

Method Development for Long-Term Laboratory Studies Evaluating Contaminant Assimilation Processes in Low-k Zones

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Abstract. Remediation technologies for soil and groundwater impacted by chlorinated solvents often have limited effectiveness in reducing contaminant concentrations. After remediation treatment many impacted field sites continue to measure for chlorinated solvents above the maximum contaminant levels (MCLs) established by the US Environmental Protection Agency (EPA), due in part, to contaminants back-diffusing from low-permeability (k) zones. This back-diffusion causes long-term impacts on water quality. Due to the persistence of chlorinated solvents and back-diffusion from low-k zones, additional research is necessary to better understand the fate and transport of chlorinated solvents within these zones. Assimilation processes in low-k zones, which include sorption and degradation, are poorly understood but can potentially play a significant role in reducing the longevity and persistence of contaminant plumes. Assimilation processes within low-k zones have been observed in field sites, but the inability to account for all contaminant mass causes many uncertainties with quantification of the observed data. Our hypothesis is that long-term laboratory studies (~5-10 years) with mathematical models are necessary to fully capture assimilation processes within low-k zones that could be consequential over extended time periods. Prior to conducting long-term laboratory experiments, methods need to be developed and tested through short-term laboratory studies. For the research presented herein, short-term diffusion reactor studies (~2 months) were conducted to test initial aquifer conditions, develop sampling methods, establish base line data, and input results into the mathematical model to determine parameter values. The model contaminant used throughout all laboratory experiments was tetrachloroethylene (PCE). Diffusion reactor vessels (DRVs) were used to evaluate assimilation processes under the condition of zero initial-concentration throughout the soil column with a PCE-saturated boundary condition at the bottom of the soil column. A headspace sampling method was developed to allow for non-destructive sampling events to capture the fate and transport of contaminant throughout the soil-column. The experimental matrix included a control of inert (i.e., non-reactive and non-sorptive) laboratory-media soil columns at three soil-column lengths (3 cm, 6 cm, and 11.5 cm) and four field soil-columns with a length of 6 cm. At day 42 of the DRV experiment, samples showed PCE breakthrough at the top of the soil-column ranging from 1.4% to 53% of breakthrough, relative to the breakthrough of PCE for the control soil-columns. The reduced diffusive transport flux across field soils is likely due to sorption or degradation. No degradation products were detected, indicating that the reduced transport rate is probably due to sorption. In addition to the DRV experiment, batch studies were conducted to support modeling of reaction and sorption processes. Batch sorption studies consisted of vials set up aerobically and autoclaved to limit microbial degradation. Measurable sorption occurred in three of the four field-soil specimens. A Freundlich isotherm was found to adequately model contaminant sorption behavior. This result will support mathematical modeling of the DRV experiments. Results of the short-term column and batch reactor studies will be used to aid in the design of the long-term studies. The laboratory experiments and modeling described herein will advance the knowledge of the importance of assimilative processes and assist in determining the assimilative capacity of low-k zones. Ultimately, this work will contribute to improved decision-making at contaminated sites, possibly allowing money spent on ineffective remedies to be redirected toward more productive solutions.