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Vacuum-Enhanced, Dual-Phase Extraction and Bioremediation with HRC® HRC-Advanced®/HRC-XTM for Remediation of Chlorinated Hydrocarbons

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Introduction

A site-wide remedial approach to address significant chlorinated hydrocarbon contamination was used at a former chemical manufacturer/distributor in northern New Jersey.

Solvent Distribution Facility

Initial remedial actions conducted included decommissioning of an aboveground storage tank farm and remediation of accessible unsaturated impacted soils; however, elevated concentrations (over 10,000 µg/l) of volatile organic compounds (including tetrachloroethene (PCE), 1,1,1-trichloroethane (TCA), and their respective daughter products) were still present in site groundwater indicating significant saturated soil contamination and the potential for Dense Non-Aqueous Phase Liquid (DNAPL) to be present. Significant volatile organic compound (VOC) contamination was migrating into a small stream traversing the property.

A purchaser sought to redevelop the property; however, due to the proposed mixed residential and commercial use, obtaining site closure became a paramount concern. No single technology was appropriate for site remediation.

A site-wide remedial strategy was developed and a fixed price to closure contract with a cost cap insurance policy was executed to allow sale and development of the property.

Based on pilot studies, a combination of vacuum-enhanced, dual-phase extraction (DPE) and enhanced bioremediation with Hydrogen Release Compound (HRC®, HRC_Advanced® & HRC-X™) was used for remediation of the site.

The integration of an extraction technology in the source area with a migration barrier technology (bioremediation) between the source area and the recovery wells has allowed for efficient and effective treatment with significant progress toward overall site remediation being achieved.

The development and implementation of this site-wide remedial strategy at this brownfields site enabled the property to be sold and redeveloped for effective mixed commercial and residential use.

Site Description

The site is a former chlorinated solvent distribution facility. PCE and TCA were stored in aboveground storage tanks and distributed in chemical totes and drums.

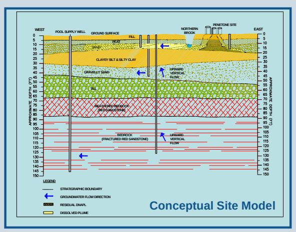
Groundwater in the overburden is generally encountered in two zones separated by a silt zone. The unconfined zone is encountered 5-10 feet below grade.

The silt aquitard is present in nearly all areas of the site, and is nearly 20-30 feet thick. The confined zone is encountered beneath the aquitard. Contaminants are not consistently detected in wells screened in this zone beneath the source area.

Bedrock (sandstone and siltstone) is encountered 80-90 feet below grade. Significant upward gradients have been observed at all well clusters screened in both overburden and bedrock. No contaminants have been detected above standards in the monitoring wells screened in bedrock.

The highest groundwater concentrations (including TCA at concentrations ranging from 12,000-55,000 µg/l) indicative of dense non-aqueous phase liquids (DNAPL) had been encountered in the unconsolidated zone in the aboveground tank farm area.

TCA and PCE daughter compounds including chloroethane (CA) and vinyl chloride (VC) were detected downgradient of the source area indicating indigenous active reductive dechlorination.



Conceptual Site Model

Site-Wide Remedial Strategy

A multi-phased remedial approach was developed to address site contamination:

- upgrading of the existing groundwater recovery and treatment system;
- vacuum-enhanced DPE and grid injections with HRC-Advanced® as source control measures; and
- injection of an (HRC® & HRC-X™) barrier system to provide management of migration control of contaminated groundwater discharging to an on-site stream.

Groundwater Recovery and Treatment

The groundwater treatment system was upgraded by installing a chemical precipitation pretreatment system consisting of:

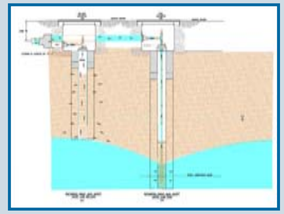
- hydrogen peroxide addition to oxidize soluble iron;
- coagulant/polymer addition to promote flocculation; and
- iron sludge precipitation using an inclined plate clarifier.

Integrated Remedial Technologies

Source Remediation

Source area remediation was implemented with installation of a high vacuum DPE system. The DPE system combines groundwater recovery and soil vapor extraction into one process. The DPE system consisted of the following:

- A single liquid ring pump located aboveground providing a vacuum which extracts groundwater and soil vapor simultaneously from an extraction well.
- Eleven extraction shallow/deep well clusters (total of 22 wells) installed across the source area with:
  - shallow extraction wells screened across the vadose zone and the upper five to eight feet of the saturated zone;
  - deep extraction wells screened across the base of the unconfined zone "keyed" one to two feet into the silt aquitard.
- Each well cluster was piped to the DPE system trailer and controlled by individual manifolds for maximum operation flexibility.
- This innovative extraction well cluster design resulted in optimum VOC mass recovery from the impacted saturated soils and groundwater.



Shallow / Deep DPE Well Cluster Operation

DPE System Operation

The DPE System was operated using alternating zones of DPE well clusters. The zoned operation resulted in enhanced dewatering of specific areas of higher levels of contamination optimizes VOC mass recovery from the saturated soils due to applied airflow in these areas. The zones of DPE wells were rotated on a periodic basis as well as overall operation of the majority of the DPE wells to ensure hydraulic control was maintained.

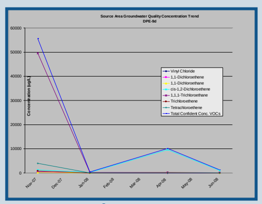
The results of recovered vapors and groundwater monitoring indicated that more than 8,000 pounds of VOCs were removed since DPE system initiation. The DPE system had the added benefit of achieving hydraulic control of the source area, virtually eliminating contaminant migration from the source area to the on-site stream.

Prior to DPE initiation, the average VOC concentration at the most contaminated surface water sampling location was more than 300 µg/l; concentrations at this location subsequently decreased to less than 10 µg/l with no compounds detected above New Jersey surface water quality standards.

A significant improvement in groundwater quality was also observed in the source area. The significant improvement in groundwater quality in the source area confirmed that the DPE system was also remediating the source of groundwater contamination.

HRC-Advanced® Grid Injections

Following several years of DPE system operation, residual areas of contamination were also remediated using grid injections of HRC-Advanced®. HRC-Advanced 3-D Microemulsion (3DMe)™, a newly derived form of HRC® from Regenesis, is the new paradigm in time release electron donors for groundwater and soil remediation. Upon injection, the controlled release of lactic acid dominates serving to initiate and stimulate anaerobic dechlorination. Over time the controlled-release of fatty acids will dominate, acting to continue microbial stimulation. The expected single-injection longevity of this product is 1-2 years and in excess of 4 years under optimal conditions.

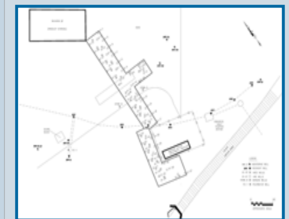


HRD-Advanced® Monitoring Well Results

HRC-Advanced® was injected using Direct Push Probe techniques in a 10-foot grid pattern encompassing each DPE well cluster. Groundwater quality monitoring from the DPE well cluster revealed that the total VOC concentrations in the well cluster reduced over 90% up to six months following injection. Based upon the results of the pilot study, three additional DPE well operations were terminated and HRC-Advanced® grid injections were conducted. Similar positive results were realized at these DPE well clusters with greater than 97% reduction in Total VOCs observed over a six month monitoring period. In March 2009, the DPE system operation was terminated and an HRC-Advanced® grid injection program implemented throughout the former source are to address residual areas of contamination, as required.

Migration Barrier

HRC® is a proprietary, food quality, polylactate ester manufactured by Regenesis, Inc. and is used to enhance in situ biodegradation rates for chlorinated hydrocarbons by fueling anaerobic reductive dechlorination processes. HRC® slowly releases lactate upon being injected into the subsurface. This lactate is metabolized by naturally occurring microorganisms, resulting in the creation of anaerobic aquifer conditions and the production of hydrogen. Naturally occurring microorganisms capable of reductive dechlorination then use the hydrogen to progressively replace halogen (chlorine) atoms with a hydrogen atom.



HRC® and HRC-XTM Migration Barrier

HRC® will typically continue releasing hydrogen for up to 18 months, depending on site conditions. A new Regenesis product, HRC-X™, has an extended lifespan of up to 36 months in the subsurface. HRC-X™ works by the same process as standard HRC® but has a slower rate of lactic acid release, prolonging the useful life of the material. Because HRC-X™ is sustained in the environment longer, it is useful for barrier applications, as the number of reinjections necessary during the life of the project is reduced. The drawback is that initial lactic acid release is slower than with standard HRC® which increases the time between injection and full biologic activity. Injecting standard HRC® at the same time will improve short-term performance. Subsequent applications were made using HRC-X™ only.

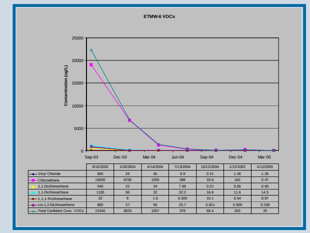
HRC®/HRC-X™ Full Scale Migration Barrier

A total of 4,260 pounds of HRC® and 6,390 pounds of HRC-X™ were injected at 69 individual locations perpendicular to groundwater flow. Two permanent monitoring wells were installed to provide monitoring of the effectiveness of the barrier.

Review of post-injection monitoring results for the first year indicated sustained concentrations of metabolic acids and/or anaerobic gas generation (methane, ethane, ethene, and CO_2) at the downgradient monitoring point. Dissolved oxygen and ORP measurements confirmed anaerobic conditions continued to be achieved in groundwater.

Approximately one year following injection, Total VOCs decreased by 50% in the well (ETMW-5) installed upgradient of the HRC® barrier; this is attributed to source remediation efforts and ongoing natural reductive dechlorination. The decrease evident in downgradient monitoring well ETMW-6 was significantly greater than that of ETMW-5. The significant greater decrease (>99%) in ETMW-6 was attributed to the HRC® and HRC-X™ injections.

The monitoring program conducted to evaluate the HRC® and HRC-X™ injections clearly demonstrated the effectiveness of the HRC® and HRC-X™ injections as a migration barrier. Subsequent barrier reinjections were conducted using primarily HRC-X™.



Migration Barrier
Downgradient Monitoring Well Results

Conclusion

The integration of multiple technologies to remediate different portions of a groundwater plume contaminated by chlorinated hydrocarbons has effectively addressed the key site-wide risks at the site by eliminating migration of contaminants to the on-site stream and off-site through groundwater flow.

Effective remediation of DNAPL and elevated concentrations of VOCs in groundwater has been achieved as well as minimizing off-site groundwater contaminant migration through the upgraded pump and treat system and the HRC®/HRC-X™ migration barrier.

Redevelopment of this brownfields property for mixed residential and commercial use is currently being implemented. A conditional no further action for soils has been received from the regulatory agency for the southern portion of the property for residential use.

The northern portion of the property will be developed with institutional and engineering controls in place for residual contaminated soils and groundwater. These controls include a deed notice, surface capping and vapor intrusion remedial systems beneath the proposed commercial buildings. The active remedial system has been relocated on the property to allow continued operation during and following redevelopment.

A site-wide remedial strategy integrating various remedial technologies, institutional and engineering controls can be successfully applied at brownfields sites to enable effective development of environmentally impacted properties.