Long-Term Performance Assessment at a Highly Characterized and Instrumented DNAPL Source Area following Bioaugmentation

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Background/Objectives. While the short-term effectiveness and impacts to groundwater from in situ bioremediation of chlorinated solvent dense non-aqueous phase liquid (DNAPL) source areas have been widely studied, the long-term (> 2 years following treatment) impacts remain poorly understood. This study investigated the long-term behavior in a DNAPL source area following in situ bioaugmentation in heterogeneous system. The investigation was performed within Plume 4-1 (operable unit 2B) at Alameda Point, California, where a detailed high-resolution site assessment in a DNAPL source area was followed by several weeks of active in situ bioremediation that included bioaugmentation, delivery of sodium lactate, and groundwater recirculation. Monitoring as part of this project was performed 2.3 to 3.7 years following cessation of active bioremediation.

Approach/Activities. Long-term post treatment monitoring was performed using a high-density monitoring network that included several discrete interval multi-level sampling wells. Three rounds of groundwater monitoring were performed, and one round of soil sampling. Analyses included microbial community, VOCs, reduced gases, TOC, volatile fatty acids, dissolved hydrogen, anions, and CSIA (for carbon).

Results/Lessons Learned. Results showed that, despite the absence of lactate, lactate fermentation transformation products, or hydrogen, biogeochemical conditions remained favorable for the reductive dechlorination of chlorinated ethenes. In locations where soil data showed that TCE DNAPL sources persisted, local contaminant rebound was observed in groundwater, whereas no rebound or continuous decreases in chlorinated ethenes were observed in locations where DNAPL sources were treated. While ethene levels measured 3.7 years after active treatment suggested relatively low (2 to 30%) dechlorination of the parent TCE and chlorinated transformation products, carbon stable isotope analysis showed that the extent of complete dechlorination was much greater than indicated by ethene generation, likely due to biological oxidation of ethene and/or vinyl chloride. The estimated first-order rate constant describing the complete dechlorination of TCE at 3.7 years following active bioremediation was approximately 3.6 yr^{-1}. Mass balance calculations further indicate that approximately 25% of the residual DNAPL mass that remained following active treatment was removed in the 3.7 years following active treatment.

Overall, results of this study suggest that biological processes may persist to treat TCE for years after cessation of active bioremediation, thereby serving as an important component of remedial treatment design and long-term attenuation. Results of this study also emphasize the need for high-resolution characterization and monitoring to facilitate improved design and performance monitoring (short- and long-term) to optimize resources needed to achieve remedial goals.