DUAL VACUUM EXTRACTION EASES SUBSURFACE CLEANUP

Conventional remediation methods for contaminated soil and ground water typically consist of vapor extraction performed on soil and pump-and-treat techniques applied to contaminated ground water. Terra Vac (San Juan, Puerto Rico and Fairport, New York) has developed a synergistic system that combines the two technologies for cleaning up VOC (volatile organic compounds) contamination. By removing both contaminated water and soil gases from an extraction well under vacuum conditions, simultaneous treatment of contaminated soil and ground water can be achieved, reducing both the time and cost of treatment.

James J. Malot et al., of Terra Vac describes the techniques and advantages of combining the two conventional technologies in a paper entitled "Innovative Technology for Simultaneous In Situ Remediation of Soil and Groundwater." The paper appears in Proceedings of HMC-Great Lakes '90, held September 26-28, 1990 in Cleveland, Ohio. The proceedings are available from Hazardous Materials Control Research Institute, 9300 Columbia Boulevard, Silver Spring, Maryland 20910-1702. (301) 587-9390 at a cost of $54.00.

Technology Description

Vacuum extraction of contaminated soil vapors has been performed by Terra Vac at over 100 sites. Under vacuum conditions, a negative pressure gradient is created within the soil surrounding the extraction well. In addition to drawing VOC vapors into the well, the vacuum conditions enhance volatilization of contaminants held up in the pore spaces or adsorbed to soil particles. Over time, as contaminants are desorbed and volatilized from the soil matrix, the level of contamination in the subsurface will decrease.

Well drawdowns were increased significantly through the application of a vacuum.

Equipment required for a vacuum extraction system includes extraction wells, a vacuum producing unit (such as a blower), a liquid/vapor separator, a vapor treatment system, and system control instruments. Vapor treatment can consist of either direct discharge, activated carbon adsorption, catalytic oxidation, or thermal incineration, depending on regulatory requirements and vapor extraction rates.

The most common cause of ground-water contamination is a release of liquid at the ground surface such as would occur during a spill. As the contaminants migrate through the unsaturated zone overlying the ground water, capillary forces hold a significant fraction within the soil pores. The authors claim that up to 55% of the pore volume may be occupied with contaminants. Due to gravitational effects, the contaminants not retained by the soil migrate down to the ground water where they may float, dissolve in, or sink, depending on chemical characteristics.

Extraction of contaminated ground water is traditionally performed by pump-and-treat methods. However, these methods of ground-water remediation do not address the residual contamination in the unsaturated soil, which will continue to contaminate the site until it is removed. Concentrations of VOCs in ground water are generally low, requiring treatment of extremely large quantities of water to achieve cleanup objectives.

By combining vacuum extraction and ground-water extraction, the disadvantages of each individual technology can be avoided. Figure 1 (page 1.4) is a schematic of a representative Terra Vac dual vacuum-extraction system. Typically, the dual system will contain all the individual components of a vacuum-extraction and a ground-water extraction system. In each individual well, both vapor and ground-water extraction takes place. The ground-water recovery system is specially designed to account for significant differences in pump performance levels under vacuum conditions.

Advantages

Testing of the dual vacuum extraction technology performed by Terra Vac thus far has shown promising results. Well drawdowns were increased significantly through the application of a vacuum. Increased drawdowns contributed to increased ground-water production rates, increased rates of dewatering, and reduced cleanup times. Other effects of the increased drawdowns were the increased radius of influence and capture zones of the wells.
Developers of the dual vacuum extraction system claim several advantages over conventional soil and ground-water remediation technologies. These advantages are primarily the result of the dramatically increased extraction rates achieved under dual vacuum conditions. Figures 2 and 3 graphically illustrate the differences in pumping rates at two sites in New York. Both sites had overburden consisting of glacial till. At site A, the hydraulic conductivity of the till was approximately $10^{-4}$ cm/sec; the permeability of the soil at site B was lower than site A, although the exact value was not specified. According to the authors, increased extraction rates relate indirectly to the permeability of the surficial geology. As shown in Figure 3, greater increases, ranging from 627% to 1950%, were associated with the low permeability settings. Vacuum extraction rates were still significantly higher than conventional extraction rates in higher permeability settings, as shown in Figure 2. Increases of 53% to 183% were observed.

- Sites with shallow ground water, and
- Sites where low permeability in the hydrologic layer typically results in low ground-water extraction rates.

**New York Case Study**

Terra Vac designed and installed a dual vacuum extraction system to recover VOCs from a solvent spill at a manufacturing facility in New York (site A). Hazardous constituents released in the spill included methylene chloride and smaller amounts of cyclohexane, 1,1-dichloroethylene, 1,1,1-trichloroethane, methanol, ethanol, acetone, and n-butanol.

The geology of the site consisted of predominantly glacial till soils, overlying a fractured sandstone bedrock. Ground-water flow occurred primarily through the upper 15 feet of the bedrock, which is highly fractured and weathered.
The project was conducted in two phases. During Phase I, four wells, two of which were vertical dual vacuum extraction wells, were installed in the upper bedrock zone. Initial operations were run for 24 days, during which time 2,675 pounds of vapor-phase VOCs and 430 pounds of dissolved-phase VOCs were removed from the subsurface. After 170 days of continuous operation, 3,276 pounds of vapor-phase VOCs and 3,108 pounds of dissolved-phase VOCs had been recovered.

During Phase II, a direct comparison between pumping under atmospheric and vacuum conditions was conducted at two extraction wells. The ground-water pumping rates with the vacuum system increased 183% and 53% over the atmospheric pumping rates at the individual wells (Figure 2, wells 3 and 4). Under dual vacuum conditions, the drawdowns were nearly five times as great as those recorded at atmospheric pressure. For instance, a drawdown of 0.6 feet was recorded at 20 feet from one well under atmospheric conditions after 100 minutes of pumping. At the same well, under vacuum conditions, the drawdown measured 2.6 feet. Transmissivity values under vacuum conditions were more than twice those under atmospheric conditions. The average transmissivity under atmospheric conditions was 250 gallons per day (gpd) per foot, as compared to 525 gpd/ft under vacuum conditions.

Performance

Over 250 days of operation, 3,276 pounds of vapor-phase VOCs and 3,385 pounds of dissolved-phase VOCs were recovered. Wellhead vapor concentrations were reduced 99.9% in the 120 days predicted for soil cleanup. The dewatering of the soils surrounding the extraction wells increased air flows by three times, which, in turn, greatly increased the vapor-phase VOC extraction rates. As a result, operation of the ground-water extraction system under vacuum conditions achieved greater than twice the extraction rate of a typical unit operating under atmospheric conditions.