Solubilization of Radionuclides and Metals by Iron Reducing Bacteria

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Iron oxides are ubiquitous mineralogic components of vadose zone and aquifer sediments, typically existing as particle coatings and intergrain cements. Fe(III) oxides are reactive, act to buffer subsurface redox capacity, and are strong sorbents of metallic and radionuclide contaminants. Iron oxides serve as a major in-ground repository of contaminants on DOE lands. Ascertaining the long term stability of contaminant-Fe(III) oxide associations and devising means to effectively extract sorbed contaminants are important scientific needs for DOE site remediation and closure that are being investigated by this project.

Research is investigating hydrogeochemical controls on the activity of dissimilatory iron-reducing bacteria (DIRB) in subsurface sediments and the potential of DIRB for solubilizing sorbed metals associated with Fe(III) oxides under anoxic conditions. The project focuses on bacterial ferrous iron mineralization and the impact of biomineralization on redox buffering capacity and contaminant solubility. Batch and stirred-flow reactors with synthetic and subsurface materials are inoculated with DIRB to investigate how different C-sources and e-donors, interfacial chemical reactions and water advection meter the activity of DIRB. The reductive solubilization of sorbed metals by DIRB is investigated using synthetic and subsurface materials spiked and aged with important DOE contaminants [Ni(II), Hg(II), Co(II/III) and Eu(III)], and a contaminated subsurface material. A novel biogeochemical modeling approach is used for experiment interpretation whereby surface and aqueous complexation reactions and precipitation are linked with Monod kinetics and water transport. Mossbauer spectroscopy, X-ray adsorption spectroscopy and other techniques are used to characterize the chemical and mineralogic nature of the Fe(III) oxides, biomineralization products and biogenic contaminant host phases as a basis for chemical model development.

In the first project year we have shown that: (1) hematite and goethite in subsurface sediments are more bioavailable (to DIRB) than synthetic goethite and hematite because of crystallite disorder and surface heterogeneities, and (2) Co(III) and Ni(II) can be solubilized from crystalline Fe(III) oxides by DIRB in mole fraction excess to iron leading to their net depletion from the oxide phase. In the second year, we have investigated the bioreduction of fresh, aged and heated hydrous ferric oxide (HFO) spiked with Ni and Co. Aging and heating produces a poly-phase Fe(III) oxide association much like those found in subsurface materials. Using a combination of Mossbauer spectroscopy and high resolution electron microscopies, we have found that sorbed contaminants inhibit the crystallization of HFO, alter bioreduction through a combination of physiologic and surface chemical effects, and direct the formation of different biomineralization suites, some of which are highly effective at contaminant capture through coprecipitation. We have determined biogeochemical conditions favoring both mobilization and immobilization of contaminants and are now linking geochemical and microbiologic modeling to quantitatively describe these processes.