PERFORMANCE EVALUATION OF A FORCED HOT AIR REMEDIATION SYSTEM

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Groundwater contamination from chlorinated solvents such as tetrachloroethylene (PCE) is fairly common. These solvents often exist as dense nonaqueous phase liquids (DNAPL). Since DNAPL usually occurs in isolated pockets and is immiscible with water, it cannot be removed simply by pumping groundwater and therefore, the contamination can last for an indefinitely long period of time. For the first time, a new technology involving the use of forced hot air, was successful in remediating PCE DNAPL at a site in the Piedmont of South Carolina. The PCE DNAPL was found at depths of up to 65 feet below the water table in fractured rock and saprolite soil. Since there have been no previously known cases of successful remediation of PCE DNAPL, extensive measures were undertaken to evaluate the performance of this new technology. Forced hot air injection and enhanced vapor extraction were very effective in removing high levels of contamination since these intensive cleaning steps were focused on the mass of residual PCE contamination within the localized high concentration DNAPL source area. Crosshole hot air/water flushing through fractures was very effective in recovering immobile DNAPL, especially when using air preheated to >1000^{o}F above ambient temperatures. By increasing the temperature of the target zone from 60^{o}F to >250^{o}F, PCE vapor concentrations increased (from <20 ppmv to >400 ppmv), and thus recovery rates increased by 20 times. In less than 30 days, PCE concentrations in one of the primary wells decreased 97%, from greater than 4,000 ppb to less than 100 ppb. The thermal techniques used in these tests created insitu steaming, which increased volatility and decreased subsurface absorption of residual and dissolved PCE. Temperatures of purge water from the primary well remained at or near 240^{o}F for several days and 160^{o}F for several weeks following the test.

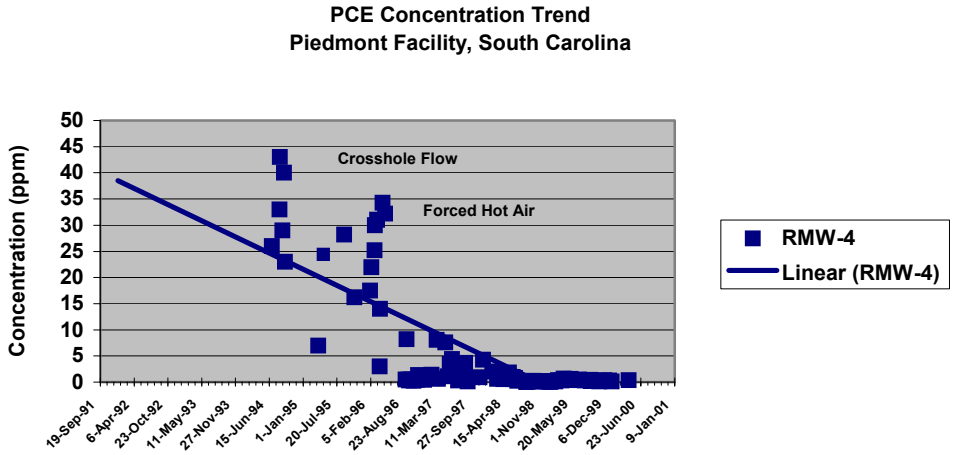
As explained in the Semi-Annual and Annual Effectiveness Reports provided to the State, the overall performance of the DNAPL source area remediation system is based primarily on the amount of PCE contamination removed during the 3 year period of testing, development and operation (1995-98); and on the subsequent changes in PCE concentrations as measured quarterly and semi-annually in a network of up to 87 monitoring wells installed at the site. 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 (i.e. hundreds of ppb).

Also, 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. PCE concentration changes over time as measured in the source area extraction wells, have shown a marked decrease from 1995 to 1998. 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 and since 1998 average concentrations are continuing to hold between 0.1 to 0.2 ppm. Since these concentrations are from extraction wells that were continually pumping groundwater from the PCE/DNAPL source areas, they provide the best indication of the highest concentrations remaining within these areas.

By comparing the total pounds of PCE removed versus the estimate of total pounds released, an accounting of pounds remaining can be made. In this case, the estimated release was 500 gallons or approximately 7,000 pounds of PCE of which approximately 3,500 pounds were recovered by vapor extraction and 1,500 pounds were recovered by groundwater pumping from the shallow soils prior to the start-up of source remediation system. Thus, the remaining 2,000 pounds recovered from the transition zone and shallow bedrock by the source remediation 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 some concern that when remediation pumping stops and water levels recover, that concentrations will rebound due to dissolution of the PCE retained in the matrix. To evaluate this potential for rebound, a one year shutdown test was initiated in June of 1999, in the recovery wells positioned within the center portion of the DNAPL source area. Despite a full recovery of water levels and complete flooding of the target remediation zone, PCE concentrations have remained below 200 ppb and are similar to those in the dissolved plume as measured in the surrounding monitoring wells.

Time-Concentration Graph



In Conclusion the use of hot air injection in combination with standard SVE techniques applied simultaneously in multiple wells, has been demonstrated to be very effective in rapidly removing high concentration PCE/DNAPL from a source area beneath the water table. The use of multiple wells, as opposed to single well remediation technologies, induces strong pressure gradients between wells and throughout the subsurface zones targeted for remediation. The pressure gradients increase the mobility and recovery of DNAPL in low-permeability zones. To this date, the extensive supporting data indicate that thermal treatment has proven to be very effective for remediation of PCE DNAPL at this site.