HRC ENHANCED BIODEGRADATION OF CHLORINATED ETHENES

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During the period 1990 through 1997, microbiologists at Harding ESE (then ABB Environmental Services) conducted bench scale testing followed by field pilot scale testing of enhanced biodegradation of perchloroethylene (PCE) under the EPA Superfund Innovative Technology Evaluation (SITE) – Emerging Technology Program. This research successfully demonstrated a sequential anaerobic/aerobic biodegradation process using various electron donors (lactic acid was found to be the most effective electron donor). During bench scale tests, saturated soil column simulations of anaerobic aquifer conditions demonstrated complete degradation of 20 mg/L PCE to 60% vinyl chloride (VC) and 40% ethylene with a contact time of 2 hours. Aerobic soil column simulations demonstrated that VC was degraded by methanotrophic bacteria when oxygen was provided through the addition of hydrogen peroxide.

The subsequent field pilot test was conducted at a site with contaminated groundwater containing 1,500 µg/L of PCE, 16,000 µg/L of trichloroethylene (TCE), 3,500 µg/L of dichloroethylene (DCE) and 100 µg/L of VC in Watertown, Massachusetts. The pilot test was conducted by isolating a small circulating groundwater cell (approximately 30 ft in diameter) in the central area of a larger solvent plume by using extraction and injection wells, and supplying lactic acid as electron donor. After a 4-month acclimation period, a significant reductive dechlorination period began which reduced the PCE to approximately 100 µg/L and the TCE to approximately 1000 µg/L, with DCE remaining essentially unchanged at approximately 3000 µg/L and VC increased to approximately 1000 µg/L. This degradation period was approximately 4 months long. At this time, the circulating cell was transformed to an aerobic condition by hanging ORC™ socks in the injection wells. Significant reductions were achieved (total ethenes reduced by half) in TCE, DCE and VC over the next 3 months until a premature ending of the test due to an accidental destruction of the equipment shed. Overall, total ethenes were reduced by approximately 70% in 11 months.

During the latter stages of the sequential pilot test, discussions with Regenesis led to the testing of their new product for enhancing reductive dechlorination during 1997-98. The site in Watertown was allowed to return to its original level of contamination, and then HRC-containing canisters were suspended in the injection wells and the circulating cell was once more initiated. After 206 days under anaerobic conditions created by the HRC, the initial concentrations of 1000 µg/L PCE, 13000 µg/L TCE, 3000 µg/L DCE, and 200 µg/L VC were reduced by 97% in total mass (Dooley, et. al., 1999). VC rose from approximately 200 µg/L to 3000 µg/L after the first 6 months, but then rapidly decreased to less than 100 µg/L. No significant accumulation of VC

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occurred and complete biodegradation of PCE, TCE and daughter products was demonstrated. After this successful demonstration of total biodegradation anaerobically, other projects using HRC were initiated. In the following, results from four enhanced biodegradation projects are described.

At a site in Michigan, a plume of DCE and VC is found in a silty sand aquifer. A totally passive application of HRC was implemented by using Geoprobe injection points in a fence-like pattern to intercept the plume. The concentration levels of both DCE and VC continuously decreased over a period of 6 to 7 months. The DCE reduction during this time exhibited a half life of approximately 80 days; the VC reduction was much less pronounced, but indicated a half life of approximately 200 days if no production of VC from the reductive dechlorination of DCE is considered.

At a site in Kansas a plume of primarily PCE, with low concentrations of daughter products, was found in an aquifer consisting of clayey soils. Concentrations of PCE in the treatment area were in excess of 6000 μg/L. HRC was injected as a fence across the migrating plume. Typical downgradient behavior showed that within 30 days, the PCE was almost totally degraded, but DCE increased markedly for 120 days to concentrations that were approximately 4 times the original PCE concentration (5 times on a molar basis). By the end of one year the total mass of contamination had been reduced to approximately 25% of the maximum attained on Day 120, and the levels of all constituents, including VC, were decreasing. Although a significant amount of DCE was produced due to an increased desorption effect, a continued supply of HRC caused biological activity to ultimately destroy the contamination without an excessive amount of VC being produced.

At a site in Tennessee a plume of primarily PCE and TCE was found to be slowly migrating in a clayey aquifer. Figure 1 shows results from a monitoring well located immediately downgradient of the injection fence line. At this location, initial concentrations of PCE at 12000 mg/L and TCE at 6800 mg/L were reduced to 0.075 mg/L and 0.38 mg/L respectively within 80 days. They were completely destroyed after 10 months. Concentrations of DCE initially increased and remained at elevated levels for until about 5 months after injection and then began to decrease. The total chlorinated solvent concentrations showed an 89% reduction in total ethenes from January to November. Although there was a significant increase in DCE during this period, VC levels remained relatively low and were not detected in the November sampling event. The overall results from this project indicate that the enhanced biodegradation technology was very effective at stimulating indigenous microbes to degrade the chlorinated solvent contamination. It is apparent that although there was significant generation of DCE in the reductive dechorination process, excessive VC accumulation did not appear to be a problem.

In the Blackstone River Valley in central Massachusetts a new high profile pilot test was recently begun at a Brownfields site which is in EPA's Superfund Innovative Technology Evaluation (SITE) program. A sampling episode conducted 7 months after injection revealed large decreases in TCE (typically from approximately 1000 μg/L to approximately 200 μg/L), large increases in DCE (typically from approximately 400 μg/L to approximately 1200 μg/L), but no

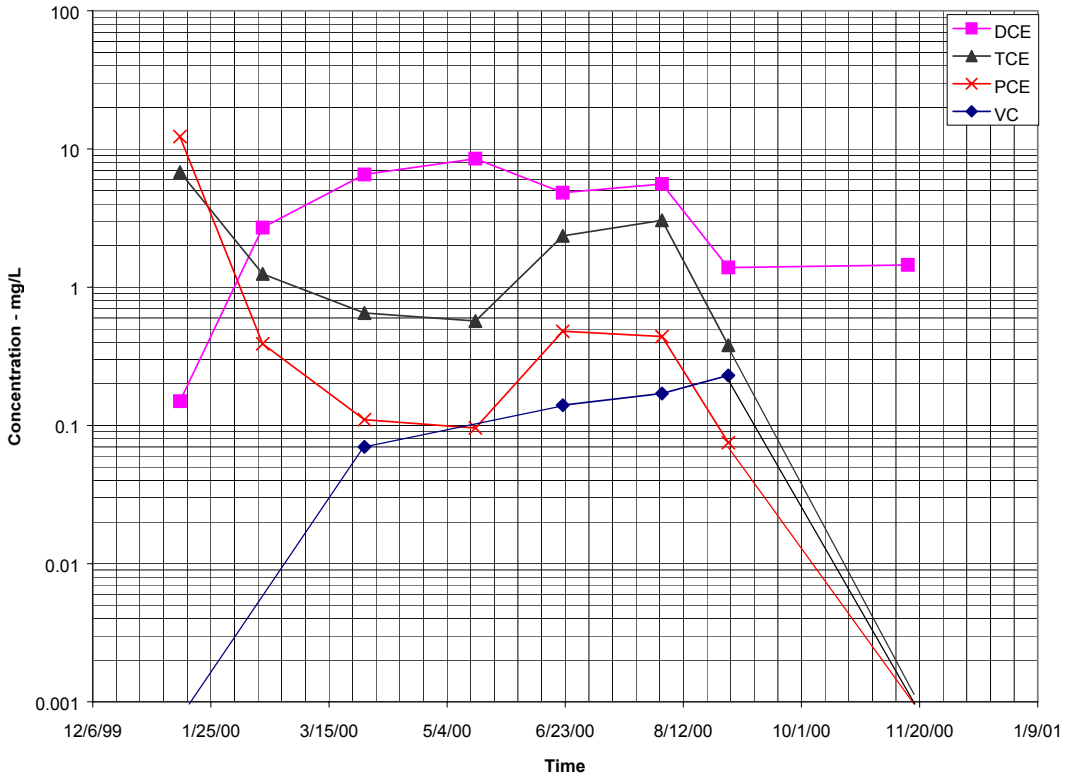

Figure 4. Tennessee Site – Downgradient Fence VOCs

change in VC which remained at less than 5 µg/L. Total ethenes increased in three monitoring wells from 11% to 26%, and since these wells are also associated with large conversions from TCE to DCE, the increases are no doubt due to the desorpton effect of increased biological activity. Three other monitoring wells showed decreases in total ethenes of 38% to 63% and these are no doubt an indication of total mass destruction, with no accumulation of VC.

The results from the various projects described herein all have similar implications. The first is that with HRC-enhanced biodegradation, it can be expected that initial results will show increases in total contamination. This is a result of increased rates of desorption of PCE and TCE off the aquifer solids due to their reduced concentrations in the groundwater. Then as soon as the PCE and TCE appear in the groundwater they are immediately biodegraded to DCE which keeps the process going. There may also be the microbial surfactants created in the aquifer to contribute to the production of increased concentrations where residual DNAPL is present. This should not be a concern but rather an assurance that the natural microbes have been stimulated into action. The second implication is that as long as the HRC electron donor does not become depleted, the total destruction of the chlorinated ethenes proceeds without significant accumulation of VC, and in some cases with no accumulation of VC.