Remediation of Chlorinated Solvent Groundwater Plume Using NoVOCs Recirculating Well Technology – a Field Study

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Abstract: During a site assessment conducted in 1997, dry cleaning solvent compounds exceeding regulated standards (natural attenuation default concentrations and MCLs), were detected at the Nu-Look Cleaners facility in Coral Springs, Florida. PCE was detected at a maximum concentration of 1,900 μg/l, thereby providing presumptive evidence of DNAPL. The maximum sum concentration of PCE and its degradation compounds was 21,000 μg/l. A comparison of remedial techniques concluded that NoVOCs recirculating well technology would facilitate removal of dissolved phase contaminants while maintaining existing in-situ anaerobic reductive dechlorination conditions. The system was operated in a "closed loop" configuration to minimize introduction of atmospheric oxygen to the in-well stripping column. Following removal/degradation of PCE and TCE, the system provides the flexibility to be re-configured into an "open" configuration to increase the in-situ oxygen levels and promote aerobic degradation of DCEs and vinyl chloride, if necessary. A single recirculating well was installed and tested over a 30-day period. Test data indicated a radius of influence of approximately 62 feet. The area of contamination exceeding natural attenuation default concentrations was reduced from 10,000 sq. feet to 1,500 sq. feet.

Assessment Summary: The highest contaminant concentrations detected in the groundwater during the site assessment were 1,990 μg/l PCE, 11,700 μg/l TCE, 10,200 μg/l cis-1,2-DCE, 5.5 μg/l trans-1,2-DCE and 1,000 μg/l vinyl chloride. DNAPL was not observed during the assessment phase; however, it was presumed present based on the detection of PCE at concentrations greater than 1% of its solubility in water. The areal extent of groundwater exceeding MCLs was approximately 1.25 acre. Contaminants exceeding MCLs extended to approximately 54 feet bls.

Site geology within the contaminated zone is generalized as follows: Dark brown fine sand and organic materials from 5 to 7 feet bls, followed by interbedded layers of fine to medium grain sand, unconsolidated limestone and traces amounts of silt and shells from 7 to 54 feet bls. From water table elevation data and dissolved plume orientation, the groundwater flow direction was determined to be toward the southwest in the direction of the Coral Springs Wellfield.

A remedial alternatives analysis, comparing traditional and innovative technologies, was performed to determine the most viable remedial technology. Recirculating well technology was selected over enhanced biologic and chemical oxidation technologies, primarily because: 1.) This technology would maintain the in-situ anaerobic conditions; 2.) It has the flexibility to be converted to an aerobic system; 3.) It could be modified to deliver oxidants or bio-enhancements in the future; and 4.) The presence of protected woodlands above portions of the dissolved plume required that none of the trees be damaged or destroyed during remedial activities.

Pilot System Design: The site-specific NoVOCs pilot system was designed to induce a sub-surface groundwater recirculation loop from a single well. The well was designed with two

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distinct zones, a lower induction zone (19 to 24 feet bls), located at the depth interval of highest dissolved contamination and an upper discharge zone (7 to 12 feet bls). If necessary, this configuration could be run in reverse, with the induction loop on top and discharge on bottom. Pressurized air was delivered to a diffuser below the upper-screened section of a recirculation well casing. Groundwater was airlifted from the lower intake screen to the upper discharge screen. Stripping and volatilization of the VOHs occurred during this seven-foot up-lift. Vapor effluent was then directed back through the single blower, carbon canisters and air cooler/dehumidifier in a "closed loop" system for re-injection, so as to minimize the introduction of atmospheric oxygen into the recirculation loop and help maintain the in-situ anaerobic conditions that are beneficial for the degradation process already being demonstrated. The groundwater, stripped of VOHs, is re-infiltrated back into the ground through the upper-screened portion of the well. The re-infiltrated water then travels in a torus shaped path back to the lower screen, completing a recirculating loop. Vertical gradients, created in the recirculation loop, enhance the physical removal of contaminants from lower permeability units within the circulation zone, as compared to traditional pump & treat methodologies that have limited effectiveness on these trapped contaminants. It should be noted that following degradation of PCE and TCE, the system could be operated in an "open" configuration to enrich dissolved oxygen concentrations and enhance aerobic degradation of DCEs and vinyl chloride. The "open" configuration uses two blowers, the first for in-well stripping and the second for vapor extraction.

Pilot Test: On February 14, 1999, the four-week pilot test was initiated to evaluate the performance of the NoVOCs recirculating well system. Air was introduced via the diffuser into the well at an average rate of 35 scfm and 5 psig pressure. A sampling and monitoring schedule was developed to evaluate the performance of well dynamics, equipment skid and effect of the NoVOCs system on the dissolved phase plume. This primarily consisted of monitoring the water table elevation in piezometers adjacent to the recirculating well; monitoring system flow rates, pressures and vacuums; and monitoring various groundwater quality indicators and dissolved contaminant concentrations in strategically located wells on a weekly schedule.

During the first week of the pilot test, water table elevation data collected from the shallow piezometer, located adjacent to the NoVOCs well in the discharge zone indicated increasing mounding, while monitoring of the deep piezometer, located within the induction zone indicted reduced drawdown. Based upon these observations, the system was temporarily shutdown on February 24, 1999 (10^{th} day of operation) to evaluate potential causes. It was determined that a buildup of bio-fouling deposits had plugged the lower intake screen and the upper discharge screen, effectively reducing groundwater flow into and out of the well. These deposits were attributed to iron bacteria that are stimulated by the increase of oxygen into the system. The well was reconditioned by a combination of jetting, surging and bailing. A 6% sulfamic solution was introduced into the induction and discharge zones in an effort to control iron bio-fouling. Additionally, a well screen with a fine mesh filter sock was added to the eductor pipe (conveyance pipe from lower portion of well to upper portion of well) to retard the migration of iron bio-fouling deposits from the induction zone into the discharge zone.

On March 11, 1999, the pilot test was restarted, regular maintenance of the well revealed the addition of the filter sock had limited the degree of bio-fouling on the upper well screen, the

eductor screen, and within the recharge zone. However, the sock itself was becoming encrusted with a layer of iron bio-fouling deposits in approximately three to four day cycles.

On March 24-25, 1999, a short-term tracer test was conducted to provide direct evidence that recirculation had been achieved by the NoVOCs well. The test consisted of applying a non-reactive tracer, sodium bromide, at the well intake screen and monitoring for bromide at several monitoring points at an increasing radial distance from the well. Test data indicated an estimated radius of influence of at least 25 feet. However, due to the low bromide concentrations observed at the monitoring wells during the test, the use of analytical data for determination of the radius of influence was deemed to be a more accurate indicator.

Pilot Test Results: The pilot test was concluded after the fourth monitoring event on March 31, 1999. Groundwater analytical data collected during the test indicated a sharp increase in total VOH concentrations immediately following system start-up in shallow discharge zone monitoring wells MW-21 (57 feet down-gradient) and MW-18 (38 feet cross-gradient). However, following the second and third week sampling events, respectively for MW-21 and MW-18, groundwater contaminant concentration rapidly decreased. Using a 75% reduction of total VOH concs., the estimated radius of influence of the recirculating well was 62 feet.

Comparison of results from the pre-start baseline sampling event (February 4, 1999) and results at system shutdown (March 31, 1999) indicate an overall reduction of contaminant concentrations, that eliminated the 1,000 μg/l total VOH contour and created a slight lateral shift of the 100 μg/l total VOH contour cross-gradient to the south. However, the lateral extents of the plume (i.e. 1 μg/l total VOH contour) did not undergo a shift from the baseline condition. On April 15, 1999, two weeks after completion of the test, sampling was conducted to determine the potential for contaminant rebound. These results confirmed the contaminant distribution pattern observed at system shut-down. In fact, the April 15, 1999 monitoring event illustrates a reduction of the northern portion of the plume, possibly indicating an enhancement of natural attenuation processes.

Six months and one year after pilot test completion, groundwater samples were again collected to determine the possible presence of contaminant rebound. Analyses of these data indicate the presence of limited contaminant rebound in two groups of wells. The first group of wells is located up-gradient of the recirculating well, in close proximity to a vadose zone source. Therefore, this rebound might possibly be attributed to contaminant leaching. The second group of wells is located down-gradient of the defined recirculation zone, and therefore, may indicate the need for a second, down-gradient recirculating well to successfully remediate the site.

Conclusion: The pilot test successfully eliminated the core of contamination (total VOHs greater than 1,000 μg/l). Additionally, comparison of contaminant concentrations indicates that the impacted area exceeding the natural attenuation default criteria has been reduced from approximately 10,000 to 1,500 square feet. Full-scale implementation of this technology is planned for this site. System design is being altered to aboveground treatment in an effort to reduce bio-fouling.