Innovative and Sustainable Fractured Bedrock Remediation via a Surfactant-Enhanced Aquifer Remediation Approach

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Background/Objectives. An active manufacturing facility located in southeastern US has operated over 40 years producing razor blades. These historical operations resulted in the release of hazardous waste streams from TCE still bottoms, TCE-contaminated solids, and facility-related oil waste. In addition to storage and use of TCE-containing solvents, the facility experienced multiple unintentional TCE releases which resulted in groundwater contamination at the site. After a series of phased investigations were conducted to assess the groundwater impacts near the source area, a remediation plan was developed which included the operation of a pump and treat system to limit plume migration. This system, still operational after 25 years, provided little to no significant mass removal. In 2012, the site moved into the state's Voluntary Remediation Program, and the 30-acre site was assessed in its entirety. This assessment revealed the presence of multiple plumes of dissolved phase constituents as well as the subsurface presence of both DNAPL and LNAPL. Because DNAPL is present at multiple locations within a fractured bedrock geology, a pilot test was designed to modify DNAPL density, and increase interfacial tension through surfactant flushing thereby increasing removal efficiencies. In addition, the client was in favor of developing a sustainable approach given the presence of potential receptors.

Approach/Activities. A customized pilot test was developed to evaluate the feasibility and effectiveness of surfactant enhanced aquifer remediation (SEAR) approach for removal of DNAPL in bedrock. Pilot testing was further complicated by cross-bed communication between the shallow saprolitic water bearing zone and the deep fractured bedrock which resulted in vertical movement of contaminants between stratigraphy. A site-specific treatability study was conducted to develop an optimal co-solvent/surfactant mixture that both lowered the DNAPL density and ultra-reduced its water-NAPL interfacial tension, a pre-requisite to allow it to flow horizontally under an induced hydraulic gradient. The SEAR approach thus involved the injection of a soybean oil-based co-solvent and an optimized surfactant mixture. The site-specific formulation, branded as TASK™, was selected based on its ability to minimize the risk of NAPL vertical migration while maximizing its mobility. Careful consideration was given to avoid unnecessary movement of DNAPL beyond the treatment area given the complex nature of the bedrock formation.

Results/Lessons Learned. The pilot test results suggest that the SEAR remedial approach was effective in extracting DNAPL from the surficial and bedrock aquifers. The pilot test also indicated that there was high TCE DNAPL recovery, and that the co-solvent/surfactant formulation was effective in capturing DNAPL and mobilizing it horizontally towards the recovery well. A tracer test also proved that the outside-in wellfield configuration offered adequate injectate capture and hydraulic control. Overall, the technology indicated: (1) microemulsions necessary to easily remove DNAPL were formed with low surfactant concentrations, (2) that a single-stage injection system designed for use with SEAR eliminated the need for multiple injection steps; and (3) a green and sustainable technology that minimized toxicity to both human and environmental receptors was possible. This data also suggests that anaerobic bioremediation was induced where residual methyl soyate, used in the surfactant formulation, was present further reducing TCE concentrations.