

A Field Method to Quantify Chlorinated Solvent Diffusion, Retardation, and Degradation Coefficients in Fractured Sedimentary Rock

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Background/Objectives. Contaminants retained in a fractured rock matrix are released to permeable pathways by desorption and back diffusion and can sustain elevated contaminant concentrations in mobile groundwater. The rates or magnitudes of retardation (by sorption), diffusive transport, abiotic and/or biotic degradation reactions exert a strong control on long term contaminant fate. Knowledge of the rates of both diffusion and biogeochemical transformation are crucial for accurate predictive modeling that leads to effective site management, including the ability to make decisions among remedial options. General scientific knowledge about attenuation processes, and their importance to the long term contaminant plume behavior is well established; however, field methods that simultaneously quantify these co-occurring processes in the low permeability matrix of a fractured rock system are lacking.

The objective of this project is to develop and test a field method capable of concurrently quantifying site specific trichloroethylene (TCE) diffusion and degradation rates and sorption coefficients in the low permeability matrix of a fractured sedimentary rock. The project is a collaboration between the University at Buffalo and US Geological Survey (USGS) scientists. The field tests were completed at the USGS Toxic Substances Hydrology Programs' Fractured-Rock Research Site in West Trenton, New Jersey.

Approach/Activities. We conducted the tests in existing boreholes with several years long record of the concentrations of TCE and its degradation products (DPs). The tests were carried out in low-permeability mudstone strata isolated using two packers. We replaced the fluid in the packed-off test interval with tracer amended groundwater from which the TCE and DPs were removed (i.e., VOC-free groundwater) and tracers were added. We monitored the concentrations of TCE, DPs, and tracers over time. Bromide was the conservative tracer and trichlorofluoroethene (TCFE) was a reactive tracer. The TCFE was selected as the reactive tracer because it degrades and sorbs similarly to TCE.

Results/Lessons Learned. The field test results showed quantifiable increases in TCE and DP concentrations, and decreases in the added tracer concentrations, over days to weeks of monitoring. Inverse modeling of the bromide concentration yielded an estimate of the formation factor. Additionally, inverse modeling was used to estimate sorption coefficients and degradation rate coefficients that best described TCE and TCFE behavior. A test with extended duration of several months was used to evaluate the effect of a short term (e.g. 4 weeks) test on parameters extracted. The results from field tests in two boreholes with contrasting initial TCE:DP concentration ratios and lithologic units are presented. Supporting laboratory experiments were completed in order to use the TCFE results to constrain the inverse modeling. We anticipate that the site specific parameters for the low permeability matrix produced from this type of test can be used to improve remedy selection in fractured sedimentary rocks contaminated with TCE.