How Effective are Biostimulation and Bioaugmentation for Chlorinated Ethenes in the Source Zone?

Laurie LaPat-Polasko (llapat@ramboll.com) (Ramboll, Phoenix, AZ, USA)
Ben Kutz and Ted McMahan (Penn E & R)

Background/Objectives. The purpose of the in situ bioremediation system was to promote biodegradation of chlorinated ethenes in groundwater via biostimulation in combination with bioaugmentation. The groundwater contains elevated concentrations (>10 milligrams per liter) of the following chlorinated volatile organic compounds (cVOCs): tetrachloroethene (PCE), trichloroethene (TCE), cis-1,2-dichloroethene (cis-1,2-DCE), and 1,1-dichloroethene. Elevated levels of 1,4-dioxane have also been observed in some areas of the site. An in situ microcosm evaluation using Bio-Traps demonstrated that the combination of biostimulation and bioaugmentation showed the highest level of conversion of chlorinated ethenes to ethene. The site is located in a groundwater discharge zone where groundwater moves not only laterally along fractures and bedding planes but also upward from depth.

Approach/Activities. A pair of recirculation wells was installed to inject the carbon sources and microbial consortium into the groundwater. The injection program was conducted in two steps: 1. biostimulation with EOS QR, a quick release carbon substrate (e.g. 99% glycerin) to promote rapid microbial growth and an emulsified oil substrate (EOS 100) to sustain the microbial population for several years and support reductive dechlorination, and 2. Bioaugmentation with *Dehalococcoides* microbial consortium (BAC-9) to promote complete reductive dechlorination of the chlorinated ethenes. Dissolved oxygen and oxidation reduction potential (ORP) were monitored to determine when bioaugmentation should be applied. After the ORP was less than 150 mV for several weeks, 20 liters of the *Dehalococcoides* consortium (BAC-9) was injected into the groundwater and recirculated using the paired wells. The monitoring program includes evaluation of cVOCs, key microbial populations and genes, geochemistry and compound specific isotope analysis. In the area where elevated 1,4-dioxane is observed, a second phase may involve the injection of a microbe that is able to utilize dioxane as a carbon source.

Results/Lessons Learned. Within one week of injecting the carbon substrates, there was an increase in conductivity in downgradient wells. There was an over estimation of the oil retention in the fractured rock, which resulted in the carbon substrate impacting wells further downgradient than was anticipated based on current knowledge of the hydrogeologic conditions. Within two months after the EOS QR and EOS 100 injection, there was a significant decline in the DO levels to less than 0.5 mg/L and likewise, there was a corresponding decrease in the ORP levels to less than -150 mV in the recirculation and downgradient impacted wells. The *Dehalococcoides* population and corresponding key enzymes (e.g. tceA reductase, vcrA reductase) markedly increased in downgradient wells post the bioaugmentation event. The geochemistry indicated that competing electron acceptors, oxygen, nitrate, iron and sulfate were considerably reduced in the groundwater and conditions were appropriate for reductive dechlorination. This was demonstrated by more than a one to two order of magnitude decrease in PCE, TCE and cis-1,2-DCE concentrations in downgradient wells about ten months post biostimulation and bioaugmentation. Likewise, ethene levels are increasing in downgradient wells. This presentation will discuss how the injection approach impacted distribution of the various amendments in the complex hydrogeology and impacted biodegradation of cVOCs.