System Design for Enhanced Biological Treatment of Chlorinated Solvent DNAPL

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Tetrachloroethene (PCE) and trichloroethene (TCE) are the most frequently found and costly to control organic contaminants in groundwater. Chlorinated solvent spills migrate downward to form dense non-aqueous phase liquids (DNAPLs), which constitute sources of contamination to groundwater that may last for decades, if not centuries. Recent research has indicated that near-saturation concentrations of chlorinated solvents can be biodegraded by specialized anaerobic microorganisms that use the chlorinated solvents as electron acceptors in energy metabolism. Efforts based upon this observation are now being directed towards use of biodegradation to reduce the life span of chlorinated solvent DNAPLs.

Among the advantages of chlorinated solvent DNAPL biodegradation are: (1) it can result in enhanced rates of solvent dissolution, (2) the high chlorinated solvent concentrations near the DNAPL and their degradation products are toxic to microorganisms, such as methanogens, that otherwise compete with dechlorinating microorganisms for electron donor, and (3) the costs for delivery of the electron donor per unit of solvent degraded are much less when applied to high solvent concentrations. A question then arises: What are the best donors for chlorinated solvent dehalogenation and what are the best strategies for their delivery to the DNAPL source area?

Possible electron donors are gaseous materials such as hydrogen and soluble organics such as formate, propionate, lactate, and molasses. There are also a variety of “slow hydrogen release” materials such as vegetable oils, precipitated compounds such as calcium oleate, natural organic solids such as compost, and various commercially available products. Two potential problems with anaerobic chlorinated solvent DNAPL dehalogenation are (1) the production of hydrochloric acid, which can create severe pH problems, and (2) the formation of acetic acid from donor fermentation, an organic acid that can produce adverse water quality problems.

Possible ways to address these potential problems are (1) donor selection and (2) remediation design. For example, both problems are reduced if formate rather than most other organics is used as the donor. First, the cation with which formate is associated (generally sodium) is released during utilization to result in self neutralization of the hydrochloric acid produced. Second, acetic acid is not generated by its use. While previous studies have indicated that the key microorganisms (Dehalococcoides) responsible for dehalogenating the intermediate products formed, such as cis-dichloroethene (cDCE) and vinyl chloride (VC), to ethene, cannot use formate as a donor, we have demonstrated that in mixed culture, the formate is converted into hydrogen, which can then be used by these organisms.

Remediation systems can also be designed to reduce the potential problems from hydrochloric acid and acetic acid production. The pH in groundwater is a function of the ratio of the log of bicarbonate concentration to dissolved carbon dioxide concentration,
the higher the ratio the higher the pH. Hydrochloric acid and acetic acid unfortunately both destroy bicarbonate and form carbon dioxide, leading to low pH. Various methods can be used to increase bicarbonate concentration and reduce dissolved carbon dioxide to help reduce this problem. For example with complex donors that produce both hydrogen and acetic acid, properly designed recirculation systems can take advantage of acetic acid production for conversion of PCE and TCE to cDCE, while using the hydrogen produced only for cDCE and VC reduction. These include the use of a combination of nested upgradient injection and down gradient extraction wells, or a combination of groundwater recirculating wells.