Project Title: "Field Demonstration of the Solvent Extraction Residual Biotreatment (SERB) Technology"

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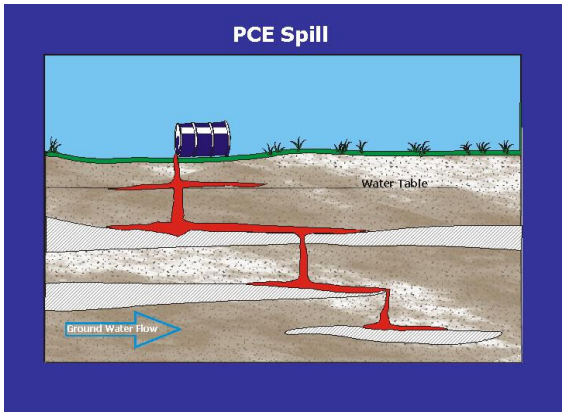
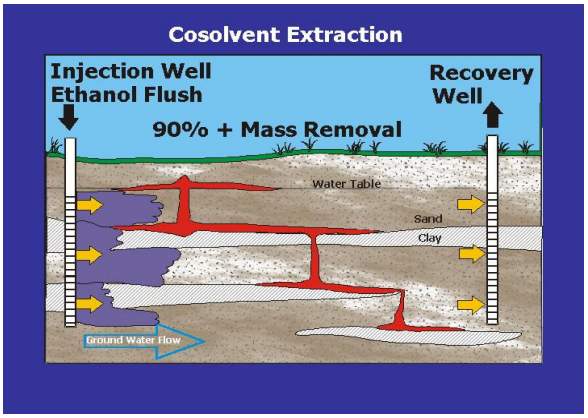
Introduction to the problem: Tetrachloroethylene (PCE) is a dense nonaqueous liquid (DNAPL) which was widely used as a degreasing agent and in dry cleaning processes. Because DNAPLs may be trapped in the pore space as a separate phase contaminant, they can serve as a long-term source of contamination to the aquifer. The physical/chemical properties of PCE and its daughter products have resulted in the chloroethenes being the most commonly detected class of organic contaminants in ground water. Parent chloroethenes can become human health hazards after being processed in the human liver or via reductive dehalogenation in the environment.

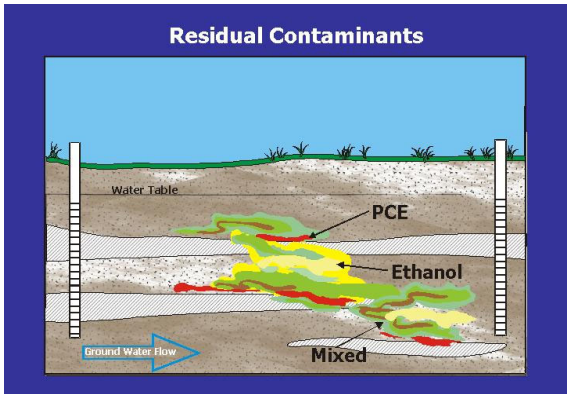
Background: The former Sage's Dry Cleaner site in Jacksonville, FL was selected for remediation of a PCE source zone by cosolvent extraction with ethanol. Ethanol was selected as the cosolvent because it has been shown to be an acceptable electron donor for indigenous microorganisms from other locations to support reductive dechlorination processes. This project was designed to investigate the potential for merging two synergistic technologies, enhanced source remediation by *in situ* flushing and bioremediation by reductive dechlorination, into a treatment train to develop a comprehensive approach for site restoration.

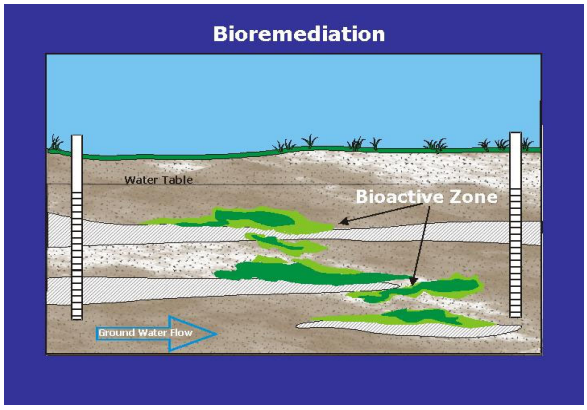
Objectives: 1) Evaluate enhancement of subsurface microbial processes following cosolvent extraction with ethanol, 2) Assess extent and rates of reductive dechlorination transformations.

Approach:



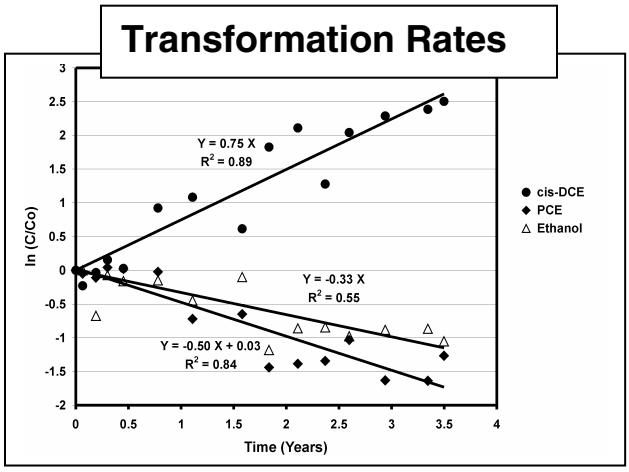






Application of the SERB technology was conducted by characterization of the source area and design of the cosolvent flushing pilot test to remove a significant portion of the PCE DNAPL. Following the cosolvent flushing test, areas of residual DNAPL were exposed to ethanol which was left in the subsurface. Indigenous microorganisms can utilize the ethanol as an electron donor and produce hydrogen, which may then be utilized as a direct electron donor by organisms capable of partial and complete reductive dechlorination. Bioactive zones in the subsurface were created and monitored to determine the capacity for transformation of PCE to non-toxic products, such as ethene.

Accomplishments to date (Summer, 2003): The cosolvent flushing pilot test was conducted during August, 1998 and quarterly sampling and analysis of ground water was conducted until April, 2003. Ground water samples were analyzed for PCE and daughter products, dissolved gases, ethanol, and additional parameters to monitor changes in contaminant concentrations and geochemistry. Evaluation of ground water results indicates that reductive dechlorination was enhanced in areas exposed to ethanol both in the source and down-gradient areas. Ground water samples collected four years after the cosolvent flushing pilot test from the source zone tested positive for three out of three primers for *Dehalococcoides*, the only known microorganism to dechlorinate PCE completely to ethene. Transformation rates calculated from site data based on changes in mass estimated from contour plots were 0.75 yr^{-1} for *cis*-DCE, -0.50 yr^{-1} for PCE, and -0.33 yr^{-1} for ethanol.



Future tasks: Biannual sampling and analysis of ground water will continue for evaluation of long-term performance of the SERB technology. Ground water flow and transport modeling of the site data will be conducted to better evaluate transformation rates and the impact of the drainage canal on ground water flow. Laboratory studies are planned to evaluate the impact of ethanol on microbial communities.

Publications:

Mravik, S.C., G.W. Sewell, R.K. Sillan, and A.L. Wood. 2003. Field Evaluation of the Solvent Extraction Residual Biotreatment (SERB) Technology. *Environ. Sci. Tech.* 37(21): 5040-5049.

Sewell, G.W., S.C. Mravik, A.L. Wood, M. Annable, R. Sillan, and K. Warner. 2002. Chlorinated Solvent Contaminated Soils and Groundwaters: Field Application of the Solvent Extraction Residual Biotreatment (SERB) Technology *in* Federal Integrated Biotreatment Research Consortium (FIBRC): Flask to field initiative (Bajpai, R. et al.), ERDC/EL Tr-02-37, U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Sewell, G.W., S.C. Mravik, and A.L. Wood. 2000. Field evaluation of Solvent Extraction Residual Biotreatment (SERB). Proc. of the 7th International FZK/TNO Conference on Contaminated Soil (ConSoil 2000), Sept. 18-22, Thomas Telford Publishing, Contaminated Soil 2000, Vol. 2: 982-988.

Mravik, S.C., G.W. Sewell, and A.L. Wood. 2000. Cosolvent-based source remediation approaches. Proc. of the 2nd International Conference on Remediation of Chlorinated and Recalcitrant Compounds, May 22-25, Monterey, CA, Battelle Press, Physical and Thermal Technologies C2-5: 269-276.

Presentations: (presenter in **bold)**

Mravik, S.C., G.W. Sewell, R.K. Sillan, K. Warner, and A.L. Wood. 2001. Performance data from the Solvent Extraction Residual Biotreatment (SERB) technology demonstration. DNAPL Source Remediation Workshop sponsored by USEPA-TIO and USEPA-ORD-NRMRL, Oct. 29-30, Dallas, TX.

Sewell, G.W., S.C. Mravik, R.K. Sillan, K. Warner, and A.L. Wood. 2001. Performance data from the Solvent Extraction Residual Biotreatment (SERB) technology demonstration. Sixth International In Situ and On-Site Bioremediation Symposium, June 4-7, San Diego, CA.

Mravik, S.C., G.W. Sewell, and A.L. Wood. 1999. Field evaluation of the Solvent Extraction Residual Biotreatment technology. International Symposium on Subsurface Microbiology, Aug. 22-27, Vail, CO.

Posters: (presenter in **bold)**

Mravik, S.C., A.L. Wood, M. Annable, G.W. Sewell. 2002. Solvent extraction residual biotreatment (SERB) demonstration at a dry cleaner site. In Situ Treatment of Groundwater Contaminated with Non-Aqueous Phase Liquids: Fundamentals and Case Studies, Dec. 10-12, Chicago, IL.

Mravik, S.C., G.W. Sewell, and A.L. Wood. 2000. Co-solvent-based source remediation approaches. Remediation of Chlorinated and Recalcitrant Compounds, 2nd Int'l. Conference, May 22-25, Monterey, CA.