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Predicting Long-term DNAPL Source Zone Response to Bioaugmentation using Mass-flux Measurements and Push-pull Tracer Tests

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Background/Objectives. Bioaugmentation in the short-term has been shown to be a promising remediation technology for the treatment of dense nonaqueous-phase liquids (DNAPL) source zones in unconsolidated materials. However, the long-term reliability of this technology has not been supported by proven data. Performance of these sites are generally assessed through long-term trends in traditional chemical and biological concentration data, which is semi-quantitative at best. Concentration data will often tend to underestimate the amount of contaminant present due to mass transfer limitation and cannot adequately describe spatial distribution of contaminants and microorganism present in aquifers. The purpose of this study is to assess the long-term performance of bioaugmentation at chlorinated solvent contaminated DNAPL source zones. Detailed site assessments have been conducted using push-pull tests and passive flux meter to assess contaminant mass present and spatial distribution within the subsurface. Integrating push-pull data with mass flux measurements allows for a quantitative approach to assess remediation performance through determination of site mass discharge, estimation of source mass balances, and tracking changes in mass with time. We believe this study is the first of its kind to assess the long-term effects of bioaugmentation on mass flux and NAPL present within a subsurface aquifer.

Approach/Activities. The PFM is a self-contained permeable unit sized to fit into a screened well such that groundwater flows horizontally through the unit. Sorbent material within the unit serves to intercept and retain both dissolved hydrophobic organic contaminants and microbial biomass in the groundwater flowing passively through the meter. The sorbent matrix is impregnated with known amounts of water soluble "resident tracers," which are leached at rates proportional to the groundwater flux. mPFMs are currently being deployed at chloroethene contaminated sites where bioaugmentation treatment of source zones ceased within the last two to five years. PFMs are being installed in wells located within and down gradient of the previously treated source zone. Wells selected have adequate pre-remedial contaminant and /or microbial water quality data available to link the measure post-remedial mass flux to a modeled mass flux for pre- and post-comparisons. The PFMs are deployed in wells for a period of approximately 21 days. Upon removal, PFMs are segmented vertically, as appropriate, to produce microbial and contaminant mass flux profiles. Push-pull tests were conducted at wells within the source zone to determine DNAPL saturation remaining in the source zone. Push-pull tests were conducted by injecting aqueous solution containing nonsorbing, nonpartitioning tracer and partitioning tracers into the monitoring wells located within the source zone. After a specific length of time, groundwater was then extracted and examined for tracers and contaminants of concern to determine amount of DNAPL remaining. The equilibrium stream tube model (EST) was used to estimate NAPL saturation and volume within the source zone.

Results/Lessons Learned. Long-term performance monitoring at this site, where DNAPL source-zone bioaugmentation was completed, suggests that source mass depletion by bioaugmentation can lead to a reduction in source strength, as measured by reduction in mass discharges and fluxes from the PFMs. Additionally, push-pull data suggests that bioaugmentation of source zones may result in a mixed NAPL.