REDOX TECH, LLC

"Providing Innovative In Situ Soil and Groundwater Treatment"

A CASE STUDY FOR THE APPLICATION OF ABC® INJECTION TO STIMULATE ANAEROBIC BIODEGRADATION OF CIS-DICHLOROETHENE AND VINYL CHLORIDE

Redox Tech, LLC developed a proprietary process to promote anaerobic biodegradation of chlorinated solvents in groundwater. The process involves the injection of a patented mixture (Anaerobic Biochem ABC®) of lactates, fatty acids, and a phosphate buffer. Unlike competitor's products, the mixture is specifically formulated for each site. ABC® contains soluble lactic acid as well as slow- and long-term releasing components. The phosphate buffer provides phosphates, which are a micronutrient for bioremediation. In addition, the buffer helps to maintain the pH in a range that is best suited for microbial growth. Using a GeoProbe® and proprietary injection equipment, Redox Tech is able to inject ABC® in most geologic environments, including low-permeability silt and clay. Redox Tech conducted a field pilot test to demonstrate the application of its injection process and its effectiveness on cis-dichloroethene (cis-DCE) and vinyl chloride.

AN INSIDE LOOK AT THE REDOX TECH REMEDIAL APPROACH

Many common organic groundwater contaminants can be treated in situ by enhanced anaerobic processes. These types of contaminants include chlorinated solvents, some chlorinated aromatics, nitroaromatics, inorganics (e.g. nitrate and perchlorate), and metals (e.g. chromium). With anaerobic biodegradation, the target contaminants are "reduced" with hydrogen, unlike chemical oxidation or aerobic processes where oxygen is the working chemical. For optimal anaerobic degradation to occur, more energetically favorable electron acceptors such as oxygen, nitrate, manganese, ferric iron or sulfate must first be consumed. There also must be sufficient food, or electron donors, for the bacteria to thrive. Microorganisms, like humans, breath electron acceptors and eat electron donors. To optimize anaerobic biodegradation, the goal is to choke the plume (deplete oxygen and other electron acceptors), before it starves (depletes food or electron donors). Electron donors can include co-contaminants such as petroleum hydrocarbons or natural organic matter. If these donors are not available or are not sufficient, the anaerobic process can be enhanced by introducing a food source into the subsurface. One of the most effective and environmentally benign food sources are fatty acids, such as ABC®. Under reducing conditions, the bacteria that degrade chlorinated organics use the chlorinated organics as electron receptors.

> Reductive dechlorination involves the sequential removal of chlorine atoms. Tetrachloroethene (PCE) is sequentially converted to its daughter products trichloroethene (TCE), cis-DCE, vinyl chloride, ethene, and ethane. Organisms capable of fully degrading PCE and TCE to ethene use hydrogen as a food source. However, excessive hydrogen levels will compete with and impede the growth of degrading microorganisms.

Natural degradation can be halted by:

- Inadequate source of food or electron donors
- Inadequate source or type of microorganism
- Highly reducing conditions in which competing microorganisms use the food source with alternative electron acceptors

[1] ABC® is protected by US Patent 6,001,252; Redox Tech has a license for this product.

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CASE STUDY RESULTS

MacDill Air Force Base

MacDill Air Force Base (MacDill) is located in Tampa, Florida. The base supports the Air Force Central Command and is approximately 5, 638 acres. It formerly served as a mission training base for F-16 fighter squadrons. Groundwater and soil at the site are contaminated with a wide range of contaminants, including petroleum products, pesticides, munitions, polychlorinated biphenyls, heavy metals, volatile organic compounds, and solvents. The pilot test was completed at Site 57, which contains trace levels of TCE, plus the anaerobic daughter products including cis-DCE and vinyl chloride (VC). The original TCE at the site has essentially anaerobically decayed, however, cis-DCE and VC levels were stagnant. Extensive geochemical data for Site 57 indicated that the conditions were reducing, but the conditions were not ideal for reduction of cis-DCE and vinyl chloride. Redox Tech formulated ABC® for Site 57 and used hydraulic fracturing to inject ABC®. The goal of the pilot test was to demonstrate that ABC® would stimulate degradation of the cis-DCE and vinyl chloride.

Redox Tech completed field activities at Site 57 in April 2003. ABC® solutions were injected near an apparent source zone of the cis-DCE plume, defined as concentrations greater than 700 ppb. The area also had high vinyl chloride concentrations, defined as concentrations greater than 70 ppb. The target interval was a silt, sand and limestone mixture, commonly called limestone mud. ABC® was injected at 18 locations circling monitoring well MW06A. As shown in Figure 1, the locations included an inner circle of 6 points located 5 to 10 ft from the well and an outer circle of 12 points located 15 to 20 ft from the well.

Redox Tech completed the injections with a Geoprobe® using standard 1-1/4 inch rods and a Geoprobe® proprietary injection tool. The injection was completed over a two and one-half day period. The formation first was hydraulically fractured with the ABC® solution at depth. Fracture initiation pressures were as high as 175 psi in some locations. The desired volume of solution was injected over each interval. Injections proceeded upwards from the bottom of the targeted interval in approximate 3-foot increments.

The enhanced biodegradation results from the ABC® injection are shown in Figure 2. Within weeks of injecting ABC®, there was a significant decrease in the observed levels of DCE. In conjuction and as expected, there was a corresponding increase in the levels of VC. The VC resulted from the anaerobic decay of the DCE. There was also an increase in ethene and ethane levels from the VC being converted to ethene and ethane. After two months, the DCE levels were below the regulatory limit. The VC continued to decrease after the DCE reach non-detect levels. Volatile fatty acid (VFA) analyses were completed during the test. The VFA levels increased after the injection and remained elevated for six months following injection. The site is now being considered for full-scale remediation with injection of ABC®.

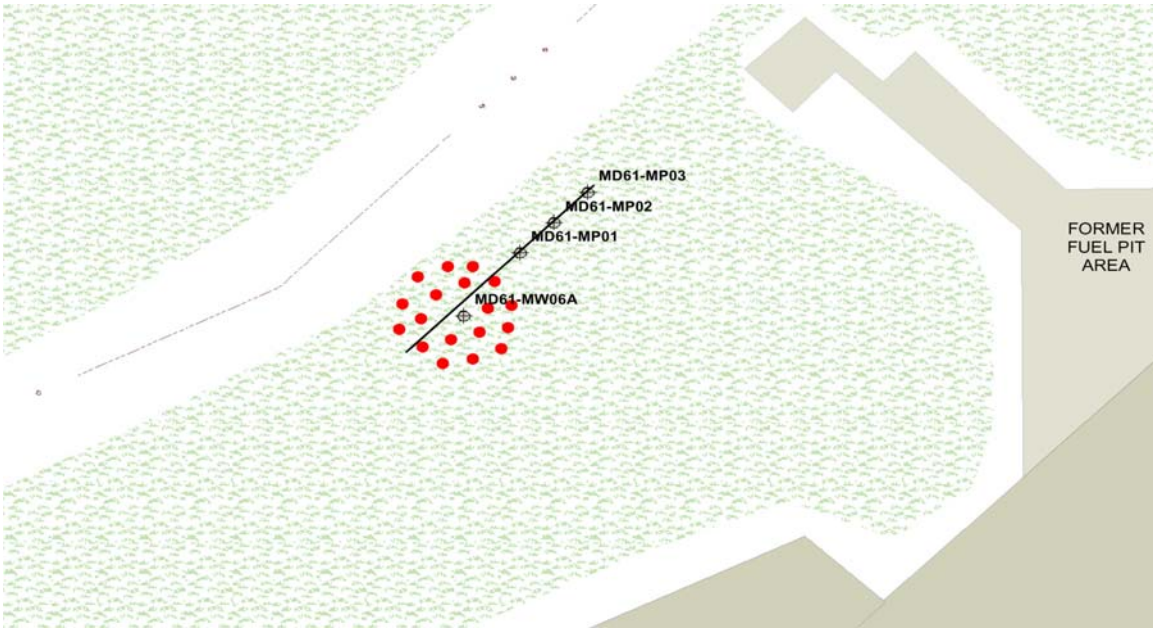

Figure 1. Injection Points and Monitoring Well Locations

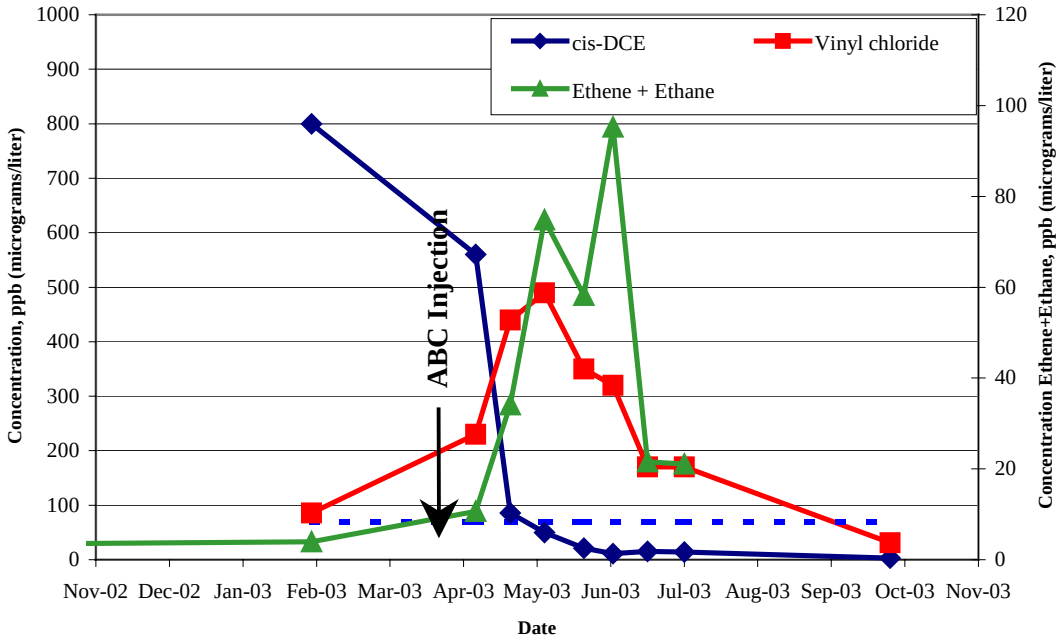

Figure 2. Monitoring Data from MW06A