Soil Vapor Extraction of PCE/TCE Contaminated Soil

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Soil Vapor Extraction of PCE/TCE Contaminated Soil

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Abstract

The A/M Area of the Savannah River Site soil and groundwater is contaminated with tetrachloroethylene (PCE) and trichloroethylene (TCE). Contamination is the result of previous waste disposal practices, once considered state-of-the-art. Soil Vapor Extraction (SVE) units have been installed to remediate the A/M Area vadose zone. SVE is a proven *in-situ* method for removing volatile organics from a soil matrix with minimal site disturbance. SVE alleviates the infiltration of contaminants into the groundwater and reduces the total time required for groundwater remediation. Lessons learned and optimization of the SVE units are also discussed.

Introduction

The Savannah River Site (SRS) is a 300 square mile complex located along the Savannah River near Aiken, South Carolina. The site's historical mission is production of nuclear materials in support of national security. The A/M Areas of the Savannah River Site soil and groundwater are contaminated with volatile organic compounds (VOCs). Contamination is the result of previous waste disposal practices, once considered state-of-the-art. The degreasing solvents trichloroethylene (TCE) and tetrachloroethylene (PCE) were utilized and disposed of in A/M Area.

Characterization of sites indicated that elevated levels of TCE and PCE were present in the vadose zone. During the 1950s, solvent wastes were disposed directly to the A-014 Outfall and the 321-M Area. The M-Area Basin was constructed in 1958 to receive the spent solvents via an underground sewer line. Flow to the M-Area Basin was discontinued in 1985, and the basin was closed under the Resource Conservation and Recovery Act (RCRA) via construction of a clay cap over the basin.

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The process sewer line was excavated and removed as part of the M-Area Basin closure. 1.2 million pounds of solvent is estimated to have been transferred to the A/M Area groundwater; an additional 1.2 million pounds of solvent is estimated to have been transferred to the A/M Area vadose zone (2.4 million pounds of solvent total).

The groundwater in A/M Area has been treated via air stripping since 1985. Clean-up in A/M Area is driven by a RCRA permit that is structured for a phased approach - to attack the worst first drives remediation. Air stripping was the first groundwater remediation technology employed in A/M Area. As of January 1998, A/M Area air strippers have treated more than 2.8 billion gallons of contaminated groundwater, and they have removed more than 360,000 pounds of degreaser solvents. Although air stripping in A/M-Area has been proven to be effective in removing and treating contaminated groundwater, it does not directly remove contamination in the vadose zone. The vadose zone is the unsaturated layer of soil between the ground surface and the water table. The vadose zone contamination continues to serve as a source of groundwater contamination. By removing the contamination from the vadose zone before it reaches the groundwater, the solvents are much easier to remediate.

In order to address contamination remaining in the vadose zone, SRS considered several vadose zone remediation techniques including soil vapor extraction (SVE), artificial recharge (injection), and enhanced biological degradation. Vacuum extraction was considered the most viable approach based upon successful applications at various sites throughout the nation. SVE was later judged the best remediation method, based upon technical effectiveness and economic viability. Vacuum extraction is defined by the United States Environmental Protection Agency as the presumptive remedy for this type of site and contaminant.

Six SVE units have been installed to remediate different point sources of the A/M Area vadose zone. SVE is a proven *in-situ* method for removing volatile organics from a soil matrix with minimal site disturbance. SVE can treat a large volume of soil at a moderate cost, compared to other available technologies. SVE uses extraction wells to induce air flow through the soil to remove volatile compounds.

The SVE system consists of a network of wells with perforated well screens (extraction wells) that are connected to the suction side of a SVE unit through a surface collection manifold. The well network utilizes both vertical and horizontal wells. All wells are located to maximize removal of the highest levels of PCE and TCE contamination. Horizontal wells allow for contaminant removal following natural paths of high permeability; these are likely to be the same paths taken by the soil contaminants as they migrate downward. Horizontal wells also allow access under surface structures and buildings. A single horizontal extraction well replaces several vertical extraction wells.

The SVE unit induces a flow of air from the subsurface through the vadose zone into the extraction wells. As air is pulled through the soil, contaminants are volatilized from the soils pore space. The extracted vapor will flow in sequence through the surface collection manifold, a knock out pot to remove water, a filter to remove particulates, the blower, and into the catalytic oxidation unit where the contaminants are reduced to elemental constituents. A heat exchanger is incorporated to improve energy efficiency.

Vapor extraction of contaminants from the vadose zone will alleviate the infiltration of contaminants into the groundwater and will reduce the total time required for groundwater remediation. The vacuum extraction systems operate under Air Quality Control (AQC) permits issued by the South Carolina Department of Health and Environmental Control (SCDHEC). Over 250,000 pounds of PCE and TCE have been treated via SVE to date at SRS.

Lessons Learned

Despite their phenomenal production, the SVE systems have not been without problems. The first Lesson Learned relates to the characterization of the contamination sites. This characterization indicated that the maximum concentrations expected during SVE operations were approximately 2500 ppm. However, data collected during operations indicated that concentrations were actually as high as 20,000 ppm. This order of magnitude error in expected concentrations impacted both the permitting and the design of the remediation systems.

The second Lesson Learned relates to the permitting of the units. Based upon the characterization data, permits were obtained from SCDHEC that allowed no more than 4 pounds per hour of hydrochloric acid (HCl) to be discharged to the atmosphere (HCl is a by-product from the catalytic oxidation of PCE and TCE). Assuming the characterization data to be correct, this would have allowed sufficient flexibility to operate the units. However, with the higher VOC loads experienced, our AQC permits restricted our operational effectiveness. During initial operations, for every one part of contaminated soil gas treated, twenty parts of dilution air was needed to stay within permit boundaries. This restriction was self-imposed by a lack of information from characterization.

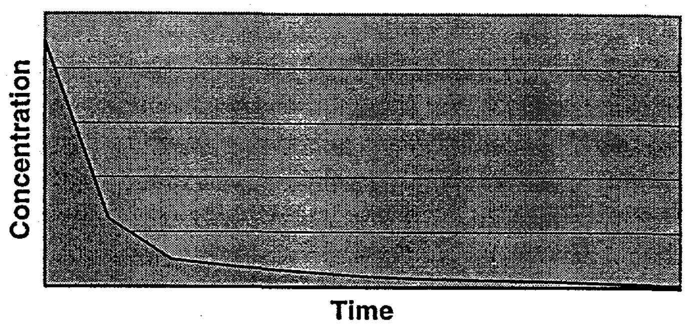
A third Lesson Learned was assuming that a high SVE destruction efficiency was required. However, a review of the OSHA personnel exposure limits, site boundary concentration air permit limits, and air dispersion modeling showed that hydrochloric acid (HCl) was significantly more harmful than PCE and TCE. Therefore, it is more protective to allow a larger portion PCE and TCE to pass untreated to the atmosphere. This is accomplished by reducing the retention time (i.e., increasing flowrate) or by lowering the destruction temperature. A permit modification was subsequently approved by SCDHEC allowing the unanticipated higher inlet loads of PCE and TCE and a lower destruction removal efficiency.

The fourth Lesson Learned relates to system component operation. During the winter months, up to 40 gallons of water per day condenses in the hoses connecting the wells to the SVE units. Because the ambient air temperature outside the hoses is less than the ground temperature vadose air inside the hose, condensation results. The knock out pot does protect most of the SVE system components, but several upstream components have had problems.

Optimization

SVE is very effective for remediating homogenous soils. However, actual soils are typically heterogeneous in nature. Advective transport of VOCs is efficient for remediating much of the contamination, but remediation of isolated soil pore spaces is limited to diffusion of VOCs. Diffusive transport tends to move at a much slower rate compared to advective transport, which will reduce the overall efficiency of SVE. In summary, large volumes of contamination will be removed quickly, but the final amounts of contamination will be hard (and expensive) to reach. This relationship can be seen in Figure 1.

Figure 1



Additional improvements are being made to the SVE systems currently in place to optimize performance in light of these natural limitations. Production at one of the first sites to be remediated has dropped to less than 1 pound per hour. A variety of alternative technologies have been piloted to compliment this mature location. *In situ* bioremediation via nutrient injection of methane, nitrous oxide, and triethyl phosphate was selected and has been installed. The nutrients stimulate the microorganisms indigenous to the soils of SRS. These microorganisms biodegrade the solvent, producing water and carbon dioxide. A deep horizontal well, installed below the water table, is used as an injection well for the nutrients. A shallow horizontal well, installed in the vadose zone, is used as an extraction well. This creates an *in situ* air stripping environment that remediates both the groundwater and the vadose zone. *In situ* bioremediation is an attractive technology because the contaminants are destroyed rather than moved from one medium to another. *In situ* biologically assisted destruction reduces the cost and time of remediation while increasing remediation efficiency and public and regulatory acceptability.

A second technology, automated controlling system operations, has been installed at four sites. It was installed not to replace a mature operation, but rather to improve the existing one. State-of-the-art technology allows routine operational tasks to be done remotely. System monitoring is designed to be done automatically, assuring regulatory compliance and maximum operational efficiency. As conditions require changes in the units' operations, the sophisticated computer control systems are designed to automatically make the operational changes to the SVE units. Sampling is done automatically. The telemetry systems are designed with a control algorithm to keep operations at their maximum effectiveness. Data would be down loaded to an engineering computer for regulatory reporting purposes, thus eliminating database entry by hand. These improvements are designed to allow remediation to occur more rapidly and effectively.

However, remote control operations have not been as successful as planned. A photo ionization detector (PID) measures concentrations of TCE and PCE of the input (untreated) stream to the SVE units. The same PID measures the TCE, PCE, and HCl of the outlet (treated) stream that discharges to the atmosphere. The PID has trouble withstanding the acid environment it experiences, and fails within a short timeframe. Furthermore, the delicate computer equipment has trouble with the wide temperature fluctuations experienced throughout the weather year. As a result of these problems, the remote control operations have not worked as planned.

As the remediation has matured and permit limits increased, the advantages of remote control operations are not as readily needed. All of our remediation sites can now extract VOCs from the subsurface at maximum capacity and still stay below permit limits. Due to this condition, the fine tuning of the remote control operations is not anticipated. The computer systems are used for turning on the SVEs, adjusting valves, and ascertaining system status. However, the sophisticated computer control that was anticipated has not been realized.

UNIT	LOCATION	POUNDS TREATED
-3M	A-014 Outfall	97,000
-4M	M-Basin	48,000
-5M	Process Sewer	26,000
-6M	321-M	53,000
-7M	Integrated Demonstration	36,000
-8M	near Integrated Demo	500