Enhancement of Bacterial Transport in Aerobic and Anaerobic Environments: Assessing the Effects of Metal-Oxide Chemical Heterogeneity

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Our research goals are to enhance our understanding of the fundamental processes required for successful, field-scale delivery of microorganisms to metal contaminated subsurface sites that exhibit both physical and chemical heterogeneity. The experiments being planned are designed to determine: (1) under what circumstances the preferential adsorption of bacteria to Fe, Mn and Al oxyhydroxides influences field-scale bacterial transport; (2) whether the adhesion properties of bacterial cells affect field-scale bacterial transport; 3) whether microbial Fe(III) reduction can enhance field-scale transport of Fe-reducing bacteria (IRB) and other microorganisms; (4) what level of site characterization, laboratory-scale experimentation and scaling-up approaches is required to accurately model field-scale bacterial transport; (5) which bacterial tracking methods yield the most reliable data for field-scale transport of living, viable bacteria; and (6) which other methods can be employed at the field-scale to enhance bacterial transport.

In the past year, two flow cells have been installed in a surficial aquifer located just south of Oyster, Va., on the DelMarVa peninsula. One flow cell was installed in an aerobic portion of the aquifer, and the other in a suboxic portion of the same aquifer. At the aerobic flow cell, 24 multilevel samplers (each with 12 sampling ports distributed over a depth of 3 m) were designed and installed by Oak Ridge National Laboratory and Golder Associates. The strata in both flow cells are comprised of quartz-rich fine-grained sands with significant grain size variations occurring over the cm to meter scale; significant variations in the concentrations of Fe, Mn, and Al oxyhydroxides also occur over the same scale. Higher levels of Fe(II) are present in the groundwater and sediment at the suboxic flow cell relative to the aerobic flow cell.

Five different strains of IRB have been recovered from groundwater and sediment samples by Florida State University and Pacific Northwest National Laboratory (funded independently by DOE/OBER) that satisfy the antibiotic resistance profiles and are currently being tested for field injection next spring by Envirogen, Inc. A 3-D hydrodynamic model of the aerobic flow cell was constructed based upon surface geophysical data gathered by Lawrence Berkeley National Laboratory and geological data gathered by Old Dominion University and pump tests and modeling performed by Golder Associates. Bacterial transport experiments confirm the existence of a dependency of the bacterial adhesion upon pH as expected for sediment containing Fe, Mn and Al oxyhydroxides. Bacterial transport models were applied to the intact core results to test hypotheses regarding bacterial transport and fate and to develop model parameterizations that were incorporated into the 3-D hydrodynamic model of the aerobic flow cell. An intact core experiment was also performed that tested the various bacterial tracking methods to be utilized during the bacterial field transport experiment. The *Comamonas* strain was labeled with both ^{13}C and a viable protein stain (CFDA) and injected into an intact core under conditions designed to simulate the field injection. The bacterial breakthrough was monitored using plate counts and CFDA direct counts and plate reader measurements (Envirogen), by ferrographic separation and counting (Univ. of Utah), by stable isotope analyses, DAPI counts and quantitative PCR (University of Montana) and by PLFA analyses (University of Tennessee). The success of the various tracking methods will be presented along with other results from a simultaneous injection of Br and ^{13}C/CFDA labeled *Comamonas* into the aerobic flow cell.