Sulfate Delivery Using Permeable Filled Borings for Hydrocarbon Biodegradation

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Background/Objectives. Dissolved benzene concentrations exceeded the 1 mg/L cleanup goal in groundwater at a former service station and remediation was required. UC Davis conducted laboratory microcosm studies using Site sediments. The microcosm results demonstrated benzene biodegradation only if sulfate was added. Sulfate was depleted in the plume core, suggesting it could be limiting benzene biodegradation. At these types of sites, sulfate addition is a potential remedial technology to enhance biodegradation.

Approach/Activities. Permeable filled borings (PFBs) were installed at the Site using a hollow stem auger and backfilled with a mix of gypsum ($CaSO_4 \cdot 2H_2O$) and gravel (crushed rhyolite). A total of 24 PFBs, 9.1-inch diameter at depths of 20 to 56 feet, consisted of 15,000 pounds of gypsum containing 8,400 pounds of sulfate. Lab tests suggested the steady release of approximately 1450 mg/L sulfate from slow gypsum dissolution. The estimated lifetime of the PFBs is approximately 8 years for steady groundwater flow. Concurrently, nine high pressure injections (HPIs) of gypsum slurry were conducted in other site locations (312 pounds of gypsum total).

Following the installation of PFBs in September/October 2015, quarterly groundwater sampling was conducted, including diagnostic tools to demonstrate benzene biodegradation. The diagnostic tools include sulfate, carbon and hydrogen isotopes for benzene, sulfur isotopes for sulfate, and other indicators.

Results/Lessons Learned. Over 3 years, sulfate release from PFBs contributed to declining benzene concentrations; two wells dropped below the cleanup goal and sulfate in one well exceeded 500 mg/L for the most recent 18 months. The other two wells near PFBs had modest changes in benzene, presumably due to greater residual nonaqueous phase liquid in adjacent sediments and greater sulfate demand. Hydrogen and sulfur isotopic enrichment in benzene and sulfate, respectively, confirmed biodegradation of benzene and stimulation of sulfate-reducing conditions, so we hypothesize that more time will reduce local source mass and eventually benzene below goals. Benzene in monitoring wells near HPIs was below the cleanup goal for all but a few sampling events before and after HPI installation, and there was no stimulation of sulfate-reducing conditions. At this site, sulfate delivery through PFBs supported more demonstrable benzene remediation than did the equally time-consuming installation of HPIs. The diagnostic tools are useful to evaluate the effectiveness of PFBs. Sulfate delivery through PFBs is a cost-effective alternative to other engineered remediation technologies.