Enhanced In-Situ Dechlorination Coupled with Bioaugmentation Successfully Treats Dry Cleaner Site

Dwight Schwendeman, REP Associates, Palm Beach Gardens, FL

Abstract

Concentrations of tetrachloroethene (PCE) and trichloroethene (TCE) were increasing in groundwater at a former dry cleaner site in Broward County, Florida. A chlorinated solvent plume had originated beneath an on-site structure and spread over an area of approximately 2,000 square feet. Over a 6-month monitoring period prior to remediation, the total concentration of chlorinated compounds increased from 6,000 to 15,000 parts per billion (ppb) (Well MW-1). Historical monitoring results showed no detection of daughter products cis-1,2-dichloroethene (DCE) and vinyl chloride (VC) indicating little or no intrinsic anaerobic biodegradation. To produce conditions favorable for anaerobic biodegradation, an in-situ, enhanced bioremediation approach coupled with bioaugmentation was selected to treat the site. Hydrogen Release Compound (HRC®) was selected as the electron donor to provide a slow, continuous release of lactic acid to the treatment zone. HRC was applied via five injection wells inside the building and 5 direct-push points to the north of the building immediately downgradient of the source area in June and September 2005. The bioaugmentation culture, Bio-Dechlor Inoculum (BDI™), was injected in seven discrete borings shortly after the HRC application. This approach was designed to establish and sustain subsurface conditions suitable for the chlorinated solvent degraders to be added, then to flourish and break down the chlorinated solvents. Monitoring results from 4 wells within and downgradient from the treatment zone indicated a decreasing trend in PCE and TCE concentrations accompanied by an increase in DCE and VC, indicating accelerated anaerobic biodegradation. PCE and TCE concentrations in MW-1 had decreased 95% by November 2005, approximately 5 months after the HRC application. By September 2006, PCE concentrations in MW-1 and MW-2 had declined to below the 3 ppb cleanup goal. Concentrations of DCE declined by more than 90% within ten months. A follow up application was implemented in late February 2008 to treat residual vinyl chloride in peripheral portions of the contaminated plume. The application included approximately 18,400 pounds of 3-D Microemulsion (3DMe)™ injected into 16 direct-push points similar to the location of the original HRC application.

In-Situ Bioaugmentation & Biostimulation

The remediation objective was to initiate a reducing environment to treat high concentrations of chlorinated solvents to cleanup goals (Table 1). HRC was applied to the subsurface both inside and outside the building, as seen in Figure 1. BDI was applied shortly after HRC.

- ***Application Type – Biobarrier***
- ***Application Rate – 7.3 lbs/ft HRC***
- ***Injection Spacing – 10 feet on-center***
- ***Total Product Cost - $20,416***
- ***Soil Type – Sand***
- ***Groundwater Velocity – 0.5 ft/day***
- ***Treatment Area – 2,000 ft²***
- ***Depth to Groundwater – 4 to 5 feet***

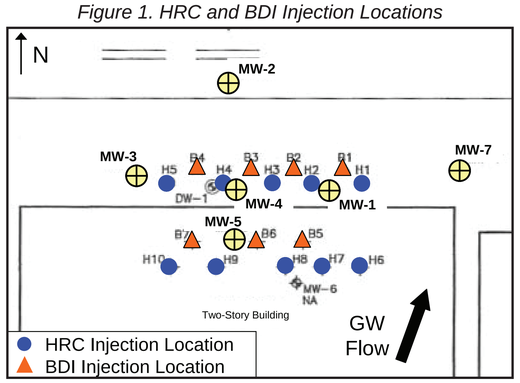
Table 1. Pre-HRC Concentrations (MW-1) & Cleanup Goals (ppb)

Contaminant	Concentration	Cleanup Goals
PCE	12,000	3
TCE	3,600	3
DCE	ND	70

Table 2 Product Details

Product	Quantity	Product Cost
HRC	1,380 lbs	$10,350
BDI	13 L	$2,340
3DMe	18,346 lbs	$7,726

Figure 1. HRC and BDI Injection Locations



Hydrogen Release Compound (HRC®)

HRC is a patented, controlled-release, polylactate ester mixture specially formulated to slowly release lactic acid upon hydration. When placed into a contaminated aquifer, the lactic acid from HRC stimulates a multi-step process, resulting in hydrogen production. The newly available hydrogen stimulates a microbially-mediated process resulting in the degradation of chlorinated compounds. Newly developed 3-D Microemulsion (3DMe)™ incorporates a fatty acid component as well as micelle technology for increased longevity and distribution.

Figure 2. Hydrogen Release Compound (HRC®)

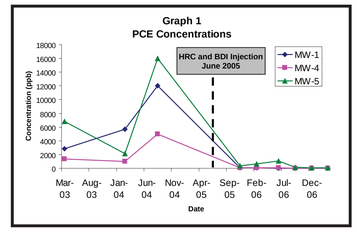
Bio-Dechlor Inoculum (BDI™)

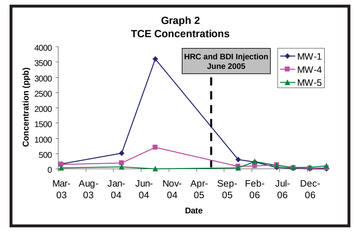
Figure 3. Dehalococcoides

BDI is an enriched microbial consortium containing species of *Dehalococcoides*. Originally isolated from an aquifer contaminated with chlorinated solvents, this microbial consortium has since been enriched to increase its ability to rapidly dechlorinate specific contaminants during in-situ bioremediation processes. This product offers the ability to accelerate the process of complete dechlorination at various stages of site remediation.

Results

As shown in Graph 1 and Graph 2, concentrations of PCE and TCE in closest proximity to the treatment area (MW-1, MW-4, and MW-5) increased significantly prior to the application of HRC and BDI. Within this same treatment area, concentrations were reduced substantially by November 2005 or 5 months post-injection. The decreasing trend was sustained as PCE and TCE concentrations reached less than 100 ppb.





Outside the injection area, Wells MW-2 and MW-7 demonstrated similar, positive results. PCE and TCE concentrations in Well MW-2 declined to non-detect levels within 8 months of the application. In Well MW-7, PCE and TCE were reduced by more than 87%, while concentrations of daughter products DCE and VC increased, demonstrating a clear sign of reductive dechlorination. Concentrations in Well MW-3 remained non-detect throughout the monitoring period.

Table 3. DCE and VC Concentrations in MW-4 (ppb)

Contaminant	Mar 2003	Feb 2004	Aug 2004	HRC BDI Applied	Nov 2005	Feb 2006	June 2006	Sept 2006	Dec 2006	Mar 2007
DCE	ND	ND	ND		370	250	53	31	71	75
VC	ND	ND	ND		5.1	170	16	94	66	56

Table 4. DCE and VC Concentrations in MW-5 (ppb)

Contaminant	Mar 2003	Feb 2004	Aug 2004	HRC BDI Applied	Nov 2005	Feb 2006	June 2006	Sept 2006	Dec 2006	Mar 2007
DCE	ND	ND	ND		44	450	140	530	160	180
VC	ND	ND	ND		ND	7	3	72	170	210

Prior to the HRC and BDI injection, there was little evidence of biological degradation occurring at the site and PCE and TCE concentrations continued to increase. Following the application of HRC and BDI, PCE and TCE concentrations declined by more than 95% within a 5 month period. The removal of the parent products can clearly be attributed to sequential biological degradation as evidenced by the formation and subsequent reduction of daughter products indicated in Tables 3 and 4.

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