REMEDIATION OF CHLORINATED ETHENES WITH ENHANCED BIOREMEDIATION

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Effective in-situ remediation strategies for soil and groundwater contaminated with chlorinated solvents such as tetrachloroethene (PCE) and its daughter products trichloroethene (TCE), 1,2-dichloroethene, and vinyl chloride, are restricted. Enhanced bioremediation through substrate enhancement has the potential to remediate chlorinated solvent sites. Addition of molasses and soybean oil to a PCE spill site reduced the initial concentrations by greater than 50 percent in the source area wells within 12 months of the substrate injection.

Contamination from chlorinated solvents was discovered at a textile knit facility in Eastern North Carolina. PCE, which was used in the dry cleaning process at the knitting facility, was stored in a 1,000-gallon aboveground storage tank (AST) behind the main facility. The AST was contained within a diked wall, consisting of concrete blocks and mortar, with a gravel floor. Three other ASTs containing spent PCE and sludge were also located inside the diked area. The PCE was transported from the ASTs to the knitting facility via surficial pumps and an underground piping system.

The soil characteristics/lithology of the site are described as a coarse to fine sand with clay lenses bounded by a dense clay at approximately 20 feet below ground surface. The clay acts as a confining unit. The initial contaminant plume extended approximately 1,000 feet down-gradient, where it intercepted a surface water feature. This surface water flows into a nearby river and is classified by the North Carolina Department of Environment and Natural Resources (NCDENR) as a Class C surface water. The uses of Class C water are aquatic life, fishing, and secondary recreation.

The concentrations of total volatile organic compounds (TVOCs) in the source area wells ranged from about 30 to 68,000 micrograms per liter (µg/L). The dissolved concentration of several VOCs in the source area wells was much greater than 1 percent (1%) of the aqueous solubility, which suggests the presence of dense non-aqueous phase liquid (DNAPL).

After the ASTs and the containment dike were removed, S&ME devised a two-phase plan to remediate the soil and groundwater. The first phase was designed to target the source area and residual contamination.

S&ME excavated approximately 650 cubic yards (875 tons) of contaminated soil. The soil was treated on-site by a steam distillation unit. Each batch of contaminated soil was

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processed in the unit for 2 hours with operating temperatures reaching 225°F. After cooling, the soil was unloaded from the unit and stockpiled on plastic sheeting. Soil samples from the stockpile confirmed the reduction in contaminant levels below NCDENR standards, and the soil was returned to the excavation as fill.

The second phase of remediation was designed to remediate the dissolved contamination in the saturated zone. Based on the presence of the daughter products in the source area which suggested that some degradation was naturally occurring, S&ME explored in-situ bioremediation as the remedial option.

Prior to implementing a full-scale remediation system, S&ME performed a laboratory treatability study. The objective of the treatability study was to determine the suitability of several organic substrates to enhance long-term reductive dechlorination of the chlorinated ethenes.

Nine different substrates were initially screened to determine their relative ability to enhance biodegradability. Each substrate was subjected to a Biological Methane Potential (BMP) assay, which consisted of the incubation of carbon substrate in an anaerobic liquid medium and the measurement of the resulting gas production. Based on the total gas production, three of these substrates (molasses and two types of soybean oils) were chosen for further testing.

Using soil and groundwater collected from the site, the testing proceeded by adding the three substrates and PCE to soil microcosm assays. The results of the additional testing indicated that indigenous microorganisms were present at the site that were capable of oxidizing organic substrates for the complete dechlorination of PCE to ethene. Two separate methods were designed to deliver these carbon sources to the subsurface.

1) An infiltration gallery was installed in the area of the former ASTs to infiltrate a water-molasses mixture into the saturated zone.
2) Food-grade soybean oil was injected into the lower portion of the surficial aquifer through numerous Geoprobe® points.

The infiltration gallery consists of four, rectangular distribution loops. Each loop is approximately 8 feet wide and 23 feet long and consists of 4 inch corrugated drain pipe. The gallery is enclosed within a geotextile membrane and No. 5 washed stone. Molasses injection has reached steady-state at approximately 7 GPM and 3,000 mg/L.

In order to expedite the bioremediation process in the lower portion of the surficial aquifer, food-grade soybean oil was injected directly into the aquifer with a Geoprobe®. Soybean oil was selected for injection because it has a lower solubility than molasses. Therefore, it was expected to last longer in the aquifer and create a biologically active zone without the need for continuous operation. An injection method was employed to leave a 10-foot slug of oil at the base of the surficial aquifer.

Results of the geochemical data suggest that the source area is conducive to the reductive dechlorination process. The data from two source area monitoring wells showed adequate evidence for biodegradation, after using the EPA Region 4 protocol for evaluating monitored natural attenuation. In addition, the results of the dissolved gas data show the presence of methane and ethene in the source area wells, which are good indicators that the anaerobic degradation of chlorinated ethenes is occurring.

Initial analytical results indicate that remediation is occurring without the accumulation of the more toxic daughter products, 1,2 dichloroethene and vinyl chloride. The latest analytical data indicates that the average concentrations of TVOCs in the source area wells have been reduced to approximately 3,600 µg/L. Initial PCE and TCE concentrations in the source area wells have been reduced by 97% and 96%, respectively.