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DNAPL Remediation Using FE ACTIVE™

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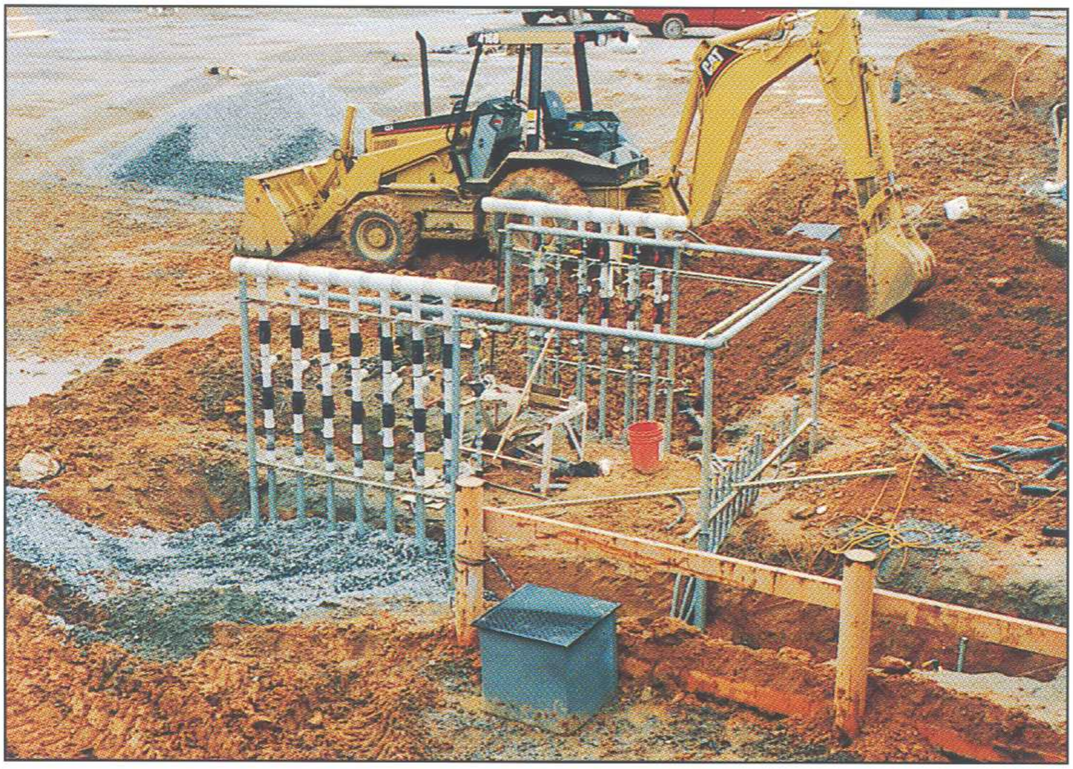
Remediating DNAPLs: It can be done



By Richard C. Dorrler, P.G., William S.S. Pendexter, Ph.D., P.G., and Kenneth J. Mathys

Groundwater remediation is a tough job. DNAPLs are especially difficult to clean up since they are immiscible in, and denser than water. However, a process used to remediate PCE DNAPL in fractured rock at a site in the Piedmont of South Carolina has put the site near closure.

PCE was used in the manufacturing process at a facility in South Carolina which operated from 1978 to 1984. Sometime during that six year period, about 1900 liters of PCE was spilled or leaked to the ground near the building. In 1984, investigations were initiated to determine the extent of the contamination. In 1985, remediation activities were initiated with the installation of recovery wells in the vicinity and slightly downgradient of the building.

First stab at remediation

From 1986 to 1989, the groundwater recovery system was expanded to include more than 40 shallow wells and an extensive soil vapor extraction system. The water was treated through an air stripper before discharge to a local POTW sewer line. The permitted discharge limit was 458 liters per minute (lpm). There were no requirements to treat discharges to the air if kept below the limit of 450 kg per month of total volatiles.

Eventually, more than 100 monitoring wells were installed at the site. It is evident that simply from the patterns of well installation over time, the majority of the contamination had spread only a distance of a few hundred meters from the PCE handling area behind the building to the low area just beyond the southern end of the building. From 1987 to 1989, heavy pumping lowered water levels to 7 meters, and vapor extraction from the shallow soils significantly reduced contaminant levels in this central portion of the site.

As a result of the removal of 3-pore volumes and thus the cleanup of the PCE plume, in 1989 most of the recovery wells were shut off and a submission to close the site was made to the state regulatory agencies. The state's response was that, since the DNAPL source area was not cleaned up, the groundwater pump and treat system would have to continue to operate to contain contaminants from leaving the site. Without DNAPL source area remediation, it was suggested that containment pumping would likely last for 50 years or more.

Containment pumping continued at the site while a search for an innovative technology to remediate PCE DNAPL was conducted. Pilot tests including air sparging, and dual phase extraction failed due to the depth of the DNAPL and the low yield of the fractured bedrock. In 1994, a three-month pilot test using the F.E. ACTIVE™ system was implemented and determined to be successful. Subsequently, a full scale DNAPL remediation with this system was implemented in April 1995.

DNAPL remediation strategy

After meeting with the client and state, certain objectives and goals were established and a remediation strategy was formulated for the site. The primary objective was to reduce the remediation project life cycle costs while minimizing capital expenditures with the ultimate goal of rendering the property suitable for sale as soon as possible.

The strategy selected to achieve this goal included aggressive remediation of the PCE DNAPL hot spot areas and allowing natural attenuation of the remaining residual contamination. This strategy is consistent with the state's Mixing Zone Guidance, and meets the business needs of the client by minimizing the time and costs necessary to sell the property. The projected time frame for remediation of the source areas was two years. To assure the DNAPL would no longer be a continuing source, a target cleanup level for PCE within the source area was set at 1 ppm, which is less than one percent of its solubility in water.

An FE ACTIVE system is installed to remediate DNAPLs at a contaminated site. A combination of technologies applied simultaneously in multiple wells induces strong push-pull forces between wells and through the subsurface formation zones targeted for remediation.

How F.E. ACTIVE works

ACTIVE stands for aggressive cleaning and treatment with injection and vapor extraction. This system uses a combination of innovative remedial technologies applied simultaneously in multiple wells, thereby inducing strong push-pull forces between wells and through the subsurface formation zones targeted for remediation. Thus by using multiple wells as opposed to single well remediation technologies, the aggressive cleaning action can be directed crosshole and extended throughout the zone targeted for treatment.

This advanced multiple well/crosshole technology is specifically designed to take advantage of the flow characteristics of the formation. The locations and depths of the wells, the patterns of injection and extraction points and the air and water flow rates and pressures are all designed for the specific purpose of mobilizing and controlling the movement of the DNAPL into the primary recovery streams leading to the extraction wells. The recovery streams or flow ways that are developed are dependent on the hydraulic characteristics of the formation.

The system also uses the chemical properties of the specific contaminant to assist with its recovery. Since PCE is highly volatile and has low solubility, air is used as the primary carrier rather than water. Also, the diffusion of PCE is four orders of magnitude greater in air than water. Thus air is a more effective and thorough cleaning medium than water for this type of contaminant.

The F.E. ACTIVE system is designed to remediate isolated

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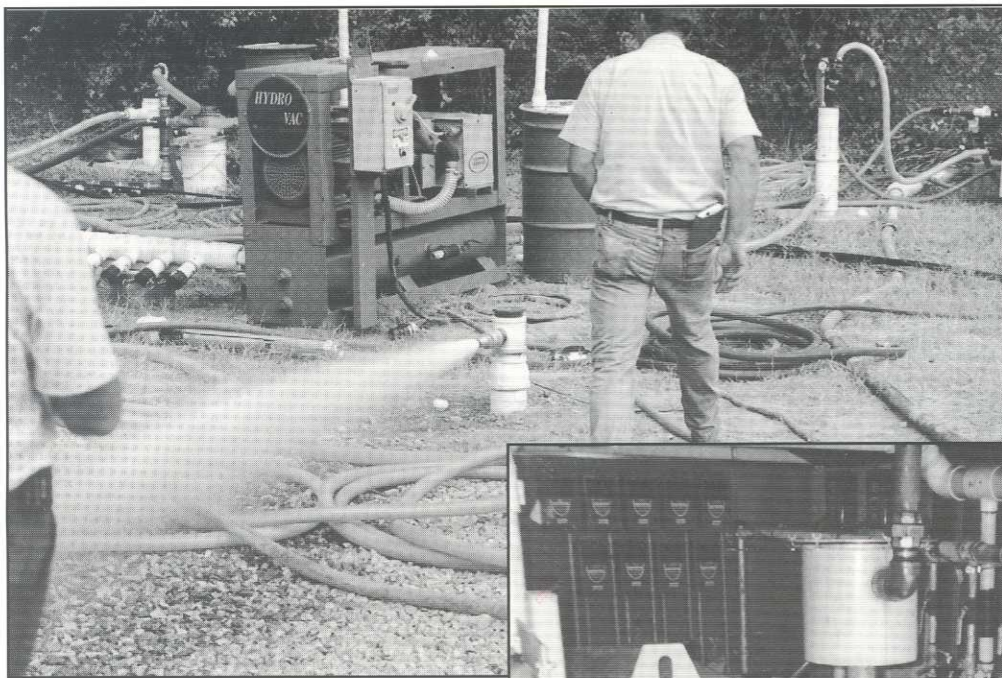
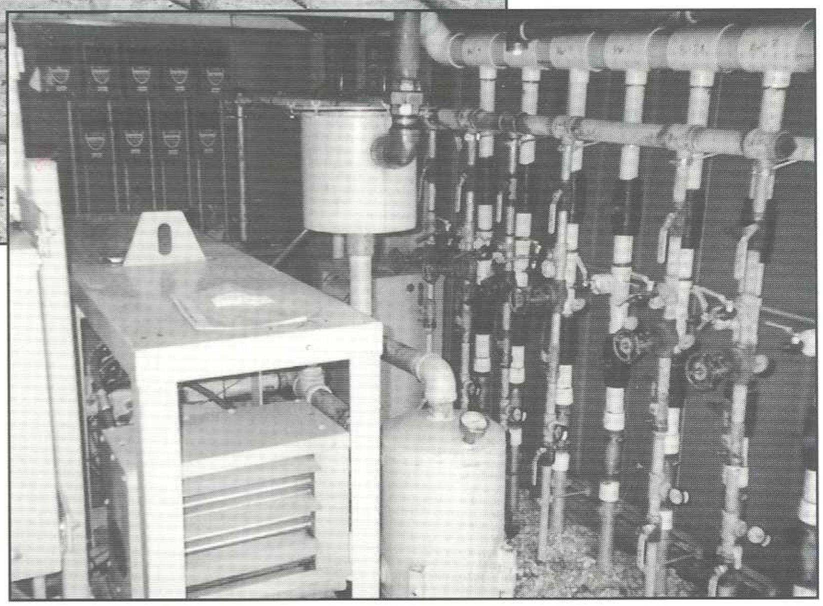


At left, workers monitor a crosshole air flow demonstration during the pilot test of the F.E. ACTIVE system. Below, a look inside the system's central control station.



DNAPL hot spots beneath the water table. This is accomplished by first dewatering the local formation and then using vapor extraction techniques similar to those used for the light nonaqueous phase liquids (LNAPLs) such as gasoline, which more often occur above the water table.

F.E. ACTIVE at Piedmont site

Pneumatic fracturing and high vacuum dewatering — the first two steps of the system — were very effective in opening up the dead-end fractures and greatly increasing the yield of the bedrock aquifer. In some cases, pressures up to 400 psi were needed to create cross-flow between wells.

Up to 16 existing wells were used within the 15 by 15 meter DNAPL source area. In many of these wells, yields increased from less than 3.8 lpm to greater than 37.8 lpm. After several months of high vacuum dewatering, localized drawdowns of up to 24 meters were achieved.

Air injection and vapor extraction — the last two steps of the system — were very effective in removing high levels of contamination since these intensive cleaning steps were focused on the mass of contaminants within the localized high concentration DNAPL source area. Crosshole air/water flushing through fractures at the target depths of 17 to 23 meters was very effective in recovering immobile DNAPL, especially when using air preheated up to 22° C above ambient temperatures. Increasing the temperature of the target zone formation air from 15.5° C to 37.7°C increased the PCE vapor concentration and thus recovery rate by a factor of four.

Biweekly monitoring of recovered vapor and water flow rates and PCE concentrations allowed continuous adjustments and tuning of the injection and extraction points to optimize contaminant recovery. A central control station facilitated sampling and adjustments to the network of recovery wells.

Performance evaluations

The overall performance of the DNAPL source area remediation system is based on the amount of PCE contamination removed during the two year operation period (1995-1996); and on the subsequent changes in PCE concentrations as measured quarterly and semi-annually in a network of up to 87 monitoring wells installed at the site. The PCE concentrations within the remaining hot spots have dropped below the 1 ppm target level and are now at levels that are equivalent to those within the surrounding areas of the dissolved plume.

Also, PCE concentration changes over time, as measured in the extraction wells, have shown a marked decrease from 1995 to 1996. The average concentrations in 1995 ranged from 1 to 7 ppm, whereas in 1996 the average concentrations ranged from 0.5 to 0.9 ppm. Since these concentrations are from extraction wells that are continually

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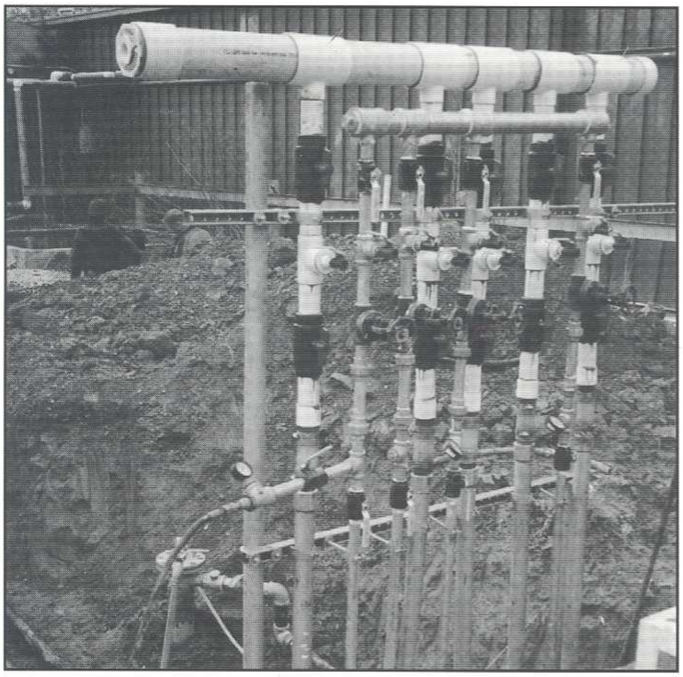

pumping groundwater from the PCE DNAPL source areas, they provide the best indication of the highest concentrations remaining within these areas.

The source area recovery system is continuing to remove PCE from the groundwater and the overlying dewatered transition and saprolite soil zones. The rate of removal from the vapor phase is greater than that of groundwater removal because, with the F.E. ACTIVE system, the water levels are constantly being depressed, exposing more and more residual phase PCE for removal by vapor extraction. The eventual decline in vapor concentrations and kilograms is a strong indication that the residual PCE contamination is finally being cleaned up.

By comparing the total kilograms of PCE removed vs. the estimate of total kilograms released, an accounting of kilograms remaining can be made. In this case, the estimated release was 1895 liters or about 3175 kg of PCE of which about 1588 kg were recovered by vapor extraction and about 680 kg were recovered by groundwater pumping from the shallow soils before the startup of the F.E. ACTIVE system. Thus, the remaining 907 kg recovered from the transition zone and shallow bedrock by the system accounts for the bulk of the remaining PCE that was initially released.

Finally, since some portion of the PCE could be absorbed into the matrix of the soil or rock, there is always concern that when remediation pumping stops and water levels recover, concentrations will rebound due to dissolution of the PCE retained in the matrix. To evaluate this potential for rebound, a two week shutdown test was conducted in two recovery wells positioned within the center of the DNAPL source area. Despite a 60 percent recovery of water levels and complete flooding of the target remediation zone, only a 15 percent increase in PCE concentrations from 925 to 1100 ppb was observed in groundwater samples during this two week period.

Site closure plans

Currently, the groundwater remediation systems are continuing to operate while a Mixing Zone Application and groundwater model are being prepared for submission to the state. According to the Mixing Zone Criteria, it must be demonstrated by predictive modeling that the contamination left at the site will not exceed the maximum concentration level of 5 ppb within the groundwater once it reaches the downgradient property line of the site.

Early indications are that the major pathway for contaminants within the groundwater will be to the creeks onsite. Thus, modeling of contaminant migration, natural attenuation and dilution by the creek, should be supportive of the Mixing Zone application. Although state approved site closure can not be obtained until all contamination on the site is below MCLs, it is anticipated that the goal to sell the property can be achieved shortly after obtaining the state approved Mixing Zone Application. ▮