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Sulfate Delivery Using Permeable-Filled Borings to Enhance Petroleum Hydrocarbon Biodegradation

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Background/Objectives. Dissolved benzene concentrations can persist at concentrations above 1 mg/L in groundwater at UST release sites, exceeding regulatory action levels. At some of these sites, toluene, ethylbenzene, and xylene (TEX) concentrations are well below 1 mg/L and do not require remediation. There is evidence for sulfate-reducing conditions contributing to TEX concentration reductions at many of these sites. Sulfate is often 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.

Benzene concentrations exceeded 1 mg/L at a former service station in northern California ("Site") and remediation was required to reduce benzene below 1 mg/L. Site TEX concentrations have for years been below 1 mg/L. UC Davis conducted laboratory microcosm studies using Site sediments and groundwater. The microcosm results demonstrated benzene biodegradation under sulfate-reducing conditions, but no degradation was noted under methanogenic conditions.

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-inch diameter at depths of 20 to 56 feet, consist of 15,000 pounds of gypsum containing 8,400 pounds of sulfate. Lab tests suggest the steady release of approximately 1450 mg/L sulfate from slow gypsum dissolution. The estimated lifetime of the PFBs is 7 to9 years for steady groundwater flow.

Following the installation of PFBs in September/October 2015, quarterly groundwater sampling has been 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. Four monitoring wells located in the vicinity of PFBs are used to evaluate remediation effectiveness. Six sampling events, 18 months following PFB installations, provide evidence for sulfate addition contributing to declining benzene concentrations. Two of the monitoring wells have significant benzene reductions; in one of those wells sulfate concentrations are as high as 644 mg/L. Hydrogen isotopic enrichment in each of the four monitoring wells suggests biodegradation of benzene. ^{34}S in sulfate is enriched in these monitoring wells, evidence for sulfate addition stimulating sulfate reducing conditions. These diagnostic tools are useful to evaluate the effectiveness of PFBs.

Sulfate delivery through PFBs is a potential cost-effective alternative to other engineered remediation technologies. UC Davis is also evaluating other delivery strategies using gypsum as a sulfate source.