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Source Area Bioaugmentation of Multiple Chlorinated VOCs in Overburden and Bedrock Aquifers

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Background/Objective: This bioaugmentation pilot study was performed as part of a remedial design effort to address dissolved trichloroethene (TCE), 1,1-dichloroethene (1,1-DCE) and carbon tetrachloride (CT) in the source area of a 132-acre commingled VOC plume. The plume in overburden and fractured bedrock extends through a mostly residential area located in the Newark Basin of the Piedmont Physiographic Province of Northern New Jersey. The objective of this bioaugmentation pilot study was to reduce the source mass and contaminant mass-flux and demonstrate the effectiveness of bioaugmentation as a potential remedy scalable to larger areas.

Approach/Activities. This pilot study follows a high-resolution fluorescent tracer dye 3-D mapping of the bedrock fracture network. In November 2015, pilot study injections were implemented with SDC-9 and customized emulsified vegetable oil (EVO) into overburden via DPT and bedrock via injection wells at the site. The challenges of bedrock bioaugmentation are the lack of naturally-occurring bacteria, the vertical extent of contaminant and the variable groundwater velocities (up to 10 feet per day). Using hydraulic conductivity data generated during the fluorescent tracer dye study, customized EVO products with appropriate droplet sizes were selected for the bioaugmentation injections. A total of 8,500 gallons of emulsion was injected into the bedrock for this pilot study. Additionally, the overburden injection of small droplet EVO was completed with seven DPT injection points. Five performance monitoring events were completed in the years following the bedrock injections.

Results/Lessons Learned. Bioaugmentation achieved the remedial goals at the overburden area. The most significant reduction was observed in the bedrock injection wells and adjacent bedrock well. Carbon tetrachloride (CT) showed more rapid and complete reduction than chlorinated ethenes. The lessons learned from the pilot study are:

- The bioaugmentation impact followed the groundwater flow paths, which were demonstrated by the 3-D tracer test. Bedrock monitoring wells could be located near one injection well, but was actually impacted by the further injection well.
- Due to the lack of well density, the effective reduction of contaminants was not yet observed beyond 50 feet from the injection well. However, change of the geochemical conditions was noticed in the 300 feet away from the injection well during the last monitoring event.
- The bedrock demonstrated poor buffer capacity. Instant increase of pH to 12 was observed during the injection while pH was decreased to 2 after one year. The elevated iron and viscous iron-containing deposits were observed in the monitoring wells.
- The microbial analysis identified that *Dehalococcoides* (DHC) was significantly less than Dehalobacter (DHB). The more optimal results of CT degradation could be the results in microbial concentration. The well with more rapid groundwater flow showed less microbial population and diversity.

Effective bioremediation was observed near the injection wells. However, the decrease of pH and excessive iron production suggest the need for optimization. The next step is bench-scale

study to test sulfate in conjunction with EVO to inhibit iron production and pH decrease during bioaugmentation.