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Treatment of Multi-Layer Aquifer with In Situ Bioreactors (ISBRs) and Liquid Activated Carbon Leads to Nondetect Results within Months

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Background/Objectives. Long, diffuse chlorinated solvent plumes can be challenging to remediate because biodegradation can stall or be slow to completely dechlorinate contaminants to ethene. In a multi-layer aquifer that contains Atlantic Coastal Plain sands and clay lenses, tetrachloroethene (PCE) and limited daughter products have extended a mile from the former source area toward the boundary with the Atlantic Ocean. PCE was detected in clay lenses that continued to back-diffuse into the transmissive sand layers, causing the formation of a persistent plume. The current study describes the use and performance of a three component treatment train combining in situ bioreactors (ISBR), liquid activated carbon, and electron donor to promote reductive dechlorination of PCE to nondetect in sand and clay layers of this aquifer that extended to 60 feet below ground surface.

Approach/Activities. The study site is a former dry cleaning facility where the multi-layer aquifer had been impacted predominately by PCE (55-627 µg/L) that had migrated a significant distance off site. A source zone treatment was applied consisting of the use of Plume Stop combined in sustained bio-augmentation via bioreactors and the injection of an electron donor (Hydrogen Release Compound® [HRC]) throughout the varying geologic layers at the site. An ISBR unit was installed in an existing shallow monitoring well to bioaugment and provide a continuous supply of the necessary microbial organisms for reductive dechlorination. HRC was injected into multiple zones, including shallow aquifer (7-25 feet [bgs]), intermediate (32-41 ft bgs), and deep (48-60 ft bgs) sand intervals and the clay aquitard layers to stimulate anaerobic biodegradation. PlumeStop® Liquid Activated Carbon™ (PlumeStop) was injected into the deep aquifer to provide a sorption capacity into the zone that contained the highest levels of chlorinated solvents. Groundwater samples were routinely obtained from the three treatment intervals for contaminant concentrations, geochemical conditions, microbial population, and carbon stable isotope analysis (CSIA). The microbial samplers were periodically recovered from each treatment interval for qPCR quantification of *Dehalococcoides* and functional genes (e.g., vinyl chloride reductases) to evaluate ISBR performance and the corresponding biostimulation actions in the intermediate and deep aquifer. It was our experience with working with bioreactors that the cultured indigenous microbial organisms would migrate towards the areas of highest residual contamination.

Results/Lessons Learned. The results of this treatment train of technologies were dramatic, with reductions in the PCE and TCE from 627 and 422 µg/L to 13.4 and 6.3 µg/L one month after treatment, with further reductions (6.9 and 3.84 respectively) in the deep unit three months after the treatment. Similar results were observed in the CSIA, where the fractionation of the PCE was from -43.22 δ13C +4.0 δ13C in three months. Corresponding increases in the reductive dechlorinating bacteria *Dehalococcoides mccartyi* (DHC) and other known biodegraders were also observed when comparing the background levels to the commencement of the combined biostimulation and bioaugmentation remedy.

Overall, the results conclusively demonstrated combined use of sustained bioaugmentation via the bioreactors combined with electron donor and Plume Stop injections can rapidly reduce the duration of these biodegradation processes.