Vadose Zone Microbial Community Structure and Activity in Metal/Radionuclide-Contaminated Sediments

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The objective of the project is to determine the effect of unsaturated flow rate, exogenous nutrients and metal concentrations on microbial community structure, activity, diversity and dynamics in vadose zones with low natural recharge which have been impacted by anthropogenic recharge. Uncontaminated vadose zone sediments from near the DOE Hanford Site in Washington, and exposed to irrigation water for three years, were used in unsaturated batch and column experiments.

An unsaturated flow column experiment (8 columns) was conducted to evaluate the impact of different levels of unsaturated flow on vadose zone microbiological properties. No nutrients were added to the columns. Both unsaturated (0.15 volumetric water content) and saturated flow conditions increased microbial growth as measured by cell membrane synthesis by a factor of ~5 compared to no-flow columns with 0.05 volumetric water content. Select ribosomal RNA and phospholipid fatty acid (PLFA) analyses are being performed to determine if, and which, specific microbial groups were stimulated by the different flow conditions.

Chromate toxicity to microbial communities was determined under aerobic, saturated and unsaturated conditions, comparing short and long-term exposure effects. The toxicity of chromate to microbial communities was quantified using cell membrane synthesis as the response variable. Chromate concentrations resulting in 50% inhibition (IC_{50}) were lower under unsaturated conditions than saturated conditions and lower after long-term exposure (4 weeks) than short-term exposure (3 days).

An unsaturated aerobic batch experiment composed of 27 treatments with varying chromate, nitrate, and carbon levels was conducted to select a subset of treatment combinations to be evaluated in subsequent unsaturated flow column experiments. Chromate concentrations of IC_{50} and IC_{90} after long-term exposure were used. Nitrate was included because it is a common co-contaminant at Hanford's chromium-contaminated sites, and organic carbon was added to stimulate bioremediation. Studies by others have shown chromate can be reduced under both aerobic and denitrifying conditions. Samples have been analyzed for aerobic heterotrophic plate counts; cell membrane synthesis; chromium VI(reduced, soluble), VI(adsorbed) and III(oxidized, precipitate); concentration of nitrite reductase genes; and terminal restriction fragment length polymorphism (T-RLFP) analysis of rRNA to identify changes in the composition of the metabolically active microbial community. Chromate, nitrate, and carbon levels — individually and in combination — altered microbial populations, diversity and activity. Select samples will also be further analyzed by both PLFA and nucleic acid probe analysis of flotation films.

In the third year of the project, we will evaluate several chromate bioremediation approaches in unsaturated flow column experiments using the same analytical techniques.