Biodegradation of Chlorinated Solvents: Reactions Near DNAPL and Enzyme Function

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Research Objectives

Chlorinated solvents are among the most common organic chemical groundwater contaminants at DOE sites, as well as at DOD and industrial facilities. Included are the solvents trichloroethene (TCE), tetrachloroethene (PCE), and carbon tetrachloride (CT). Commonly these contaminants occur as dense non aqueous phase liquids (DNAPLs) that continue to contaminate groundwater as it moves through the DNAPL location. Also, commonly, these contaminants are associated with other contaminants of concern. An example is the Hanford site where nitrates, tritium, and carbon tetrachloride co-mingle in significant plumes. The objective of this study is to obtain basic information on processes affecting the in situ biodegradation of the above chlorinated solvents and their degradation daughter products, especially near the DNAPL source where concentrations are exceptionally high. Here, we have found anaerobic biological processes provide the best opportunity for efficient in situ biodegradation because the high concentrations of solvents and daughter products tend to be inhibitory to other microorganisms, such as methanogens, that compete for electron donor that may be added to enhance this process. We have laboratory cultures that are capable of degrading saturation concentrations of PCE, and are cooperating with DuPont Chemical Corporation, who has several mixed cultures, as well as molecular probes, that will be useful in this study. The study will be conducted in three separate phases. In the first, the kinetics of chlorinated solvent biodegradation at or near saturation concentrations will be investigated. Important here is the potential for inhibition by individual chlorinated solvents and end products, as well as those of potential co-contaminants. The second phase is to develop a better understanding of the underlying biochemical processes involved in key enzymatic reactions, such as the dehalogenation of vinyl chloride. From these studies, molecular probes that can detect the presence and activity of dehalogenating enzyme activity will be developed for field application. The third phase is concerned with obtaining better basic knowledge of a highly unique denitrifying bacteria (Pseudomonas stutzeri strain KC) that degrades carbon tetrachloride without producing chloroform as a hazardous intermediate. We have successfully field tested bioaugmentation for CT degradation with this organism, and have the genes involved in synthesis of the cellular component that carries out this interesting process. With the further development here proposed, we will gain an understanding of what conditions are required to produce the dehalogenating factor and how best to apply this organism or the dehalogenating factor it produces for in situ biodegradation of carbon tetrachloride. The three phases represent an integrated approach to addressing an important in situ remediation process.