Coupled Biogeochemical Processes for Evaluating TCE Cometabolism

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Two tasks within a larger project investigating cometabolism of trichloroethene (TCE) in aerobic groundwater have the objectives of detecting and quantifying cometabolic activity by assaying the responsible enzymes, and simulating TCE transport in groundwater using a realistic description of cometabolic kinetics. Here we focus on progress in the enzyme activity assessment. Chlorinated solvent plumes occur in complex geologic settings at numerous government and private sites across the country. One such site is Test Area North (TAN) at the Idaho National Lab, where a plume of groundwater contaminated with TCE extends about 3 km from a former waste disposal well and lies at a depth of about 60 to 120 m below ground surface in a fractured rock aquifer. Aerobic conditions in most of the plume inhibit anaerobic reductive dechlorination, but previous studies indicate that cometabolic degradation of TCE occurs at an environmentally significant rate. The goal of our study is to evaluate the activity of cometabolic organisms in this plume using multiple innovative technologies. Cometabolism by organisms that have either the soluble methane monooxygenase (sMMO) or toluene oxygenase enzyme was evaluated using a suite of enzyme activity probes, which indicate if a targeted enzyme is not only present but active in a microorganism. The number of cells likely to have cometabolic capability was measured using fluorescent in situ hybridization (FISH) and gene expression.

Native planktonic microorganisms from the Snake River Plain Aquifer (SRPA) were sampled from multiple wells in the medial zone of the TAN plume, where TCE concentrations currently range from 100-300 $\mu g\ L^{-1}$. Total cell abundance was similar at all wells sampled, $2.41 \pm 1.2 * 10^6$ cells per mL of groundwater. Polymerase chain reaction (PCR) for the mmoX of the sMMO gene and each of the toluene oxygenase genes resulted in positive amplifications in every groundwater sample assayed, clearly indicating that the indigeneous microbial community has the genetic potential to produce these enzymes. sMMO enzyme activity was variable, but the enzyme activity probe showed a significant response relative to controls at all wells evaluated. Toluene oxygenase activity determined by enzyme probes was also variable, with 5-20% of the total cells in any given groundwater sample having a positive response. FISH results for the sMMO enzyme supported the enzyme probe results, with higher percentages of active cells detected using FISH corresponding with higher enzyme activity probe results. These data provide direct evidence of the genetic potential for TCE cometabolism and that significant aerobic cometabolic activity is occurring in the medial zone of the TAN TCE plume. The results of these analyses suggest that MNA could be a viable remedial strategy for the medial zone. Future work will include characterization of attached microorganisms that colonized solid substrate in a medial zone well, and incorporating cometabolic kinetics into a flow and transport model for this plume.

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