

# Optimizing Enhanced In Situ Bioremediation of Commingled Chlorinated Ethanes and Ethenes at Two Groundwater Remediation Sites

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**Background/Objectives.** Enhanced in situ bioremediation was implemented at two sites in the northeast United States to address commingled chlorinated ethanes, primarily 1,1,1-trichloroethane (1,1,1-TCA) and ethenes, primarily tetrachloroethene (PCE), in groundwater. At Site A, treatment was targeted in impacted overburden and intensely weathered bedrock within approximately 40,000 SF and a depth interval from 8 to 35 ft bgs. Site B had an impacted overburden treatment area of approximately 4,200 SF, with a depth interval of 6 to 31 ft bgs. The primary remediation objective at both sites was aggressive reduction of chlorinated volatile organic compound (CVOC) impacts and mitigation of off-site migration of degradation products.

**Approach/Activities.** At Site A, the groundwater remediation was initiated in 2014, and employed a combination of fast and slow release carbon sources to enhance bioremediation via enhanced reductive dechlorination (ERD) in combination with bioaugmentation. Sequenced injections of lactate and emulsified vegetable oil (EVO), followed by anaerobic chase water and a bioaugmentation culture, were accomplished through a network of overburden and bedrock wells. The distribution of amendments in the bedrock was optimized through simultaneous extraction (recirculation) of groundwater from wells around the point of injection.

At Site B, the groundwater remediation was initiated in 2012, and consisted of the injection of zero valent iron (ZVI), pH buffer, lactate, EVO, and bioaugmentation culture through a grid of direct-push injection points. As a secondary measure, an aerobic barrier zone was established near the downgradient property boundary to further reduce vinyl chloride and mobilized metals.

Supplemental sampling and analysis of groundwater for a suite of non-traditional nutrient and microbial parameters was performed at both sites to understand the differences in the extent of degradation observed between the sites. A set of bench-scale tests, using groundwater and soil from Site B, was also conducted to attempt to enhance the complete degradation of 1,1,1-TCA.

**Results/Lessons Learned.** At Site A, the amendments were optimally distributed in the treatment zone. An evaluation of 36 months of performance monitoring data showed near complete degradation of 1,1,1-TCA, following some intermediate buildup in chloroethane. At Site B, an evaluation of approximately 54 months of performance monitoring data indicated: distribution of amendments and established reducing conditions in the injection zone; significant reduction of CVOCs within the treatment volume; no production of vinyl chloride; and effective establishment of oxidizing, co-metabolic conditions in the vicinity of the down-gradient aeration barrier. CVOC and geochemical temporal trends within and downgradient of the source area varied. The reduction kinetics for chlorinated ethenes were faster than for the chlorinated ethanes. The buildup of chloroethane at Site B was greater than at Site A. The performance, operational, and supplemental monitoring results will be interpreted to explain the differences in the degradation behavior of the commingled CVOCs between the two sites. An initial finding of the bench-scale testing for Site B is that the rate of chloroethane biodegradation may be able to be enhanced.