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Concurrent Application of Biological and Chemical Reduction Technologies to Treat DNAPLs in Groundwater: An Update

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Background/Objectives. This presentation provides the results of a full scale application of a combination of treatment technologies that was applied to address the challenges of achieving cleanup goals in a low permeability, heterogeneous formation with numerous subsurface obstructions in close proximity to a surface water body. To facilitate site reuse, expedited remedial implementation and site cleanup was a major driver for the project. The implemented technologies included 1) in situ chemical reduction (ISCR), 2) enhanced reductive dechlorination (ERD) with bioaugmentation and 3) a zero valent iron (ZVI) permeable reactive barrier (PRB). Contaminants consisted primarily of volatile organic compounds (VOCs), including tetrachloroethene (PCE), trichloroethene (TCE), cis-1,2-dichloroethene (cis-1,2-DCE) and vinyl chloride (VC) at total concentrations ranging from approximately 1 to 200 milligrams per liter (mg/L). VOC concentrations are indicative of the presence of dense, non-aqueous phase liquids (DNAPLs); the maximum concentration of PCE in groundwater approached the solubility limit. Additionally, hexavalent chromium was collocated with VOCs in some areas. The overall remedial strategy for the site was to treat VOCs hot spots or areas close to surface water with ISCR and ERD, prevent the discharge of chlorinated ethenes to surface water with a PRB, and to apply monitored natural attenuation (MNA) wherever VOC concentrations were less than ten times the final cleanup goals.

Approach/Activities. The PRB was installed by excavating a trench with a biopolymer slurry around several buried utilities. The trench was backfilled with a mixture of sand and ZVI. The PRB was positioned as close as possible to the surface water body at one end of the treatment zone. After the PRB was installed, ISCR injection and the first ERD injection occurred approximately 1 month apart. Additional ERD injections occurred approximately 7 and 18 months after the initial injection. The combination of ISCR and ERD technologies were applied together in the same treatment zone in order to minimize the temporary accumulation of catabolites, such as VC. ISCR was applied via direct push technology using a mixture of ZVI and a solid, plant-based material (EHC). ERD was applied using a combination of powdered cheese whey, nutrients and a base for pH control. ERD was applied using injection wells and extraction wells to create temporary groundwater circulation within the treatment zone. Groundwater samples from monitoring wells were analyzed for VOCs, geochemical indicators and microbial indicators.

Results/Lessons Learned. The combination of ISCR and ERD reduced the mass of chlorinated ethenes in the source zone by approximately 50 percent two months after the ISCR and first ERD injection events. The mass of chlorinated ethenes in the source zone has been reduced by greater than 80 percent after the ISCR and three ERD injection events. Four years after the last ERD injection event, the maximum concentration of PCE, the predominant VOC at the site, has been reduced from 137,000 µg/L to 75 µg/L and the remedial action goals have been achieved at all but two locations where the PCE/TCE daughter products, cis-1,2-DCE and VC are still above cleanup goals. Results will be presented to indicate the extent of the treatment zone and the usefulness of different geochemical indicators for treatment optimization and evaluating treatment effectiveness. Overall, the combined application of ISCR, ERD and a PRB has been successful in treating DNAPL and chlorinated ethenes in groundwater.