A Field Comparison of Biogeochemically-Enhanced Biological and Chemical Reduction for Treatment of Chlorinated Organics

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Background/Objectives: For over two decades, biological (enhanced reductive dechlorination [ERD]) and abiotic (in situ chemical reduction; ISCR) reductive processes have been applied to degrade chlorinated volatile organic compounds (CVOCs) in situ. Recently, biogeochemical reduction (BGCR), a process which combines biological and chemical processes, has been combined with ERD and ISCR to provide an additional mechanism to more aggressively degrade CVOCs in situ. The BGCR process enhances ERD and ISCR by contemporaneously generating reactive minerals in situ. These minerals have been demonstrated to abiotically degrade CVOCs by the β elimination pathway. This pathway extends treatment longevity and minimizes the generation of toxic degradation products thereby reducing the clean-up time. During ERD and ISCR, highly reducing conditions are generated which are favorable to the production of BGCR-enhancing iron sulfide minerals such as mackinawite (FeS), and pyrite (FeS_2). BGCR enhancement is achieved by the inclusion of a source of iron and sulfur with the ERD and ISCR reagents. Recently, a field study was conducted to evaluate the effectiveness of inclusion of iron sulfide BGCR to enhance ERD and ISCR for treatment of CVOCs

Approach/Activities: At a confidential site in California, soil and groundwater had been affected by a discharge of high concentrations of CVOCs, primarily trichloroethene (TCE). Site conditions were determined to be appropriate for ERD and ISCR. The potential for BGCR to enhance ERD and ISCR to aggressively treat CVOCs at the site was evaluated.

Two pilot tests were conducted in the high concentration portion of the plume to evaluate the effectiveness of 1) BGCR-enhanced ERD and, 2) BGCR-enhanced ISCR. These studies were conducted by injection of a BGCR-enhanced ERD reagent (Geoform Soluble), and a BGCR-enhanced ISCR reagent (Geoform Extended Release; Geoform ER) at two locations in the affected aquifer. Geoform ER was injected as a slurry and was intended to evaluate its applicability for establishment of a permeable reactive barrier (PRB). Geoform Soluble was injected as a completely soluble reagent for extended distribution for potential later distribution through injection wells. For these tests, the reagents were delivered to the subsurface by high pressure direct push technologies. Conservative tracers were also injected to evaluate the distribution characteristics of the injection process. Following the injection, soil and groundwater samples were analyzed for parameters necessary to evaluate degradation pathways and rates. Additional samples were analyzed to define reagent distribution characteristics. In addition, laboratory column and batch tests were conducted to evaluate the degradation processes and to design the full-scale application.

Results/Lessons Learned: The tests demonstrated that BGCR-enhanced ERD and ISCR reagents are effective for treatment of high concentrations of CVOCs in groundwater. Because of the high ambient sulfate concentration, Geoform ER and EHC were applied for full-scale as a permeable reactive barrier. An organic ferrous iron containing substrate (EHC-Liquid) was applied upgradient to reduce the flux of contaminants and competing electron acceptors into the PRB. The combination of ERD and ISCR with BGCR provides a more aggressive approach for in situ treatment of CVOCs.