over a 30 day period with solid phase distribution coefficients ranging from 10^2 to 10^3 .

Elevated solid phase concentrations of strontium (up to 2.0 weight percent) were attained in less than one day by using bacterial urea hydrolysis to produce calcium carbonate (calcite) with decreases in dissolved strontium concentrations of up to 90 percent. Solid phase distribution coefficients approached four orders of magnitude (10^4). This discovery demonstrates that solid phase capture of strontium by microbial carbonate mineral precipitation is not only feasible, but can be highly effective and accomplished in a rapid fashion.

Considerable potential exists to adapt this novel immobilization concept to the development of new clean-up strategies for DOE sites where strontium and other metal/radionuclides exist as ubiquitous and often mobile contaminants. At this early stage, further laboratory investigations and confirmation of process performance under model field conditions are considered to be the most appropriate course of action.

Planned Activities

The focus of work in the next year will be on strontium immobilization experiments in microcosms (months 20-26) and columns (months 27-36) incorporating natural and synthetic HFO-coated sands to investigate bacterial controls on the solid phase capture of metal/radionuclide contaminants under model field conditions, as outlined in the original project proposal.

Other Access To Information

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3. Leonardo, M.R., F.G. Ferris, and E.E. Roden. 1998. Analysis of iron-carbonate mineral formation during microbial reduction of synthetic amorphous iron oxide. American Society for Microbiology General Meeting, Abstract Volume, p. 379.
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