Colloidal Zero-Valent Iron Injection for Enhanced Biotic/Abiotic Degradation of a TCE DNAPL Source

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Background/Objectives. Full-scale bioremediation of a trichloroethene (TCE) source zone and plume began in 2005 beneath an active manufacturing building near Portland, Oregon using food-grade vegetable oil (VO). Remediation targets a 4,000-square-foot source zone beneath a former vapor degreaser and a 12-acre downgradient plume. Dense non-aqueous phase liquid (DNAPL) was observed during drilling and subsequent groundwater monitoring; the maximum baseline TCE concentration in groundwater (1,170,000 µg/L) exceeded the TCE solubility limit. Five source zone injections of high-concentration VO emulsion were successful at treating the downgradient plume and reducing TCE mass in the source, however, TCE concentrations remained high in the source. The fifth injection in 2014 also contained ferrous sulfate to stimulate abiotic degradation as a complementary degradation pathway to biological reductive dechlorination. For the sixth injection in 2018, colloidal zero-valent iron (cZVI) was injected with VO at the highest concentration source zone wells to further stimulate abiotic degradation.

Approach/Activities. Biological and abiotic reactions can reduce TCE to non-toxic end products. The biodegradation of TCE is enhanced by injection of fermentable substrates. The microbial process of reductive dechlorination utilizes volatile fatty acids and hydrogen produced by fermenting organisms to transform TCE to breakdown products *cis*-1,2-dichloroethene (cDCE) and vinyl chloride (VC) and to end products ethene and ethane (E+E). ZVI stimulates abiotic reduction of TCE and cDCE primarily through β-elimination, producing chloroacetylene and acetylene, which are further reduced to E+E. Detection of acetylene in groundwater samples is a clear indicator of abiotic TCE reduction, however, acetylene is highly reactive and short lived and is rarely detected even where conditions are optimal for β-elimination to occur.

For the 2018 injection in the TCE source zone, approximately 53,000 gallons of VO emulsion and nutrients were injected at 16 injection wells located on 10- to 20-foot centers. A liquid cZVI product (110 gallons) was injected with the VO emulsion at the five highest concentration source zone wells where dissolution and desorption continued to be dominant over biodegradation.

Results/Lessons Learned. The cZVI injection has enhanced TCE mass destruction through β-elimination. Within 4 months of cZVI injection, TCE concentrations at all source zone wells were reduced to below 100,000 µg/L for the first time since treatment began and total chlorinated ethenes for source wells (molar sum) were at an all-time low. TCE at the five cZVI-injected wells decreased by 43 to 81 percent. By 28 months post-injection, partial to complete TCE rebound occurred at two of the five cZVI-injected wells, indicating a need for follow-up treatment. Acetylene detections are definitive proof of enhanced β-elimination at the site. Acetylene was detected as high as 300 µg/L at source wells. Acetylene at the cZVI-injected wells increased by four to 33 times compared to prior detections.

Effective treatment continues downgradient of the source zone, with E+E dominant on a molar basis over chlorinated ethenes at nearly all wells beyond the source.