Environmental Actinide Mobility: Plutonium and Uranium Interactions with Naturally Occurring Microorganisms

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Objectives. Our overall goal is to understand the interactions of actinides and bacteria that can stabilize or destabilize actinides in the subsurface environment with respect to mobility. Our objectives toward achieving this goal include the following: (1) characterize the chemical toxicity of actinides to bacteria that could stabilize actinides using biostimulation or bioaugmentation, (2) determine and characterize the binding of actinides to extracellular polymers and whole cells, and show how that binding will affect environmental speciation and distribution, (3) examine and quantify the siderophore-mediated redox, speciation, and membrane translocation of actinides, and (4) investigate the redox influence of bacteria on actinides as a function of initial form.

Chemical toxicity. When considering the bioremediation of sites contaminated with radioactive materials, microbial tolerance to the metal contaminant must be addressed. We have determined the toxicity of a variety of metals, radionuclides, and organic chelators to several bacteria. We found that actinides are less toxic than most other metals [e.g., Ni(II), Cd(II), Pb(II), Al(III])], inhibiting growth only at concentrations in the micromolar to millimolar concentration range, far above contamination levels reported in the U.S. Also, by testing the toxicity of isotopes with differing specific activity ($^{238, 239, 242}$Pu), we found that actinide toxicity is primarily chemical, not radiological, in nature.

Siderophore speciation and membrane translocation. We continue to investigate the redox properties of a range of Pu–chelator and Pu–siderophore complexes, including expanding our studies to include EDTA, pyoverdin, and acetohydroxamic acid. Pyoverdin, isolated and purified from *P. putida*, forms a 1:1 complex with Pu(IV), which has a reduction potential of approximately –0.400 V (versus NHE). Having previously demonstrated and quantified the microbial uptake of Pu-hydroxamate siderophore complexes, we seek to determine if this phenomenon is general. That is, are other types of actinide–siderophore complexes translocated across the cell membrane? Our initial results suggest that, at conditions under which Fe(III)–pyoverdin is accumulated by metabolically active cells of *P. putida*, the Pu(IV)–pyoverdin complex does not appear to be taken up.

Reduction by dissimilatory iron-reducing bacteria. With respect to reduction, experiments done previously by others have shown that iron-reducing bacteria (i.e., *Shewanella* sp. and *Geobacter* sp.) are capable of radionuclide reduction—primarily U(VI)—for growth. We have now shown that whole-cell suspensions of *Shewanella oneidensis* rapidly reduce concentrations (up to 10 mM) of Pu(VI) to minimal concentrations of Pu(IV), with either formate or lactate as the electron donor. More recently, experimental results have indicated that in growth cultures in the presence of varying Pu(VI) concentrations, a toxicity threshold less than the 10 mM Pu(VI) done in cell suspension exists that may limit cell growth. Once this factor has been determined, we will proceed with growth cultures utilizing Pu(VI) as the sole electron acceptor, and determine the redox potential range accessible to c-type cytochromes, possible important factors in regard to geochemical cycling and microbial metabolism in contaminated areas.