Trade-offs in Utilizing Zero-Valent Iron for Synergistic Biotic and Abiotic Reduction of Trichloroethene and Perchlorate

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Background/Objectives. Trichloroethene (TCE) and perchlorate (ClO_4^-) are common and toxic groundwater contaminants. In aerobic aquifer, zero-valent iron (ZVI) is often injected to establish anoxic conditions, beneficial for biostimulation/bioaugmentation. However, the benefits and challenges of combined abiotic reduction by ZVI and microbial reduction of TCE and ClO_4^- for remediation of aquifers are not well delineated.

Approach/Activities. We utilized bench-scale semi-batch microcosms with soil and groundwater from a contaminated Superfund site. We studied conditions representing an injection zone of ZVI and a combination of biostimulation and bioaugmentation, and a downgradient zone influenced by Fe (II) derived from ZVI oxidation.

Results/Lessons Learned. In experiments representative of the ZVI and biostimulation/bioaugmentation injection zone, high concentrations of ZVI (16.5 g L^{-1}) effectively reduced TCE to ethene and ethane, but ClO_4^- concentrations remained mostly unchanged. Microbial reductive dechlorination of both contaminants was hindered by the presence of ZVI or Fe (II). For TCE, rapid abiotic dechlorination provided by ZVI made TCE unavailable for the bioaugmented dechlorinating bacteria. For ClO_4^-, ZVI did not reduce ClO_4^-, and inhibited the indigenous perchlorate-reducing bacteria associated with the aquifer material. Furthermore, H_2 generated by ZVI reactions stimulated competing microbial processes such as sulfate reduction and methanogenesis. In experiments representing the downgradient conditions (Fe (II) and biostimulation/bioaugmentation with dechlorinating enrichment cultures), *cis*-dichloroethene (*cis*-DCE) and vinyl chloride (VC) accumulated after 56 days of microcosm operation. In the absence of ZVI or Fe (II), the bioaugmentation culture achieved complete TCE dechlorination to ethene and ClO_4^- reduction rates were faster. These results illustrate some limitations imposed by combining ZVI with microbial reduction of chlorinated compounds and provide useful information relevant to bioremediation of chlorinated compounds in subsurface environments.