Coupling Natural Attenuation and Phytoremediation to Clean Up a Shallow Chlorinated Solvent Plume at the Former Naval Training Center in Orlando, Florida

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The former Naval Training College (NTC) in Orlando, Florida was closed in 1994 under the Base Realignment and Closure (BRAC) Act. An initial investigation conducted in 1994 during the BRAC Environmental Baseline Survey (EBS) revealed that the release of PCE had occurred northeast of Building 1100 (OU4), which housed the laundry facilities for the base. Subsequent site assessment studies were conducted in January 1995, May 1996, March and April of 1997, and an Interim Remedial Action (IRA) was implemented. Groundwater samples collected between Building 1100 and Lake Druid contained PCE, TCE, and cis-1-2-DCE. Surface water samples of Lake Druid contained PCE, cis-1,2-DCE, 1,1-DCE, and VC. Sediment samples of Lake Druid also contained PCE and TCE. These observations confirmed that natural attenuation of PCE was occurring at the site.

Laboratory treatability studies were conducted to evaluate the feasibility of natural attenuation of the plume, PCE and its breakdown products. The removal of PCE from groundwater in the OU4 sediments was determined to be primarily by sorption and biodegradation (Figure 1). Field and laboratory data (Figure 2) showed that active biodegradation of the chlorinated ethenes was occurring in the surface layer (0-14 ft) with halorespiration processes responsible for degradation in the source area sediments (group I) and co-metabolic processes responsible for degradation in the non-source area sediments (group II). Sorption was observed as an important removal mechanism in the organic rich sediments (foc > 2.5%) of group II (Figure 2). The lack of organic carbon (<1%) in the deep sediments (group III) appeared to limit biodegradation and sorption of PCE. Group III is characterized by incomplete biodegradation of PCE, and the sequential biodegradation of PCE does not proceed past cDCE within the incubation period of the laboratory experiments. Thus, the application of monitored natural attenuation (MNA) as the sole remedial technology of the OU4 site does not appear to be feasible given the incomplete dehalogenation of PCE in the non-source area and deep sediments. Further limitations to using MNA are the lack of a widespread highly reducing environments and low retention of the contaminants in the shallow groundwater system. The lack of a widespread reducing environment has been attributed to the shallow water table and high hydraulic conductivity (10^{-3} cm/sec) of the OU4 sediments. The oxygen flux through the site may be high enough to prevent the depletion of oxygen and the development of an anaerobic environment.

The addition of amendments at the OU4 site has the potential to accelerate reductive dechlorination of the chlorinated solvent plume and serve as an effective remedial technology for this site. This is accomplished in several ways. First, enhanced reductive dechlorination (ERD) can aggressively alter the redox state of ground water in a short time period. Increased microbial activity speeds up the exhaustion of naturally occurring electron acceptors (e.g., oxygen and nitrate) and creates a highly reducing zone in an otherwise aerobic/anoxic groundwater system associated with shallow groundwater flow systems. Second, the relatively homogenous hydrostratigraphy allows for areas of constant and predictable groundwater flow. The ability to predict and control groundwater movement is crucial for an effective distribution of electron donors and nutrients throughout the subsurface. The amended laboratory experiments with OU4 sediment demonstrated degradation of PCE and TCE to ethene, ethane and carbon dioxide. Deep sediment dehalogenation of PCE to VC and ethene occurred only with the addition of carbon sources. The OU4 sediment appears to have a wide range of substrate specificity and responded favorably to all amendments tested.

Green plants have been shown to take up and metabolize chlorinated organic solvents; with their root exudates providing natural carbon and electron sources to enhance biodegradation within the rhizosphere. Thus, the coupling of natural attenuation and phytoremediation was recommended for OU4 at NTC, Orlando. Recognizing that in the rhizosphere of some plants, released plant exudates and enzymes stimulate biochemical activity and enhance the biodegradation of environmental contaminants, phytoremediation treatability studies of PCE and TCE were performed in the greenhouse. The phytoremediation tests confirmed the reductive dechlorination and mineralization of PCE and TCE in the root-zone (rhizosphere) of willow and cottonwood trees. As a result, phytoremediation is being implemented at OU4-NTC to achieve three goals: (1) as a polishing step for the residual chlorinated solvents following source removal, (2) to reduce the high recharge to the shallow aquifer and minimize the rate of discharge into lake Druid, and (3) to enhance natural attenuation by increasing the amount of dissolved natural organic carbon (source of electrons) in the aquifer.

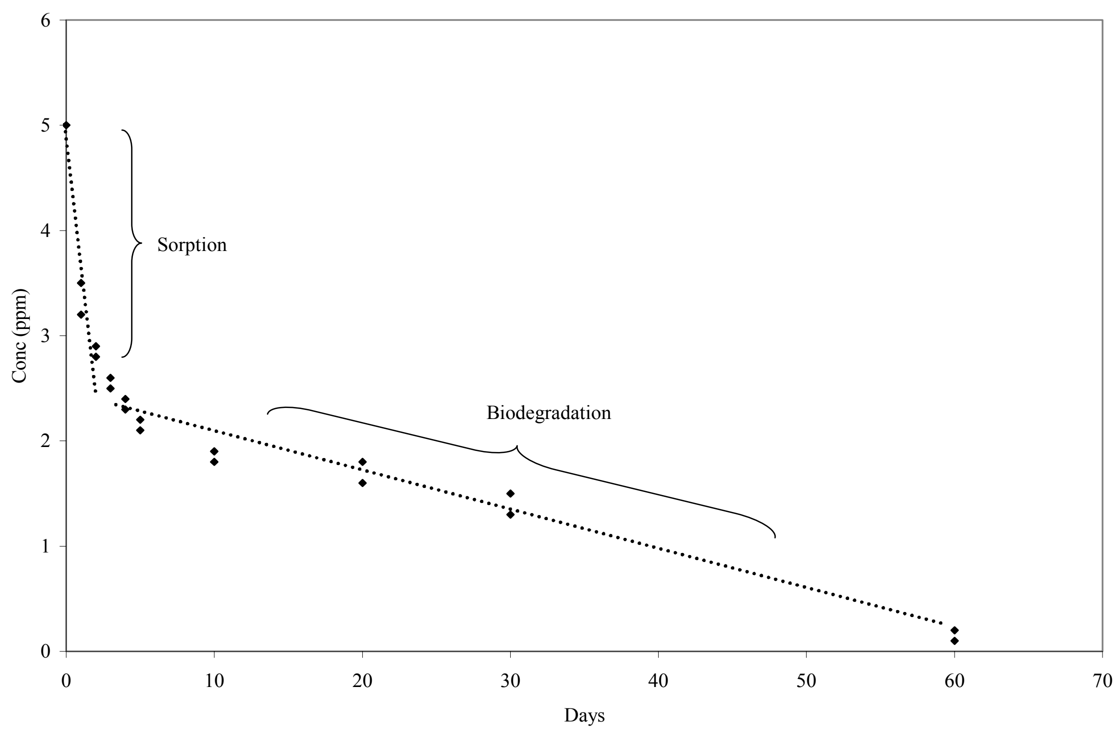

Figure 1: Primary mechanisms of PCE attenuation at OU4 Site.

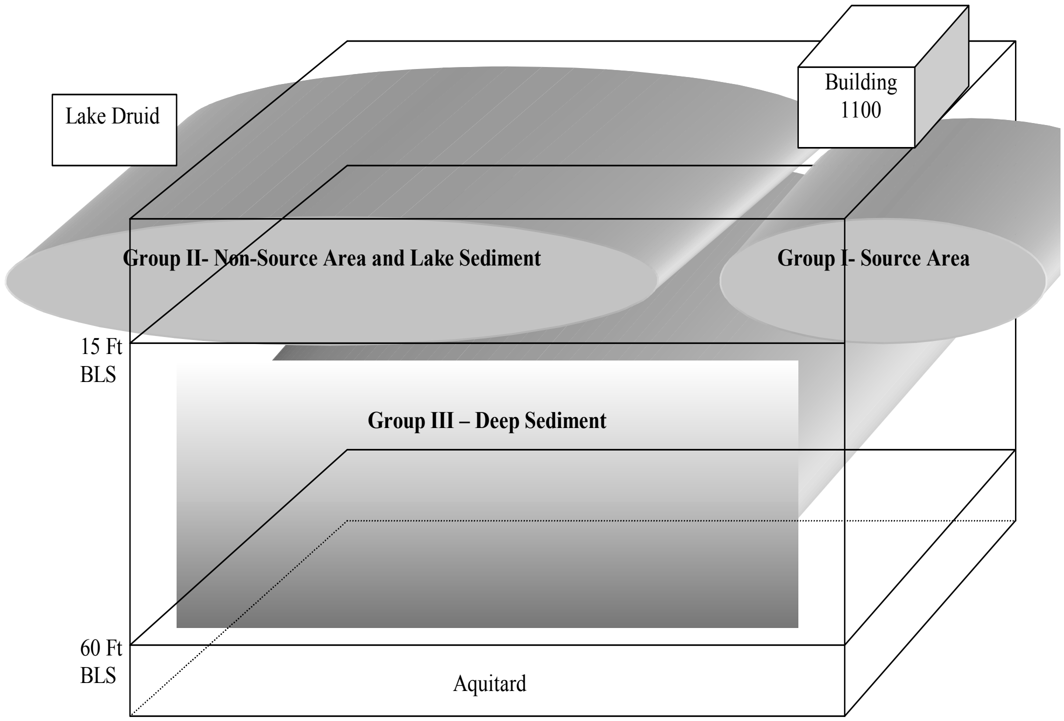

Figure 2: Zone of PCE attenuation at OU4 site

Based on the results of completed treatability studies and pilot tests, the remedial action plan for OU4 includes the use of chemical oxidation for source removal, and phytoremediation and natural attenuation as polishing steps. Willow trees will be planted near the source area and a constructed wetland installed near the Lake Druid in March 2002.