High-Resolution Delineation of Chlorinated Solvent Concentrations, Biogeochemical Processes, and Microbial Communities in Saturated Subsurface Environments

Haley Schneider (haley.a.schneider@ttu.edu), W. Andrew Jackson (Texas Tech University, Lubbock, TX, USA), Paul B. Hatzinger and Paul Koster van Groos (APTIM, Lawrenceville, NJ, USA)

Background/Objectives. The primary objective of this SERDP research effort was to develop a high-resolution passive profiler (HRPP) to quantify and delineate the distribution of chlorinated solvents, hydrogeologic conditions, geochemistry, and microbial community activity at fine scale within a complex layered aquifer. In particular, focus was placed on discerning differences in contaminant distribution and fate between low permeability and high permeability zones within stratified or heterogeneous media. Groundwater profilers are not a new concept in site remediation studies, but no design up to this point combines concentration data with microbial numbers and types, groundwater and contaminant flux, and contaminant degradation at centimeter scale resolution. The HRPP is intended for direct push insertion into an aquifer, which is more cost effective than traditional methods requiring the installation of groundwater wells. We combine laboratory studies with two field evaluations to demonstrate this technology.

Approach/Activities. The prediction of chlorinated solvent fate and transport in aquifers is often limited by flow field heterogeneity, uncertain contaminant distribution, and an inability to accurately quantify relevant biotic and abiotic reactions. Processes occurring in low permeability zones are particularly important because contaminants residing in such materials can sustain groundwater plumes. Groundwater in traditional monitoring wells is typically mixed across layers and derived largely from higher conductivity zones, making it difficult to distinguish and predict properties in low permeability soil layers in an aquifer. Therefore, we have developed a tool that yields high resolution vertical aquifer profile data regardless of soil permeability. The HRPP is designed to determine contaminant concentration and flux, groundwater velocity, microbial community structure, and, based on compound specific isotope analysis (CSIA), the potential for abiotic/biotic contaminant degradation in situ at the centimeter scale. The following key components have been accomplished: (1) designing an HRPP that has been inserted via direct push at a total depth of at least 15 meters in an aquifer; (2) testing the strength of the HRPP and membrane to determine limits of insertion depth and method; (3) incorporating solid media that has proven effective in adsorbing contaminants for CSIA analysis and promoting bacterial attachment and growth to evaluate microbial communities at centimeter intervals; (4) using conservative tracers to determine hydraulic and contaminant fluxes.

Results/Lessons Learned. We have successfully correlated measured mass transfer coefficients with groundwater velocity in laboratory flow cells and validated these correlations in two field trials (a military site in New Jersey and a US Navy site in California). The HRPP was successfully direct push inserted up to 8 meters BGS, with one HRPP having a sample length of up to 3.6 meters. At the two different sites, which were both characterized by highly stratified aquifers, the HRPPs were able to produce chlorinated solvent concentration profiles and geochemical indicators (PO_4^{3-}, SO_4^{2-}, Cl^-) at high resolution (~1 sample/10 cm). Microbial communities involved in reductive dechlorination were observed to vary appreciably over depth and are compared with well water and Bio-traps in wells. Geochemical indicators and VOC concentrations were evaluated using MIP/HPT, soil cores, well water samples, and Bio-traps in wells. Comparative velocity measurements were taken using passive flux meters in wells.