Project 1025387

Stability of U(VI) and Tc(VII) Reducing Microbial Communities to Environmental Perturbation: Development and Testing of a Thermodynamic Network Model

McKinley, James P.
Pacific Northwest National Laboratory

Istok, Jonathan
Oregon State University

RESULTS TO DATE: Previously published research from in situ field experiments at the NABIR Field Research Center have shown that cooperative metabolism of denitrifiers and Fe(III)/sulfate reducers is essential for creating subsurface conditions favorable for U(VI) and Tc(VII) bioreduction (Istok et al., 2004). The overall goal of this project is to develop and test a thermodynamic network model for predicting the effects of substrate additions and environmental perturbations on the composition and functional stability of subsurface microbial communities. The overall scientific hypothesis is that a thermodynamic analysis of the energy-yielding reactions performed by broadly defined groups of microorganisms can be used to make quantitative and testable predictions of the change in microbial community composition that will occur when a substrate is added to the subsurface or when environmental conditions change. An interactive computer program was developed to calculate the overall growth equation and free energy yield for microorganisms that grow by coupling selected combinations of electron acceptor and electron donor half-reactions. Each group performs a specific function (e.g. oxidation of acetate coupled to reduction of nitrate); collectively the groups provide a theoretical description of the entire natural microbial community. The microbial growth data are combined with an existing thermodynamic data base for associated geochemical reactions and used to simulate the coupled microbial-geochemical response of a complex natural system to substrate addition or any other environmental perturbations. The modeling software and procedures are entirely general and apply to pristine and contaminated aquatic and terrestrial environments. Emphasis in this project is on modeling the effects of various factors on the response of microbial communities in subsurface environments contaminated with radionuclides and heavy metals; subsequent research will examine other scenarios. This approach is new. Recently, the first simulations of the effect of substrate additions on the growth and activity of subsurface microbial communities and the resulting impacts on uranium and technetium mobility were simulated using conditions at the Field Research Center. The results clearly show the role of denitrifying, sulfate reducing, and Fe(III) reducing microbial groups in creating conditions favorable for the reductive precipitation of U(IV) and Tc(IV) and in maintaining their stability when donor additions are terminated.

DELIVERABLES: This approach is new. Recently, the first simulations of the effect of substrate additions on the growth and activity of subsurface microbial communities and the resulting impacts on uranium and technetium mobility were simulated using conditions at the Field Research Center. The results clearly show the role of denitrifying, sulfate reducing, and Fe(III) reducing microbial groups in creating conditions favorable for the reductive precipitation of U(IV) and Tc(IV) and in maintaining their stability when donor additions are terminated. An important component of this project is that model predictions will be tested by quantifying changes in the abundance of each of these groups using a combination of functional genes and lipid analysis. The network model will also be used to examine the stability of the U(VI) and Tc(VII) reducing microbial communities to changing environmental conditions. These predictions will be tested by challenging the microbial community with a series of perturbations representative of those likely to occur (due to heterogeneity in groundwater geochemistry) in a full-scale bioreactor at the FRC. These will include variations in pH, nitrate, and sulfate concentrations in the bioreactor influent.

COLLABORATIONS: Jack Istok, Oregon State University D.C. White, University of Tennessee Lee Krumholz, University of Oklahoma