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Soil Vapor Extraction (SVE)

The following description of Soil Vapor Extraction (SVE) is an excerpt from Chapter II of OUST's publication: ***How to Evaluate Alternative Cleanup Technologies for Underground Storage Tank Sites: A Guide for Corrective Action Plan Reviewers.*** *(EPA 510-B-95-007). This publication also describes 9 additional alternative technologies for remediation of petroleum releases. You can download PDF files of every chapter of the document at: http://www.epa.gov/swerust1/pubs/tums.htm.*

Soil vapor extraction (SVE), also known as "soil venting" or "vacuum extraction", is an *in situ* remedial technology that reduces concentrations of volatile constituents in petroleum products adsorbed to soils in the unsaturated (vadose) zone. In this technology, a vacuum is applied through wells near the source of contamination in the soil. Volatile constituents of the contaminant mass "evaporate" and the vapors are drawn toward the extraction wells. Extracted vapor is then treated as necessary (commonly with carbon adsorption) before being released to the atmosphere. The increased air flow through the subsurface can also stimulate biodegradation of some of the contaminants, especially those that are less volatile. Wells may be either vertical or horizontal. In areas of high groundwater levels, water table depression pumps may be required to offset the effect of upwelling induced by the vacuum.

Application

This technology has been proven effective in reducing concentrations of volatile organic compounds (VOCs) and certain semi-volatile organic compounds (SVOCs) found in petroleum products at UST sites. SVE is generally more successful when applied to the lighter (more volatile) petroleum products such as gasoline. Diesel fuel, heating oils, and kerosene, which are less volatile than gasoline, are not readily removed by SVE, nor are lubricating oils, which are non-volatile. Because almost all petroleum products are biodegradable to a certain degree, these heavier petroleum products may be suitable for removal by bioventing. Injection of heated air also can be used to enhance the volatility of these heavier petroleum products because vapor pressure generally increases with temperature. However, energy requirements for volatility enhancement may be so large as to be economically prohibitive.

SVE is generally not appropriate for sites with a groundwater table located less than 3 feet below the land surface. Special considerations must be taken for sites with a groundwater table located less than 10 feet below the land surface because groundwater upwelling can occur within SVE wells under vacuum pressures, potentially occluding well screens and reducing or eliminating vacuum-induced soil vapor flow.

SVE may also be appropriate near a building foundation to prevent vapor migration into the building. Here, the primary goal may be to control vapor migration and not necessarily to remediate soil.

Operation Principles

In this technology, a vacuum is applied to the contaminated soil matrix through extraction wells which creates a negative pressure gradient that causes movement of vapors toward these wells. Volatile constituents in the vapor phase are readily removed from the subsurface through the extraction wells. The extracted vapors are then treated, as necessary, and discharged to the atmosphere or possibly reinjected to the subsurface (if permitted by applicable state laws).

Some of the factors that determine the effectiveness of SVE are:

- permeability of the soil,
- soil structure and stratification,
- soil moisture, and
- depth to groundwater.

The permeability of the soil affects the rate of air and vapor movement through the soil; the higher the permeability of the soil, the faster the movement and (ideally) the greater the amount of vapors that can be extracted.

Soil structure and stratification are important to SVE effectiveness because they can affect how and where soil vapors will flow within the soil matrix under extraction conditions. Structural characteristics (*e.g.*, layering, fractures) can result in preferential flow behavior that can lead to ineffective or significantly extended remedial times if they are positioned so that the induced air flow occurs outside the area of contamination.

High moisture content in soils can reduce soil permeability and, consequently, the effectiveness of SVE by restricting the flow of air through soil pores. Fine-grained soils create a thicker capillary fringe than coarse-grained soils.

SVE is generally not effective in treating soils below the top of the capillary fringe unless water table depression pumps are used to draw down the water table. In the vicinity of the extraction wells the water table responds to the vacuum by rising, or "upwelling", which can cause the well screen to become submerged thereby reducing airflow.

System Design

Design Radius of Influence (ROI) is the most important parameter to be considered in the design of an SVE system. The ROI is defined as the greatest distance from an extraction well at which a sufficient vacuum and vapor flow can be induced to adequately enhance volatilization and extraction of the contaminants in the soil. Extraction wells should be placed so that the overlap in their radii of influence completely cover the area of contamination.

Fluctuations in the groundwater table should also be considered when designing an SVE system. Significant seasonal or daily (tidal or precipitation-related) fluctuations may, at times, submerge some of the contaminated soil or a portion of the extraction well screen, making it unavailable for air flow. This is most important for horizontal extraction wells, where the screen is parallel to the water table surface.

Surface seals might be included in an SVE system design to prevent surface water infiltration that can reduce air flow rates, reduce emissions of fugitive vapors, prevent vertical short-circuiting of air flow, or increase the design ROI. These results are accomplished because surface seals force fresh air to be drawn from a greater distance from the extraction well. If a surface seal is used, the lower pressure gradients result in decreased flow velocities. This condition may require a higher vacuum to be applied to the extraction well.

Pilot studies are an extremely important part of the design phase. Data provided by pilot studies is necessary to properly design the full-scale SVE system. Pilot studies also provide information on the concentration of volatile organic compounds (VOCs) that are likely to be extracted during the early stages of operation of the SVE system.

A pilot test is recommended for evaluating SVE effectiveness and design parameters for any site, especially where SVE is expected to be only marginally to moderately effective. Pilot studies typically include short-term (1 to 30 days) extraction of soil vapors from a single extraction well, which may be an existing monitoring well at the site. However, longer pilot studies (up to 6 months) which utilize more than one extraction well may be appropriate for larger sites. Different extraction rates and wellhead vacuums are applied to the extraction wells to determine the optimal operating conditions.

Vapor concentrations are also measured at two or more intervals during the pilot study to estimate initial vapor concentrations of a full-scale system. The vapor concentration, vapor extraction rate and vacuum data are also used in the design process to select extraction and treatment equipment.

In some instances, it may be appropriate to evaluate the potential of SVE effectiveness using a screening model such as HyperVentilate (EPA, 1993). HyperVentilate can be used to identify required site date, decide if SVE is appropriate at a site, evaluate air permeability tests, and estimate the minimum number of wells needed. It is not intended to be a detailed SVE predictive modeling or design tool.

Advantages:

- Proven performance; readily available equipment; easy installation.
- Minimal disturbance to site operations.
- Short treatment times (usually 6 months to 2 years under optimal conditions).
- Cost competitive: $20-50/ton of contaminated soil.
- Can be applied at sites with free product, and can be combined with other technologies.

Disadvantages:

- Concentration reductions greater than about 90% are difficult to achieve.
- Effectiveness less certain when applied to sites with low-permeability soil or stratified soils.
- May require costly treatment for atmospheric discharge of extracted vapors.
- Air emission permits generally required.
- Only treats unsaturated-zone soils; other methods may also be needed to treat saturated-zone soils and groundwater.

References

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Additional Information

- Glossary
- DiGiulio, D.C., and Varadhan, R., 2001. Development of recommendations and methods to support soil venting performance and closure (PDF) U.S. EPA, ORD, EPA/600/R-01/070. (435 pp, 5MB, About PDF)