Adaptive Strategies for In Situ Treatment of Shallow and Deep PCE Plumes in Interbedded Geology

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Background/Objectives. Enhanced reductive dechlorination (ERD) using periodic injections of in situ amendments has been implemented by multiple contractors since 2007 as a remedy for groundwater contamination by tetrachloroethylene (PCE) and its degradation products at the North Railroad Avenue Plume (NRAP) Superfund Site in the semiarid Rio Grande valley. The PCE plume historically extended approximately 0.75 miles south/southeast of the source, covered approximately 58 acres, and was 260 feet (ft) deep at its deepest point. A complex depositional sequence produced six different coarse-grained hydrostratigraphic units (HSUs) within the plume and four finer-grained, less permeable HSUs that isolate downgradient transport pathways vertically and laterally but cause back-diffusion where residual contamination is present near the source area. Historical pumping by water supply wells likely contributed to a PCE distribution with marked differences between shallow and deep HSUs. Objectives in order of priority are to prevent human exposures, achieve source control, limit migration, and destroy contaminant mass. These objectives led to early emphasis on treating shallow, coarse-grained HSUs and later adaptations targeting deep HSUs and shallow, fine-grained HSUs.

Approach/Activities. Quantitative polymerase chain reaction (qPCR) testing confirmed the presence of native halorespiring bacteria, including *Dehalococcoides*, and functional genes for the complete reductive dechlorination of trichloroethylene (TCE), cis-1,2-dichloroethylene (cis-1,2-DCE), and vinyl chloride (VC) to ethene. From 2007 to 2013, emulsified vegetable oil (EVO) mixed with water and sometimes ethyl lactate was periodically added and recirculated through shallow HSUs using arrays of injection and extraction wells. EVO mixtures were injected in batches to deep HSUs using individual wells until 2012. After source area concentrations began to rebound, EVO injections into fine-grained zones targeted with multiple drilling techniques were attempted in 2017 with limited success. Five years after the last EVO injections to deep HSUs, evaluation of monitored natural attenuation (MNA) by timeseries analysis, qPCR, compound-specific isotope analysis (CSIA), and fate and transport calculations found that MNA alone may not be adequate to limit migration. Alternative amendments including 3-D Microemulsion (3DME®) and sulfidated micro-scale zero valent iron (S-MicroZVI®) were tested in shallow and deep HSUs beginning in 2020 to promote reducing conditions for anaerobic biodegradation and to potentially provide an abiotic reaction pathway to avoid accumulation of cis-1,2-DCE and VC. In the source area, high-resolution site characterization identified zones of high residual contamination where sand slurry was then injected to induce fracturing of clays to improve distribution of amendments.

Results/Lessons Learned. Onsite and offsite treatment systems caused plume retreat with a decrease in PCE concentrations from >1,000 micrograms per liter (µg/L) to <5 µg/L in the shallow HSUs, except for a small area affected by back-diffusion near the source. Application of alternative amendments with fracturing of clays achieved an initial rapid decrease in PCE by Month 3 after treatment, with substantial rebound at the periphery of the treatment area by Month 15 but no rebound in the center of the treatment area by Month 32. Remediation in deep HSUs was limited by the number of wells and the flowrates achievable at moderate pressures when injecting EVO mixtures at depth. New deep wells and alternative amendments show promise for better distribution.