

Field-Scale Demonstration of Enhanced DNAPL Dissolution Using Recirculation-Based Bioremediation

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Background/Objectives. A recirculation-based enhanced reductive dechlorination (ERD) bioremediation program was implemented in a chlorinated solvent distribution, accelerate treatment, and allow for repeated substrate application to account for continued dissolution of TCE out of the DNAPL phase and into groundwater. The ERD program resulted in rapid treatment of the TCE and the generation of large quantities of ethene due to enhanced dissolution. Ethene levels were up to four times higher than baseline TCE concentrations. Groundwater recirculation is also believed to have improved inoculation of the system with *Dehalococcoides* (DHC) and eliminated the need for bioaugmentation.

Approach/Activities. Prior to implementing the ERD program, a tracer study using unique tracers released in multiple locations was completed to better understand flow dynamics in the treatment area and select optimal locations for injection and extraction wells. The tracer study and numerical flow modelling indicated that a 3x3 line-drive setup (three injection wells, three extraction wells) would result in adequate substrate distribution in the treatment area and the ability to implement various adaptive management strategies based on sampling data. The dosing skid was designed to allow for future adaptive management. Flow from the various extraction well lines could remain separate (injected into a corresponding injection well) or be combined and routed to any one of the injection wells. Substrate was applied using batch injections followed by groundwater recirculation to distribute the substrate in the treatment area. During substrate addition downhole electrical conductivity (EC) probes were used to map substrate migration through the treatment area. The EC data was then used to adjust system hydraulics to achieve more uniform distribution of substrate in the treatment area.

Results/Lessons Learned. The tracer study proved invaluable for understanding transport in treatment area and indicated the flow system was much more complex than originally thought. The groundwater modelling that was completed did a reasonable job of predicting substrate migration based on the EC data although some minor modifications were made to the system hydraulics to improve substrate distribution. The recirculation program resulted in rapid conversion of TCE to cis-1,2-dichloroethene (cDCE) in less than one month, followed by conversion to vinyl chloride (VC) and eventually ethene. As treatment progressed, ethene continued to accumulate, increasing to levels approximately four times higher than the initial TCE concentrations prior to treatment. Similar to other recirculation projects the authors have worked on, groundwater recirculation precluded the need for bioaugmentation. DHC levels increase from approximately 10^2 cells/milliliter (mL) to approximately 10^7 cells/mL after three months of recirculation. The enhanced mixing that recirculation provides, coupled with the adaptive management strategy employed were the key factors contributing to the excellent treatment performance observed at this site.