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Enhanced Biotic and Abiotic Attenuation of TCE in Fractured Sandstone

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Background/Objectives. A fractured sandstone aquifer in southern California is contaminated with trichloroethene (TCE) to depths in excess of 244 m. Field data indicate that TCE is undergoing reduction to *cis*-1,2-dichloroethene (cDCE). Laboratory microcosms prepared with crushed rock and groundwater confirmed the occurrence of abiotic and biotic transformation in unamended treatments. Amendment with lactate stimulated complete biotic reductive dechlorination to ethene, indicating the presence of indigenous *Dehalococcoides*. As promising as these results may be, the applicability to *in situ* conditions may be questioned on the grounds that crushing the rock disturbs its structure, hydrogeology and heterogeneity. The objective of this study was to construct and evaluate a novel type of intact rock core microcosm that more accurately simulates the conditions in the fractured sandstone aquifer, and by extension has applicability to evaluating remediation in other low permeability environments.

Approach/Activities. Intact rock core microcosms were designed to mimic *in situ* conditions in the fractured sandstone aquifer. Each microcosm consisted of a sandstone core (3" long, 2.375" diameter) sandwiched between stainless steel end caps of the same diameter. One of the caps was hollowed out to create a reservoir to simulate a fracture with groundwater flow. The core and end caps were encased in a heat-shrinkable Teflon sleeve. Site groundwater amended with approximately 20 mg/L of TCE, 1 mM bromide (conservative tracer) and resazurin (redox indicator) was forced through the rock under pressure. The core and end caps were then slid into a stainless steel pipe and the ends of the pipe were welded shut to create a leak-tight seal. The end caps with the hollowed out portion were filled with groundwater containing no TCE or bromide, and fitted with two Mininert® sampling valves. Once per week, 2 mL of groundwater was injected through one valve and the displaced groundwater was collected from the other for analysis. Six of the microcosms received groundwater amended with lactate; the other set received unamended groundwater.

Results/Lessons Learned. The cores were operated for over 20 months. Addition of lactate to groundwater flowing over the simulated fracture created low redox conditions and stimulated sulfate reduction. Reductive dechlorination of TCE to cDCE was completed in five of the lactate-amended microcosms and one of the unamended microcosms. However, no further reduction to VC or ethene occurred. A higher percentage of the mass of TCE initially present in the cores was recovered in the lactate amended microcosms, likely due to the lower extent of adsorption of cDCE and a higher diffusion rate. The occurrence of transformation processes other than reductive dechlorination was confirmed based on up to 5‰ enrichment of δ^{13}C-TCE in microcosms where TCE did not undergo reductive dechlorination, and up to 4‰ enrichment of δ^{13}C-cDCE in ones where TCE was reduced to cDCE. A 2D model was developed with COMSOL utilizing Monod and first-order kinetics, Fick's law of diffusion, kinetic isotope effects, and other processes. The model was calibrated with the bromide data and agrees well with the measured concentrations of VOCs and changes in δ^{13}C. Results with the intact core microcosms were consistent with those obtained from crushed rock microcosms with respect to transformation of TCE and cDCE via pathways other than reductive dechlorination. The rates of transformation determined in the rock core microcosms will be used in site-wide models to predict plume stability.