Geochemical and Microbiological Progress Metrics for Bioremediation of Mixed Chlorinated Ethenes and Methanes

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Background/Objectives.
This study demonstrates the benefits of using an advanced geochemical and microbiological monitoring design to evaluate and enhance bioremediation performance in a fractured rock environment. Bioaugmentation technology was applied to a commingled plume of chlorinated ethenes, primarily dissolved trichloroethene (TCE), and chlorinated methanes (carbon tetrachloride [CTC] and chloroform), in a fractured rock residual source area. Injected amendments and bacteria rapidly reduced CTC, however the commingled TCE was more recalcitrant. The use of advanced monitoring techniques and progress metrics led to the understanding of the complicated and changing geochemistry, including iron and sulfate common in the bedrock of the Triassic Basins of New Jersey, Pennsylvania and Connecticut, and led to the optimization of bench-scale testing as well as a third phase of augmented emulsified vegetable oil (EVO) injections.

Approach/Activities.
To address the impacted bedrock aquifer that lacked naturally-occurring bacteria (no DHC), approximately 8,500 gallons of EVO augmented with SDC-9, a DHC-containing bacterial culture, was injected into a complex fracture network comprised of bedding plane and tectonic fractures. The goal of the advanced monitoring was to support the demonstration of the effectiveness of bioaugmentation as a potential remedy scalable to larger areas, but also to characterize the reasons for challenges that presented themselves and to optimize the design. Bioaugmentation performance was evaluated and quantified using a 3D monitoring well network with analyses for both chemical and biological constituents. The parameters monitored included concentration trends of tracers, of chlorinated ethenes, ethanes, methanes and benzenes (including all daughter products), geochemical conditions (DO, ORP, pH, alkalinity, methane, ethane, ethene, sulfate, ferric and ferrous iron, manganese, TOC), biological conditions (Dehalococcoides (DHC) functional genes bvcA Reductase (BVC) and vcrA Reductase (VCR), functional gene tceA Reductase and dehalobacter (DHBt), metabolic products of the organic substrate, relatively elevated concentrations (and timing) of ketones and methane, and stable isotope changes (3D-CSIA) in chlorinated ethene parent and daughter compounds. Seasonal influences were also recognized and given consideration in our evaluation.

Results/Lessons Learned.
The results of our monitoring of progress metrics informed remedial designs in a complicated iron geochemistry setting, and showed that enhanced biodegradation of chlorinated VOCs was successful in particular portions of the fracture network that were treated by injected amendments. Lessons learned included the need to pay attention to particular metrics and trends, which in hindsight forecast the delayed production of alarmingly elevated methane concentrations.