Integrated Field, Laboratory, and Modeling Studies to Determine the Effects of Linked Microbial and Physical Spatial Heterogeneity on Engineered Vadose Zone Bioremediation

Project ID: 70165

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Research Objectives

The specific DOE problem being addressed is the large inventories of contaminants in deep vadose zones in the semiarid western U.S. and the ongoing contamination of the saturated zone by contaminants migrating through these deep vadose zones. In situ bioremediation of contaminants can offer advantages in cost, speed, public acceptance, and final cleanup levels achieved relative to physical removal methods. However, there are uncertainties regarding the feasibility of bioremediation of recalcitrant contaminants in deep vadose zones where microbial populations are low and discontinuous, and how hydrologic features of the vadose zone control microbiological processes. These uncertainties call into question the accuracy of predictions in vadose zone flow and transport models.

The overall objective of this research is to provide DOE with an increased understanding of the effect of interacting hydrologic and microbiological processes which control the feasibility of engineered bioremediation of chlorinated compounds in heterogeneous, microbially sparse deep vadose zones.

The specific project objectives are to:

(1) Determine the occurrence and distribution of denitrifiers and methanotrophs in the deep vadose zone at the DOE Hanford Site,
(2) Determine bioreactor kinetics for carbon tetrachloride removal in the presence of methane, nitrous oxide, and triethyl phosphate by denitrifiers (carbon tetrachloride to chloroform) and methanotrophs (chloroform to carbon dioxide) isolated from the field site,
(3) Determine the rate and extent of microbial colonization in response to gas-phase nutrient injection, and
(4) Use the above information to develop an improved vadose zone reactive transport model, and explore the level of site heterogeneity information that is needed for accurate premodeling of attenuation of vadose zone contaminant transport by engineered bioremediation.

Research Progress and Implications

This report summarizes work after 6 months of a 3-year project. Field samples are required to address specific objectives 1 and 2. Due to cost considerations, we must obtain samples from coring activities being conducted by other programs. We are working with DOE-Richland to identify opportunities to obtain vadose zone samples near and within the carbon tetrachloride- contaminated zone at the Hanford Site. The best near-term opportunity appears to be with the Innovative Treatment Remediation Demonstration (ITRD) program.

In recent discussions with DOE-Richland we discovered that injection of non-engineered microorganisms and aqueous-based nutrient delivery are potentially acceptable technologies at DOE sites. With this information and due to the delay in obtaining field samples, we have decided to pursue specific objective 3 using *Pseudomonas stutzeri* strain KC rather than isolates from the field site. Strain KC is capable of high rates of degradation and is the only known bacterium able to degrade carbon tetrachloride without production of chloroform. Studies are being planned to examine the ability of strain KC to colonize sediment (from a single inoculation point) as a function of varying (a) water-filled porosity, (b) pore throat size, (c) aqueous nutrient concentration, and (d) distance from a nutrient injection point.

The STOMP code (http://www.pnl.gov/etd/stomp) is the most highly developed vadose zone flow and transport model, but does not include biological processes. Building off of previous National Science Foundation funding to Dr. Selker, in specific objective 4 this project is modifying the STOMP code to include microbial reaction rate source/sink terms and cell attachment/detachment terms. Experimental work on validation of these new components of STOMP is ongoing. This research will provide DOE with a vadose zone flow and transport code that incorporates biological processes and couples hydrologic and biologic processes.

Planned Activities

Specific objectives 1 and 2: Continue to work with DOE to identify sampling opportunities and obtain pertinent field samples.

Specific objective 3: Studies have been initiated to examine the ability of strain KC to colonize vadose zone sediment (from a single inoculation point) as a function of varying (a) water-filled porosity, (b) pore throat size, (c) aqueous nutrient concentration, and (d) distance from a nutrient injection point (FY2000). Studies will be extended in FY2001 to examine colonization as a function of important vadose zone hydrological processes such as funnel flow along inclined textural interfaces.

Specific objective 4: Use experimental results from specific objective 3 to further develop and validate the biological component of STOMP.

Information Access

None to date (project is 6 months old)