ORC TECHNICAL BULLETIN # 2.2.2.8

Oxygen Release Compound, ORC®

ORC Injection Vinyl Chloride Remediation

Introduction

Residual vinyl chloride concentrations have been remediated in the field at a mid-western site with ORC®. The site was formerly an aluminum coating facility that stored aromatic and chlorinated solvents in an underground storage tank (UST). The UST created a narrow plume in a prolific sandy aquifer less than twenty feet thick. The plume was approximately 350 ft. long by 40-60 ft. wide at the completion of the site investigation and prior to the start of remediation. Remediation of the solvent plume was completed in on-site areas. An off-site plume of vinyl chloride remained with dissolved concentrations just above generic residential clean-up criteria.

The rate of natural attenuation of vinyl chloride had stalled during the previous year and vinyl chloride reached the first sentinel well RL-5A in October 1997. At the same time, prior to treatment, the off-site vinyl chloride concentrations were between 2.4 to 37 parts per billion (ppb) over five locations.

The objectives were to complete the remediation of the off-site vinyl chloride with ORC through oxidation and enhancement of the indigenous bacteria to expedite vinyl chloride attenuation. Groundwater sampling results prior to and following injection of the ORC indicated a significant reduction of vinyl chloride concentrations within the first month in the treated areas. Rebound was observed downgradient of areas that did not receive full treatment.

The ORC project was tailored to the site's unique conditions that involved multiple contaminants, and other sources adjacent to the subject plume. In this instance, this technology provided a surgical tool to address contaminants within the plume without risking the hydraulic disturbance of contaminants from the unrelated areas. With the use of ORC, the regulators were able to approve the shut down of the advanced oxidation and SVE systems to reduce operational costs.

When ORC injection was initiated, only the off-site solvents plume remained for remediation. The wells impacted included RL-1A, RL-5A, and RL-7A. Unimpacted off-site wells included NW-5, MW-7, MW-9, and MW-10. This remaining impacted area, measured approximately 250 ft. long by 40 ft. at the time of ORC injection in March of 1998 (see Figure 1). Since the on-site area has been remediated only the off-site portion of the plume is shown on Figure 1. Off-site sources in and adjacent to the solvents plume included a former gasoline retail station, petroleum bulk storage area, and a former coal gasification facility. Mainly non-chlorinated petroleum compounds were associated with the off-site sources also remain co-mingled with the off-site vinyl chloride plume. These sources are located along the vinyl chloride plume or just to the east of the vinyl chloride plume shown on Figure 1. This co-mingling of non-chlorinated compounds in these areas was justification alone for the use of a non-invasive remedial technology.

In 1994 all parties historically involved with the on-site activities opted for generic residential clean-up criteria to eliminate future liabilities. These established remedial objectives included active remediation for only the on-site portion (source) of the solvent plume. The off-site dissolved plume was not initially targeted due to the co-mingled nature of the downgradient portion (off-site) of the solvents plume and the lack of involvement of the other parties in the clean-up.

During the site investigation it was determined that groundwater was encountered in medium sands at 13 to 19 feet (3.96 to 5.79 meters) and bounded on the bottom with a silty clay at approximately 30 feet (9.14 meters). The groundwater flow in this area is to the north-northwest at a velocity of 0.012 feet/day (4.2×10^{-7} cm/sec) with a nearly flat gradient at the site.

Results

Active remediation of the site was initiated in the Fall of 1995. Closed loop soil vapor extraction was employed at the site in conjunction with advanced oxidation of the dissolved solvent plume (subject plume) located on-site. During the operation of the remediation system groundwater was extracted downgradient of the source and highly oxygenated groundwater was reinjected upgradient of the dissolved plume. The groundwater system reduced dissolved concentrations on-site to less than generic residential criteria by April of 1997.

Direct injection of ORC was utilized within an area of residual vinyl chloride contamination found off-site. Based on the vertical, aerial extent of the plume, the ORC was injected with a grout pump and direct-push drilling technology within the vinyl chloride plume in grid with a roughly 12-5 foot spacing. Each boring was injected with the ORC slurry from the aquitard at the base of the aquifer to approximately one foot above the water table. STS Consultants utilized approximately twenty-five percent more ORC that recommended by Regenesis.

The ORC injection was performed in March of 1998. Based on the results as presented on Table 1 the monthly groundwater results (per EPA Method 8260) have shown attenuation (beginning in the first month). The results suggest that it is feasible to remediate vinyl chloride in the field by delivering oxygen to the saturated zone. In areas with adequate spacing for ORC addition (ie. RL-5A), complete remediation of vinyl chloride was observed within three to four months. Table 1 shows the vinyl chloride concentrations in the wells located off-site prior to and following treatment.

The monthly analytical results indicate that these areas have attenuated at an accelerated rate since addition of ORC. Rebound was observed after four months in areas monitored immediately downgradient of untreated areas. The right of way associated with RL-1A and the roadway associated with RL-7A are the primary areas not treated in the first phase of ORC injection. At this time the sentinel well is consistently below generic residential criteria for vinyl chloride. Measurement of dissolved oxygen in the monitor wells located along the spine of the plume indicates that the effectiveness of the magnesium peroxide at this site was limited to approximately three to four months, possibly due to impact from other known contaminant sources in the system.

Conclusion

The method of oxygenation was tailored to the existing site conditions, multiple contaminants, and orientation of sources adjacent to the subject plume. This technology provided a controlled means of remediating contaminants within the site's plume without the risk of hydraulically influencing extrinsic contaminants from unrelated source areas. The use of this technology also facilitated regulatory approval to shut down the advanced oxidation system and the SVE system to reduce overall operational costs. The migration of the plume beyond the sentinel wells was effectively stopped.

Results suggest that spacing and the appropriate quantity of the ORC is important for success. Rebound occurred where planned spacing was not adhered to. The presence of roadways, buildings, and utility corridors, which precluded a uniform application, may have increased the amount of time required to remediate contaminants. Sparse placement of injection points and reduction of stoichiometrically sound quantities is not recommended.

It is important to remember that the primary focus of these activities was to remediate the plume and do this at a reasonable cost. This study did not therefore include bench studies, microbial population assays, or other ancillary field testing.

STS has recently reapplied ORC in December 1998 to the area in the same locations. This application has also included additional injection points in the roadway that bisects the body of the plume. The data will be evaluated in the months following the December 1998 treatment to further evaluate the effectiveness of this technology.

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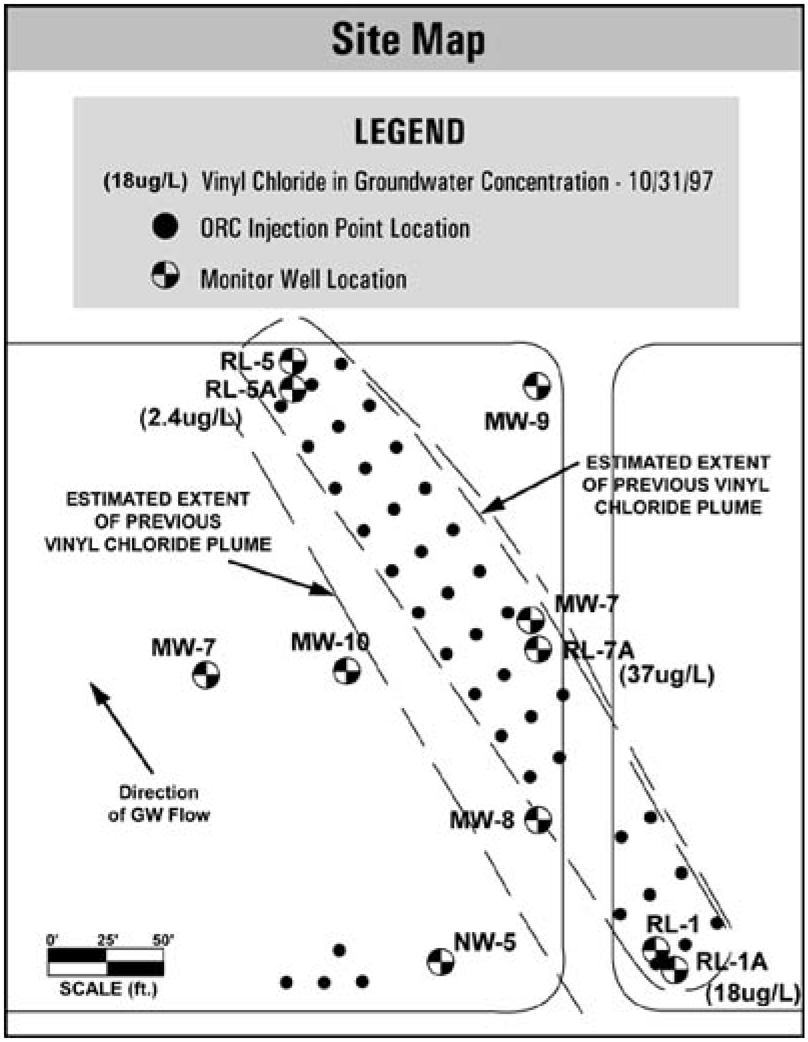

Figure 1

Date	RL-1A (ppb)	RL-5A (ppb)	RL-7A (ppb)
4/17/97	15	BQL	34
10/31/97	18	2.4	37
12/17/97	NS	5.0	NS
3/98	Inject ORC	Inject ORC	Inject ORC
4/15-16/98	5.0	BQL	24
5/18/98	BQL	BQL	13
6/24/98	BQL	BQL	BQL
7/23/98	6.0	BQL	20
8/21/98	BQL	BQL	BQL
9/25/98	BQL	BQL	6.0

Table 1

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