Abiotic Reductive Dechlorination of Tetrachloroethylene and Trichloroethylene in Anaerobic Environments

Background:
Tetrachloroethylene (PCE) and trichloroethylene (TCE) are among the most frequently detected groundwater contaminants at industrial sites, including many Department of Defense (DoD) facilities. Due to the high cost and uneven performance of traditional remediation technologies, monitored natural attenuation is emerging as a new technology for remediation of pollutants in groundwater. In anaerobic environments, PCE and TCE are susceptible to reductive dechlorination by microorganisms as well as to purely abiotic reductive dechlorination by reduced minerals such as magnetite and iron sulfide. These mineral-mediated abiotic reactions result in transformation of PCE and TCE by dichloroelimination, forming reaction products distinct from microbial reductive dechlorination, which takes place by hydrogenolysis. To more accurately apply natural attenuation as a remediation measure, a greater understanding of the factors affecting the rates of purely abiotic reductive dechlorination of PCE and TCE is needed.

Objective:
The objective of this project is to develop and apply methods to quantify the rates of abiotic natural attenuation at sites contaminated with PCE and TCE.

Process/Technology Description:
Two approaches will be used to assess the rates and importance of abiotic reductive dechlorination, including analysis of stable (i.e., nonradioactive) carbon (C) isotope fractionation and analysis of the distribution of PCE and TCE products. This second approach is based on the fact that biotic and abiotic PCE and TCE reductive dechlorination proceed by different pathways, producing different reaction products. Studies will be conducted in model systems, well-controlled microcosms, and contaminated field sites. The stable C isotope fractionation characteristic of abiotic PCE and TCE reductive dechlorination by magnetite and iron sulfide will be determined in pure systems. Isotope fractionation analysis and kinetic analysis will be used to determine rate constants for abiotic reductive dechlorination in well-defined microcosms. These results will be analyzed to determine which geochemical conditions (e.g., iron(II) abundance, dissolved hydrogen concentration) lead to the greatest rates of abiotic reductive dechlorination. Finally, indicators of abiotic reductive dechlorination (i.e., characteristic isotope fractionation and PCE and TCE product distributions) will be compared with geochemical conditions at four contaminated DoD sites to validate and/or refine the earlier findings.

Expected Benefits:
This project will advance the state-of-the-science in natural attenuation by assessing the potential for abiotic natural attenuation of PCE and TCE under anaerobic conditions. Geochemical conditions under which abiotic reductive dechlorination is significant and the reductants responsible for dechlorination will be identified. Abiotic natural attenuation rates will be quantified through analysis of product distributions and stable carbon isotope ratios. Site-specific geochemical conditions such as reactive mineral phases and terminal electron acceptors also will be correlated with rates of abiotic reductive dechlorination. (Anticipated Project Completion - 2008)

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