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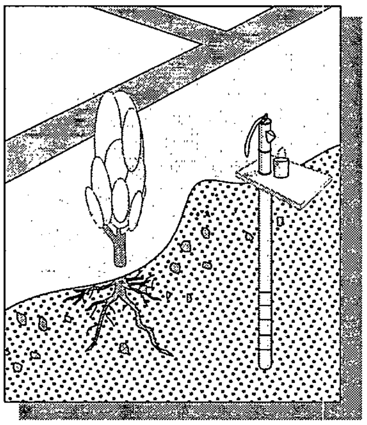
EPA Analysis of Selected Enhancements for Soil Vapor Extraction



Introduction

Soil vapor extraction (SVE) has been used at many sites to remove volatile organic compounds (VOC) from soil in the vadose zone. The effectiveness of SVE, however, may be limited for some contaminants and geologic conditions. In recent years, new approaches have been developed to enhance removal of VOCs from vadose zone soils and VOCs dissolved in groundwater or adsorbed to saturation zone soils. These approaches use SVE as a base or "platform" for integration with other subsurface and groundwater technologies.

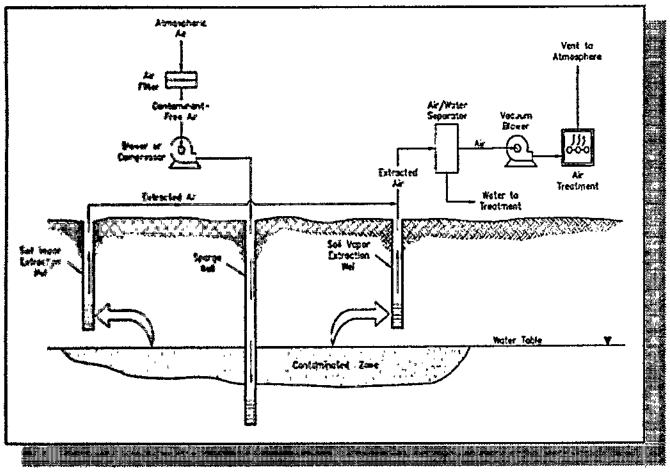
This report assists the site manager by providing an evaluation of the current status of SVE enhancement technologies. The five technologies evaluated in this report are:

- ❑ **Air Sparging**
- ❑ **Dual-Phase Extraction**
- ❑ **Directional Drilling**
- ❑ **Pneumatic and Hydraulic Fracturing**
- ❑ **Thermal Enhancement**

The report discusses the background and applicability; provides an engineering evaluation; evaluates performance and cost; provides a list of vendors; discusses strengths and limitations; presents recommendations for future use and applicability; and lists vendors and references cited for each SVE enhancement technology.

Background

SVE is an in situ remediation technique that applies a vacuum to vapor extraction wells and induces air flow through contaminated soil. As the air migrates through the soil, VOCs are volatilized and transported to the extraction wells where they are removed from the subsurface. The performance of an SVE system depends on properties of both the contaminants and the soil. Enhancement technologies should be considered when contaminant or soil characteristics limit the effectiveness of SVE, or when containments are present in saturated soil. SVE by itself does not effectively remove contaminants in saturated soil. However, SVE can be used as an integral part of some treatment schemes that treat both groundwater and the overlying vadose zone.



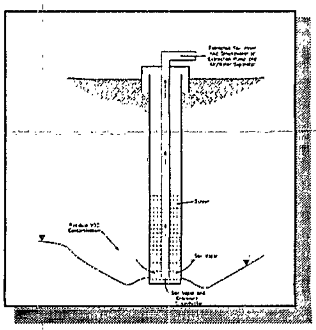
AIR SPARGING

Air sparging is a process during which air is injected into the saturated zone below or within the areas of contamination. As the injected air rises through the formation, it may volatilize and remove adsorbed VOCs in soils within the saturated zone as well as strip dissolved contaminants from groundwater. Air sparging also oxygenates the groundwater and soils, thereby enhancing the potential for biodegradation at sites with contaminants that degrade aerobically.

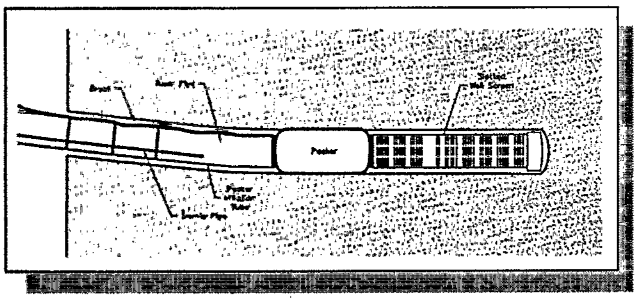
Air sparging is most effective at sites with homogenous, high-permeability soils and unconfined aquifers. Clogging of the aquifer, sparging probes, or well screens due to enhanced bacterial growth or precipitation of metals under increased oxygen levels may occur. The report identifies factors affecting the applicability of air sparging, summarizes published information on air sparging at 29 sites, and lists nine vendors of air sparging technologies.

DUAL-PHASE EXTRACTION

Dual-phase extraction (DPE) removes both contaminated water and soil gases from a common extraction well under vacuum conditions, reducing both the time and cost of treatment. By lowering the groundwater table at the point of vapor extraction, DPE enables venting of soil vapors through previously saturated and semisaturated (capillary fringe) soils. High vacuums typically associated with DPE systems enhance both soil vapor and groundwater recovery rates.



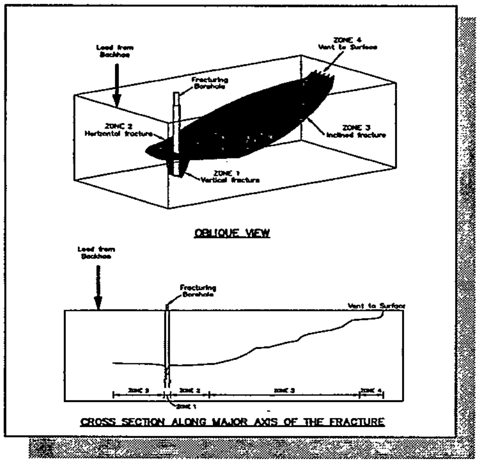
DPE is most advantageous for sites with soils that have low to moderate hydraulic conductivity. Groundwater extraction rates required for effective operation in permeable soils may be prohibitively expensive, and extraction drawdowns may be limited. The report provides cost and performance information for five case studies and lists 10 vendors of DPE technologies.



DIRECTIONAL DRILLING

Directional drilling employs the use of specialized drill bits to advance curved boreholes in a controlled arc (radius) for installation of horizontal wells or manifolds for SVE and sparging technologies. Horizontal wells can be used for enhancement of groundwater extraction, air sparging, SVE, and free product removal systems.

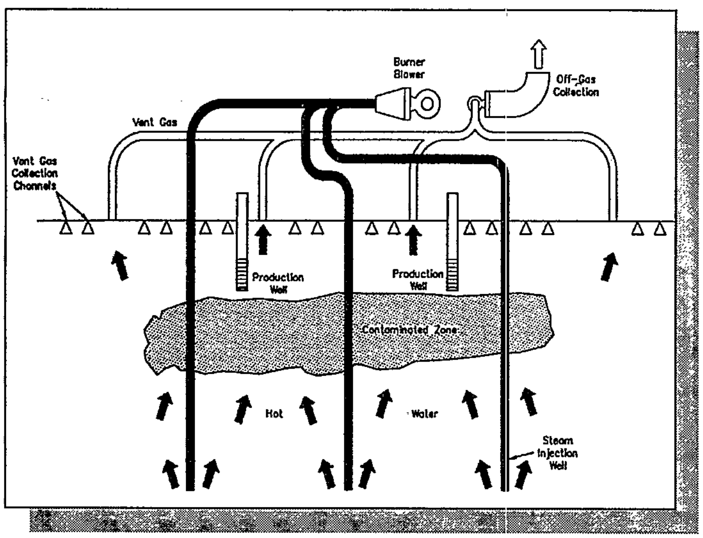
Horizontal wells are best suited for silty sand, sand, and fine gravel lithologies. Costs increase dramatically in bedrock, clay, and glacial till or when cobbles or boulders are encountered. Highly fluctuating water tables can cause problems in horizontal well SVE systems. The report identifies 11 professional contacts and two information centers, as well as listing 21 vendors of directional drilling technologies.



PNEUMATIC AND HYDRAULIC FRACTURING

Pneumatic and hydraulic fracturing involve the injection of either gases (typically air) or fluids (either water or slurries) to increase the permeability of the area around an injection well, thereby allowing increased removal or degradation rates of contaminants and potentially more cost-effective remediation. The typical application of pneumatic and hydraulic fractures is to improve the performance of wells used during SVE remediation. Fracturing also can increase the recovery of free-phase fluids by increasing the production of recovery wells.

Once horizontal fractures have been propagated, changes in soil vacuum can induce controlled vertical or inclined fractures between horizontal fractures. Fracturing is ineffective in normally consolidated soils and sediments in which the horizontal stress is less than the vertical stress. The report provides information on remediation technologies at 24 sites enhanced by fracturing, and lists 13 vendors of fracturing technologies.



THERMAL ENHANCEMENT

Thermal enhancements for SVE involve transferring heat to the subsurface to increase the vapor pressure of VOCs or semivolatile organic compounds (SVOC) or to increase air permeability in the subsurface formation by drying it out. The removal of contaminants by SVE is controlled by a number of transport and removal mechanisms including gas advection, chemical partitioning to the vapor phase, gas-phase contaminant diffusion, sorption of contaminants on soil surfaces, and chemical or biological transformation. Thermal enhancement technologies raise the soil temperature to increase the reaction kinetics for one or all of these removal and transport mechanisms. Thermal enhancement technologies include hot air or steam injection, radio-frequency heating (RFH), electrical resistance (ER) heating, and thermal conduction heating.

Steam injection and hot air injection are limited to medium- to high-permeability soils; ER heating is more appropriate for heating and drying lower-permeability soil in the vadose zone. Whereas ER heating can be used to enhance bioremediation, the high temperatures associated with RFH inhibit biological activity. The report provides performance data for 18 sites and lists 11 vendors of thermal enhancement technologies.

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