

Formulating and Comparing Carbon Substrates with Bioaugmentation for Full-Scale In Situ Bioremediation of Chlorinated Solvents

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Background/Objectives. The purpose of the in situ bioremediation (ISB) system was to promote reductive dechlorination of chlorinated ethenes in groundwater via biostimulation in combination with bioaugmentation in the source areas. There are elevated concentrations of various chlorinated volatile organic compounds (cVOCs): tetrachloroethene (PCE), trichloroethene (TCE), and cis-1,2-dichloroethene (cis-1,2-DCE) in site groundwater. Both quick- and slow-release carbon substrates were evaluated at the full-scale level.

Approach/Activities. A series of injection wells was installed in three areas to address the higher concentrations of cVOCs. During the past few years the injection amendments have included: Phase 1, biostimulation using a quick-release carbon substrate (e.g. CarBstrate™), and Phase 2, a slow-release carbon substrate, emulsified oil, and bioaugmentation with a *Dehalococcoides* microbial consortium. A bromide tracer study was also performed to evaluate the radius of influence of the injected amendments. A monitoring program was developed to evaluate the effectiveness of the treatment system.

Results/Lessons Learned. During the first phase of the ISB program, the quick release carbon substrate promoted anaerobic conditions around the injection wells; however, the anaerobic conditions were not sustained for an extended time period as the organic carbon source was quickly utilized. Groundwater monitoring indicated that after the CarBstrate™ had been injected into the groundwater, the dissolved oxygen (DO) and oxidation reduction potential (ORP) rapidly decreased; however, the DO and ORP significantly increased in several of the downgradient monitoring wells within less than a year. As the carbon substrate initially promoted conditions conducive to reductive dechlorination, there was a significant increase in cis-1,2-DCE in many of the downgradient wells. However, ethene levels were not elevated in the wells, indicating that complete reductive dechlorination was not occurring in these areas. The second phase of the ISB program involved evaluating the use of a slow release carbon substrate (e.g., EOS PRO) and bioaugmenting with a *Dehalococcoides* microbial population.

This presentation will discuss the groundwater geochemistry including the competing electron acceptors (oxygen, nitrate, iron and sulfate), cVOCs, total organic carbon, volatile fatty acids and microbial parameters (key microbe *Dehalococcoides* and genes: TCE and VC reductases) and their impact on reductive dechlorination of site cVOCs during Phase 1 and 2 ISB programs. The bromide study indicated that there was a greater radius of influence of the amendments in some areas of the plume, which indicated the heterogeneity of the site groundwater. The Phase 2 results demonstrated that the slow release carbon substrate promoted a significant reduction in DO and ORP and competing electron acceptors, which correlated with a reduction in site cVOCs in a majority of the site monitoring wells. This paper will also discuss the advantages and disadvantages of the various carbon substrates and in situ bioremediation distribution approaches.