# In Situ Bioremediation of Chlorinated Ethenes in Heterogeneous Glacial Till

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**Background/Objectives.** The purpose of the in situ bioremediation (ISB) system was to promote biodegradation of chlorinated ethenes in groundwater via biostimulation in the source area. The groundwater has displayed elevated concentrations (> 1 milligram per liter) of total chlorinated volatile organic compounds (cVOCs) including: tetrachloroethene (PCE), trichloroethene (TCE), cis-1,2-dichloroethene (cis-1,2-DCE), and 1,1-dichloroethene. Shallow groundwater at the Site occurs under unconfined conditions and is encountered at a depth range of 26 to 30 feet below ground surface (bgs).

The site is underlain by basal glacial till composed primarily of silt, gravel, and cobbles, with relatively little sand and clay. It is dense and compacted, with generally very low permeability typical of basal till. A conspicuous cobble zone is present over most of the site at depths of approximately 15 to 30 feet bgs. A relatively thin but significant layer of silty coarse sand and gravel was identified at a depth between 40 to 49 feet in the general vicinity of the source area. This thin zone provided an important control for limiting the vertical spread of contamination and was targeted by permanent injection wells for amendment distribution.

**Approach/Activities.** A series of injection were performed in four different locations of the site, which showed elevated cVOC concentrations. Available monitoring wells were used to inject carbon sources and microbial consortium into the groundwater. The injection amendments included: biostimulation with quick release carbon substrate and an emulsified oil substrate, EOS Pro to sustain the microbial population for an extended time period and support reductive dechlorination. A monitoring program was developed to evaluate the effectiveness of the treatment system, which included field parameters, cVOCs, geochemical parameters and key microbial populations and genes.

**Results/Lessons Learned**: Within less than 9 months after injecting the carbon substrates, there was a one to three order of magnitude increase in total organic carbon (TOC) in downgradient monitoring wells, which corresponded to a decrease in oxidation reduction potential (ORP) to as low as -101 millivolts. As the EOS was degraded there was a significant increase in acetone and 2-butanone, which was probably produced during anaerobic fermentation processes. There was also an increase in dissolved iron and manganese in some downgradient monitoring wells. During this time period, there was up to a 97% reduction in PCE, a 99% reduction in TCE and an 85% reduction in cis-1,2-DCE in downgradient wells.

The groundwater geochemistry indicated that competing electron acceptors (oxygen, nitrate, iron and sulfate) were sufficiently reduced to develop conditions that would be conducive to reductive dechlorination. This was demonstrated by significant decreases in concentrations of PCE, TCE and cis-1,2-DCE in downgradient wells post-biostimulation and bioaugmentation. This presentation will discuss the varying hydrogeologic, geochemical and microbiological conditions of the site groundwater and how these challenges were addressed to maximize biodegradation of the chlorinated ethenes in groundwater.