Optimization of a Permeable Reactive Barrier for Chlorinated Solvents

Aaron Sutton (aaron.sutton@parsons.com) (Parsons, Denver, Colorado, USA)
Bruce Henry (Parsons, Pagosa Springs, Colorado, USA)
Ed Heyse (Parsons, Huntsville, Alabama, USA)
Christiana Hewitt (United States Air Force, Lackland Air Force Base, USA)
Jeff Roberts, (SiREM, Guelph, Ontario, Canada)

Background/Objectives. Enhanced anaerobic bioremediation was selected to treat chlorinated solvents in groundwater for a plume at the former Galena Forward Operating Location in Alaska. Factors that influenced remedy selection included the remote location, large seasonal variation in the groundwater table (up to 30 feet) and annual reversal of groundwater flow due to fluctuation in Yukon River stage, low groundwater temperatures (4-6 degrees Celsius), and long cold winters which hinder field operations. As a result, a passive remedy with no maintenance or operational requirements was selected.

In addition to low groundwater temperatures, the aquifer at Galena is high in iron that poised the oxidation-reduction (redox) state in iron-reducing conditions resulting in incomplete dechlorination of trichloroethene (TCE) and accumulation of dichloroethene (DCE). In addition to bioaugmentation for the permeable reactive barrier (PRB) application, sulfate was added to induce lower redox conditions and to produce sulfide to precipitate with ferrous iron as reactive iron sulfide minerals. Emulsified vegetable oil (EVO) was selected as the organic substrate.

Three PRBs were designed for the site to sustain anaerobic degradation for a period of five years. After four years of monitoring, a Remedial Process Optimization effort was performed to evaluate the distribution and longevity of injection amendments, determine if reinjection is necessary to meet remediation goals, and to optimize the design of continued in situ treatment. Five years of monitoring data are now available to optimize the design of a re-injection event.

Approach/Activities. Decreases in concentrations of TCE and/or increases in dechlorination products cis-1,2-DCE, trans-1,2-DCE, vinyl chloride (VC), and ethene were observed within three years at most locations up- or down-gradient of the PRBs. A clear correlation between elevated dissolved organic carbon (DOC), elevated *Dehalococcoides* cell counts, VC reductase genes, and sequential dechlorination to ethene indicates the remedy is operating as intended when sufficient DOC (greater than 10 milligrams per liter) is distributed within the PRB reactive zones. However, the presence of elevated DOC is temporal or absent at some locations. This is thought to be due to substrate depletion and non-uniform distribution due to complex groundwater flow. While many locations achieved remedial objectives after a single injection, additional injection is required where sufficient DOC is not present or has been depleted.

Results/Lessons Learned. The design life expectancy was based on the anticipated flux of electron acceptors through the PRB. A higher than anticipated groundwater flux depleted the EVO substrate more quickly than designed. Non-uniform flow (change in water table elevation and reversal of flow) can also shift the reaction zone in different directions during the year. While increasing the zone of substrate influence, this also lowers the effective substrate concentration. Both amendment distribution and longevity are key components of the optimization study. Recommendations for optimization will be presented, including a limited injection to target areas of residual chlorinated solvents to meet remedial objectives. Adjustment of the amendment mixture (EVO, sulfate, and bioaugmentation culture) in based on whether substrate was depleted faster or slower than anticipated and whether sufficient reducing

conditions were achieved. The number and spacing of the PRBs is also optimized based on observed variation in groundwater flow and the utilization rate of dissolved organic carbon.