

Chlorinated Solvent Remediation and Plume Management at a Dry Cleaning Facility using an Enhanced In-situ Biodegradation Technology

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ABSTRACT: Injection of a time-release source of lactic acid (HRC[®]) into a plume of PCE-contaminated ground water in a shallow aerobic aquifer beneath a dry cleaning facility resulted in (1) a significant increase in the rate of biologically-mediated degradation of PCE and its daughter products and (2) a greater than 95% reduction in PCE concentrations near the source area in 12 months. The injection of a lactic acid source created an anaerobic and nutrient-rich environment, thus accelerating reductive dechlorination. Degradation rates increased most rapidly near the source area where an acclimatized bacterial population may have been present due to an historic discharge of No. 2 fuel oil that provided a carbon source for reductive dechlorination. Lower rates of degradation and a lag effect for the onset of accelerated degradation were observed in other areas of the treatment zone. Fresh water influx due to differential recharge near the margins of the plume appears to have somewhat limited the effectiveness of the lactic acid source in altering the aquifer geochemistry near the plume margins. Ongoing ground water monitoring indicates that, more than one year after injection, most of the treated area remains anaerobic and PCE concentrations continue to decrease.

Application of a time-release source of lactic acid (Hydrogen Releasing Compound [HRC[®]]) was performed at a dry cleaning facility in central New Jersey to enhance natural degradation of chlorinated hydrocarbons in ground water. HRC[®] is a food-grade polylactate ester (glycerol tripolylactate) designed to provide a carbon energy source and create anaerobic, reducing conditions in ground water to stimulate reductive dechlorination of chlorinated solvent compounds such as tetrachloroethene (PCE) and trichloroethene (TCE). The results indicate that successful alteration of groundwater chemistry and resulting accelerated degradation of contaminants have been achieved.

The dry cleaning facility is located at the end of a strip mall and bordered on the north and east by residential properties. Subsurface geology consists of a shallow sand aquifer overlying a clay confining unit with an average depth to ground water of approximately 10 feet (3 m). Water levels have a strong seasonal influence (± 1.5 feet [0.5 m]), and differential recharge between the fully paved shopping center and the residential yards appears to significantly affect ground water flow.

A plume of chlorinated hydrocarbons (PCE and degradation products TCE and *cis*-1,2-dichloroethene [*cis*-1,2-DCE]) emanates from the rear of the dry cleaners and extends offsite to the north. PCE concentrations between 1,000 and 3,000 ug/L were detected near the source area and up to 4,000 ug/L were detected near the downgradient property boundary, approximately 120 feet (37 m) from the source area. Soil sampling indicated a source area near a storm sewer catch basin behind the dry cleaners. Source area soils were removed to mitigate a potential continuing source of volatile organic compounds (VOCs) to ground water. Concurrently, an adjacent underground fuel oil tank was also removed and evidence of a minor fuel oil release

was observed. This fuel oil may have provided a carbon source and created reducing conditions in ground water in the immediate vicinity of the UST.

The presence of degradation products of PCE (TCE and *cis*-1,2-DCE) in site ground water indicated that degradation was occurring naturally, but at a very slow rate. However, ground water geochemistry parameters including dissolved oxygen (DO) and oxidation reduction potential (ORP) indicated that the aquifer was slightly to moderately aerobic with DO ranging from 1,000 to 3,000 ug/L and ORP around +200 mV. Total organic carbon (TOC) concentrations ranged from 0 to 1,000 ug/L. Such conditions are not considered favorable for biologically mediated natural attenuation of chlorinated compounds.

HRC[®] was applied in a grid designed to completely cover the on-site plume area and in a downgradient permeable barrier wall at the off-site leading edge of the plume. Ground water monitoring was performed to monitor the effects on aquifer geochemistry and the increase in biodegradation rates. The use of HRC[®] resulted in a significant increase in the rate of degradation of chlorinated solvents and a greater than 95% reduction in PCE concentrations near the source area during the initial 6-month period and continued reduction up to one year following application. Changes in VOC and geochemical parameter concentrations during the application period are provided on Table 1.

TABLE 1: Representative Ground Water Monitoring Data from Full Scale Treatment

	MW1S			MW2		
	Initial	6 mos.	12 mos.	Initial	6 mos.	12 mos.
PCE	1400	30	2.3	550	310	190
TCE	ND	48	1.6	11	220	93
<i>cis</i> -1,2-DCE	110	270	240	ND	28	49
DO	5,300	1,000	280	2,420	9,600	700
ORP	240	-66	-146	223	-5	37
TOC	ND	720,000	NA	ND	2,400	NA
lactic acid	ND	394,000	NA	ND	ND	NA
	MW3			MW6		
	Initial	6 mos.	12 mos.	Initial	6 mos.	12 mos.
PCE	280	42	51	31	14	63
TCE	5.9	570	110	0.6	0.4	19
<i>cis</i> -1,2-DCE	41	140	390	3	0.96	22
DO	ND	1,400	700	2,730	400	710
ORP	106	-167	-130	287	-141	-46
TOC	1,000	64,200	NA	ND	5,800	NA
lactic acid	ND	1,700	NA	ND	ND	NA
All concentrations in ug/L			ND - Not Detected			
ORP in mV			NA - Not Analyzed			

The conclusion that the rate of reductive dechlorination in the treatment areas increased dramatically following treatment is based on the decrease in PCE concentrations, the increase and subsequent decrease of TCE concentrations, and the increase in *cis*-1,2-DCE concentrations within the plume area. At MW1S, located 16 feet (5 m) downgradient of the source area, PCE was consistently between 1,000 and 2,000 ug/L in the two years prior to the HRC[®] application. PCE decreased to 75 ug/L by 67 days after treatment and was most recently measured at 2.3 ug/L at 376 days. Concurrently, TCE levels increased from < 1 ug/L to 1,000 ug/L at 67 days, and

have since decreased to 1.6 ug/L at 376 days. *Cis*-1,2-DCE concentrations initially increased and have remained stable over the last six months, indicating that *cis*-1,2-DCE is also degrading. Vinyl chloride has not been detected in any wells suggesting either extremely rapid degradation or an alternate degradation pathway for *cis*-1,2-DCE.

Geochemical parameters in MW1S all indicated the development of favorable anaerobic, reducing conditions. DO remained below 0.5 ppm; ORP readings remained less than -100 mV; and there were significant increases in ferrous iron concentrations and some sulfide formation. The TOC concentration increased dramatically after the first month following treatment and has since remained above 200,000 ug/L. Similar, though not as marked concentration trends were observed in MW3, also located within the core of the plume.

MW2, located near the plume margin and residential properties, may be affected by fresh water influx due to differential recharge between the unpaved residential areas and the paved shopping center. PCE concentrations decreased by 50% since the injection while TCE and *cis*-1,2-DCE have steadily increased indicating reductive dechlorination is occurring, but at a slower rate. However, unlike MW1S and MW3, PCE concentrations remain higher than those of either of its daughter compounds. Changes in the aquifer geochemistry were also less at MW2. At this location, HRC[®] did not create the same level of reducing conditions as in core wells MW1S and MW3. DO readings fluctuated between anaerobic and aerobic conditions and ORP remained consistently near 0 mV. The increase in TOC concentrations averaged less than 10,000 ug/L.

Concentration trends at off-site well MW6 have been less clear. PCE initially decreased after treatment, but subsequently increased to concentrations higher than the initial concentration. The increased concentrations of TCE and *cis*-1,2-DCE indicate reductive dechlorination. However, because a large portion of the off-site plume (between the site and the offsite barrier array near MW6) was not directly treated, it is believed that the increase in PCE concentrations at MW6 is a result of the migration of contaminated ground water from the untreated area toward the barrier wall. Chlorinated compounds have not been detected at levels of concern in a sentinel well (MW5S) downgradient of the barrier wall.

In summary, injection of HRC[®] into a plume of PCE-contaminated ground water beneath a dry cleaning facility effectively changed the chemistry of the aquifer to an anaerobic and nutrient-rich environment, thus accelerating reductive dechlorination of chlorinated solvent compounds. In the core of the plume (MW1S and MW3), PCE concentrations have decreased by up to 99% in the one year since injection of the HRC[®]. Ongoing ground water monitoring indicates that more than one year after injection, the majority of the treated area remains anaerobic and PCE concentrations continue to decrease. The results from this site provide further evidence that in-situ methods of altering ground water chemistry to create a favorable environment for biodegradation can be an extremely effective means of remediating ground water contamination, particularly at sites with a reasonably permeable aquifer. In treatment design applications, it appears that both full plume coverage and barrier wall-type systems can be effective. Where practicable, complete coverage of the source and nearby areas will likely be more effective at mitigating impacts than a barrier wall only design. In addition, the potential for the influx of untreated aerobic water near the plume margins should be evaluated to ensure adequate amounts of the treatment agent are injected in areas where fresh water influx may be significant.