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Bioaugmentation of DNAPL in Fractured Bedrock and Low Permeability Soil

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Background/Objectives. Tetrachloroethene (PCE) dense non-aqueous phase liquid (DNAPL) was detected in the overburden, and PCE had migrated into fractured bedrock at a site located in New Jersey. Between August 2014 and June 2016, an interim remedy was implemented using bioaugmentation with SDC-9 and emulsified vegetable oil (EVO) at the site. The objective of this project was to reduce the source mass and contaminant mass flux.

Approach/Activities. The field injection was conducted between October and November 2014, and four performance monitoring events were completed during 1.5 years. The challenges for the bioaugmentation were due to the complex geologies and elevated contaminant concentration. The PCE concentration at the source area was up to 110 milligrams per liter (mg/L) during the baseline event. The most elevated PCE concentration was detected in the overburden/weathered bedrock, which consists of glacial till with low permeability. An injection strategy using high location density and low volume per location enabled the delivery of the mixture of EVO and SDC-9 to the target source area. Furthermore, two customized EVO products with different droplet sizes were injected into the low permeability overburden and highly fractured bedrock.

Results/Lessons Learned. The results showed that bioaugmentation can be a viable technology for source and bedrock treatment, and the customized EVO products assisted in overcoming low permeability or fast groundwater flow. Bioaugmentation of DNAPL can be significantly longer. At the source area, the co-solvent effect from EVO induced a transitory increase of total PCE and TCE concentration up to 1,400 mg/L, which then decreased over 99.4% in one year. Meanwhile, the daughter products, especially cis-1,2-DCE, although decreased 50% from its peak level, is still significantly higher than baseline levels. In contrast, at areas where the baseline concentrations were at several mg/L, total chlorinated solvents were reduced 99% to just several micrograms per liter (ug/L) in one year. Reductive dechlorination and co-metabolic pathways contributed to DNAPL reduction. The presence of DNAPL significantly impacted the proliferation of *Dehalococcoides* spp, (DHC), suggested by DHC concentrations at areas with either moderate contaminant levels or with DNAPL presence. The DNAPL area had more total population and more diverse microbial community than the areas where contaminants were reduced to near detection limits. Although elevated sulfate and methane were detected at the DNAPL area, sulfate reducers and methanogens had continuously decreased to below detection limits while methanotroph concentrations had been elevated. The microbial results suggest that co-metabolic microbes may be more resistant to the elevated contaminants than DHC. The degrees of fracture significantly impact groundwater flux, thereby resulting in various EVO longevities. Furthermore, geochemical changes in bedrock prevent reducing contaminant levels to below detection limits. The customized large-droplet EVO had lasted 1.5 years but its end concentrations vary depending on the degree of fracture. For wells located on the groundwater flow path from injection wells, bioaugmentation resulted in significant reduction of all chlorinated solvents, and a biofilm was observed in bedrock wells 60 feet away from the closest injection well. However, the bioaugmentation effectiveness disappeared when contaminant concentrations reached very low levels (less than

20 ug/L). Meanwhile, iron concentrations continuously increased, suggesting that iron-reduction could consume organic carbon in the fractured bedrock.