Combined ISCR and Bioaugmentation: New Insights for Sulfidated ZVI

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Background/Objectives. The synergy between zerovalent iron (ZVI) and biological reductive dechlorination (either biostimulation or with bioaugmentation) has long been recognized and applied as an effective remediation strategy at chlorinated solvent sites. The reactivity of ZVI in water has beneficial effects on biological reductive dechlorination. By scavenging natural oxidants (i.e., oxygen, nitrate, sulfate) in the subsurface, the reactions facilitated by ZVI create strongly reducing conditions—together with the hydrogen produced by ZVI reacting with water—that support biological reductive dechlorination. Recent research has led to a new type of ZVI, sulfidated ZVI (S-ZVI), of which the corrosion reaction with water is significantly inhibited. This leads to enhanced efficiency of S-ZVI for abiotic dechlorination that tends to produce significantly less reductive dechlorination intermediates (cDCE, VC). However, the interactions between abiotic and biological reductive dechlorination remain largely unknown for S-ZVI. This bench-scale treatability study compared the treatment performance for reductive dechlorination between two ZVI-organic carbon (OC) composites and three novel S-ZVIs in combination with bioaugmentation. The Capital Region of Denmark funded this project to identify the optimal ZVI-biodegradation combination for a permeable reactive barrier (PRB) at a former industrial site.

Approach/Activities. Microcosm reactors were prepared using site groundwater and aquifer materials under anaerobic conditions. For each ZVI product, the treatments included ZVI alone, and ZVI + KB-1® (a dechlorination culture). A mixture of chlorinated ethenes (TCE, cDCE and tDCE) was spiked to each reactor with an initial total concentration of 16 mg/L. Samples were periodically collected over the course of two months to analyze chlorinated compounds, dissolved hydrocarbon gases, as well as geochemistry parameters. Two respikes were performed on Days 14 and 63 for all S-ZVI treatments given the fast dechlorination kinetics to evaluate the persistence of S-ZVI reactivity. Subsequent column tests were conducted to test two ZVI products (one ZVI-OC and one S-ZVI) to evaluate the longevity of each product for dechlorination. The operational parameters of the column tests were determined based on the site hydrogeologic conditions and the parameters used for a field injection test conducted in January 2019.

Results/Lesson Learned. The three S-ZVI products all exhibited rapid dechlorination of TCE without apparent decreases in degradation rates following each respike. Degradation of cDCE was notably slower than that of TCE, and the kinetics also slowed down after each respike. Minimum to small amount of accumulations of cDCE and/or VC and significant productions of ethene/ethane indicated that abiotic dechlorination was the dominant process in all the S-ZVI treatments, with and without the addition of KB-1®. With the two ZVI-OC composites, degradation kinetics of TCE and cDCE were significantly slower than what were observed in all the S-ZVI treatments, The ZVI-OC + KB-1® treatments exhibited evidence of TCE transformation to cDCE, but no further dechlorination was observed during the two-month period of the microcosm experiments. The column experiments so far have shown similar results to the batch microcosm test in terms of the relative dechlorination kinetics observed between the ZVI-OC product and the S-ZVI product tested. The column tests are still ongoing and further monitoring will provide more insights regarding the reactivity and longevity of the tested ZVI-OC and S-ZVI products for reductive dechlorination.