



SVE and Air Sparging Remedial Wall

By Michael J. Pierdinock, LSP, and Joseph B. O'Brien, Senior Project Engineer

This first case describes the selection of and conceptual design of a SVE/AS Remedial Wall, and provides the results of an ongoing case study at a vehicle-maintenance facility.



Remedial wall installation.

A historical release of gasoline from multiple underground storage tanks (USTs) impacted soil and groundwater at a vehicle-maintenance facility operated by a utility company located in the Boston metro area. A subsurface soil and groundwater investigation was conducted to assess the extent of gasoline impacted soil and groundwater on-site and off-site. As a result of the concern for the potential migration of gasoline impacted groundwater and vapors to subsurface utilities and the basement of residences directly adjacent to the site, an in-situ Soil Vapor Extraction (SVE) and Air Sparging (AS) Remedial Wall was designed and installed within one month to remediate gasoline impacted vapors and groundwater prior to the migration off-site.

Background

Based upon the inferred groundwater flow direction, and soil and groundwater analytical concentration gradients, the estimated extent of the plume is 275 ft long by 140 ft wide. Groundwater was encountered approximately 8 ft below grade. The concentration of petroleum related compounds (Volatile Petroleum Hydrocarbons and target volatile organic compounds (VOCs)) detected in soil and groundwater were at or near solubility concentrations throughout the entire length of the plume, and were distributed within the shallow portion of the aquifer. Light non-aqueous phase liquids (LNAPL) was only observed directly adjacent to the USTs or source areas of the release.

As a result of the conditions encountered at the site, an Immediate Response Action (IRA) was required pursuant to the Massachusetts Contingency Plan. The objective of the environmental response action was to limit the migration of impacted media off-site and to prevent the potential

for an explosive condition or generation of vapors in the basement of the downgradient residences and utilities. To meet those objectives, a remedial technology was required that was technologically and economically feasible to either remediate or inhibit the migration of gasoline impacted groundwater and vapors off-site. The technology selected

contaminants from subsurface soils and groundwater. In addition, the movement of air through the subsurface stimulates microbial activity and enhances the biodegradation of petroleum hydrocarbons.

Air Sparging. The AS process involves the injection of contaminant-free compressed air beneath the groundwater table (saturated zone) as indicated in **Figure 1**. The injected air forms

approximately 1/3 of the depth of the injection point below the groundwater table.

Within the middle zone, air travels along the micro-channels over the saturated soil particles. The primary mechanism for contaminant removal in this zone is the partitioning of dissolved phase contaminants into the vapor phase, followed by vapor transport. This zone can extend radially from the injection point one to two times the depth of the injection point below the groundwater table.

Within the outermost zone, dissolved oxygen (DO) migrates outward through diffusion, driven by the concentration gradient produced by the air injection. Although no air flow occurs, elevated DO levels have been detected. This zone can extend outward radially typically beyond three times the depth of the injection point.

Soil Vapor Extraction. SVE has been demonstrated to successfully remediate contaminated soils above the saturated zone. When SVE is combined with air sparging, a synergistic remedial approach to treating both soil and groundwater can be achieved. The SVE process involves applying a vacuum to the subsurface through a series of vapor extraction points as indicated in **Figure 2**. The applied vacuum induces the flow of air through impacted soils and increases the rate of contaminant partitioning to the vapor phase. Vapors are then drawn into the extraction wells for above-ground treatment. The SVE technology combined with air sparging can capture vapor phase contaminants "stripped" through sparging within the saturated zone, thereby reducing the potential for fugitive emissions. SVE flow rates are typically three

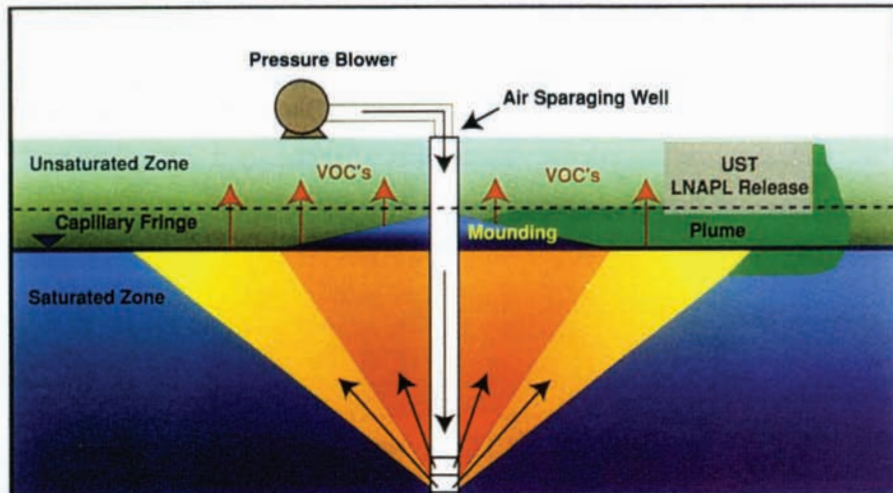


Figure 1. Air Sparging Detail

would be required to be designed and constructed quickly and cost effectively.

Remedial Technology Evaluation

Conventional groundwater containment technologies were evaluated: groundwater gradient control, extraction and treatment, slurry walls, sheet piling, and interceptor trenches. The disadvantage of these technologies is that they create groundwater management issues and require ongoing operation and maintenance, and do not actually remediate groundwater. In addition, there is a considerable expense to design and install these systems.

An alternative approach to containment is the use of an in-situ treatment technology such as SVE/AS. Air sparging combined with SVE provides a synergistic remedial approach that aggressively remediates dissolved and pure phase petroleum constituents and captures impacted vapors prior to migrating off the property. This technology also enhances bioremediation by creating an aerobic subsurface environment that stimulates naturally occurring microorganism populations, thereby increasing the rate of natural biodegradation of the hydrocarbons. In this application, a conservative design approach was utilized with the horizontal and vertical positioning of SVE/AS wells perpendicular to groundwater flow to create a remedial wall.

SVE/AS Remedial Technology Description

SVE and AS are air driven, in-situ remedial technologies that rely on mass transfer to remove

micro channels that migrate horizontally and vertically away from the injection point. The micro channels contact contaminated soils and groundwater causing the VOCs to partition into the vapor phase from the liquid and dissolved phases. This results in an in-situ air stripping effect of the volatile compounds in groundwater and soil. As the air migrates away from the injection point,

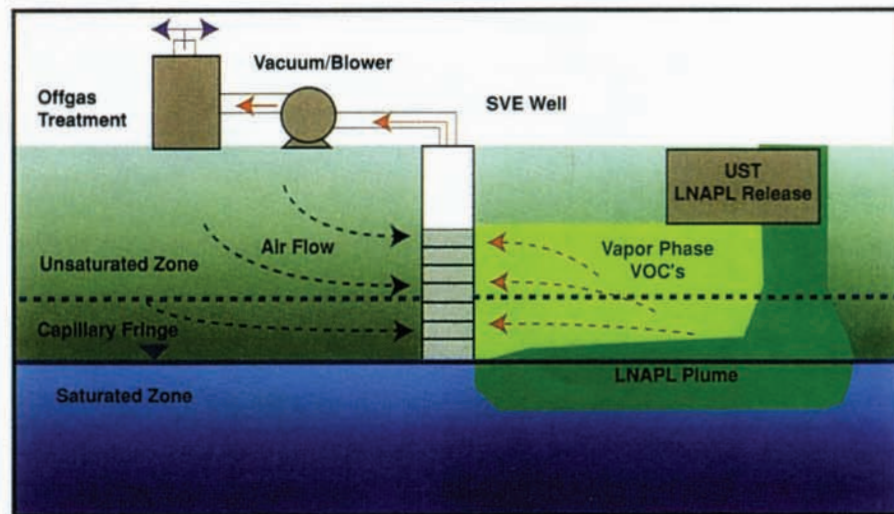


Figure 2. Soil Vapor Extraction Detail

three remedial zones are created. Within the innermost zone, almost all water in the soil pores is displaced by air. Contaminant removal is primarily by volatilization and the mass transfer of residual VOCs. Groundwater mounding can occur within this zone, but this effect has been observed to be short term. This zone can extend radially from the injection point, to approxi-

times greater than AS injection rates to safeguard against fugitive AS emissions.

Bioremediation. In addition to mass transfer of contaminants to the surface for treatment, SVE also enhances biostimulation of the naturally occurring microbial populations associated with the hydrocarbon release. By creating a subsurface aerobic environment with SVE, microbial popula-

tions can flourish and increase biodegradation rates for volatile and non-volatile compounds within the saturated and unsaturated zones.

The advantage to these combined technologies is a three-phase remediation approach involving in-situ groundwater treatment, soil treatment, and soil and groundwater biodegradation through biostimulation for both volatile and non-volatile compounds. This approach provides an aggressive and synergistic remediation program.

SVE/AS Remedial Wall Conceptual Design

The SVE/AS Remedial Wall was proposed to be installed parallel to and adjacent to the street, and span the estimated petroleum plume migration pathway as indicated in **Figure 3**. In response to addressing the off-site migration of petroleum impacted groundwater as quickly as possible, a conservative design was implemented in lieu of a pilot test. Installation was completed within 15 days after design approval.

Table 1. AS Injection Pressure

$$P_i = H_i + P_a + P_d \text{ [3]}$$

where:

- P_i**=air sparge injection pressure (in psi);
- H_i**=saturated thickness above AS screen interval (ft of water);
- P_a**=air entry pressure of soil formation (ft of water);
- P_d**=air entry pressure for well screen (ft of water);

and in this case study:

- H_i**=10 ft of water;
- P_a**=estimated at five ft of water [4];
- P_d**=estimated at three ft of water [4];

and therefore:

P_i=18 ft of water or about eight psi.

The SVE/AS Remedial Wall is designed to limit the migration of petroleum impacted groundwater by stripping the constituents from the migrating groundwater and delivering them in the vapor state to the unsaturated zone to be collected by the SVE system. Important design considerations included:

- Free phase product or LNAPL was not present at the proposed remedial wall location;
- There are no basements or residences within 50 ft of the proposed Remedial Wall location;
- Henry Law constants and vapor pressures for gasoline related compounds benzene, toluene, ethyl-benzene, and total xylenes (BTEX) are con-

sidered high which is ideal for air stripping and volatilization the primary remedial components of AS [1]; and

- The geology of the unconfined aquifer sand and gravel fill with estimated intrinsic soil permeability of 10^{-6} to 10^{-4} cm² [2].

Depth of AS Injection Wells. Based on the LNAPL characteristics and soil and groundwater analytical results, the SVE/AS Remedial Wall was designed to treat the upper 10 ft of the saturated zone. The design involves two AS injection screens per well location. The first AS screen was con-

structed with the top of its two-ft screen at 10 ft below the groundwater table and the second AS top of screen at 5 ft below the seasonal low groundwater table. This design allows for any soil heterogeneity that may exist between the screen intervals in the upper and lower impacted saturated zone.

AS Well Zone of Influence. Based on the injection depth of 10 ft, the expected radius of influence of the AS Point could be up to 30 ft radially from the AS point. A conservative 10-ft AS radius of influence was used for design

The image shows the cover of the journal 'environmental TECHNOLOGY'. The title is in large, stylized letters with a green-to-yellow gradient. Below the title, it says 'Journal of Advanced Science & Engineering www.environmentcenter.com Vol. 8 Issue 7 November/December 1998'. The main visual is three laboratory bottles with stoppers, one in the foreground and two behind it. Overlaid on the bottles is the text 'Product News' in a large, bold, white font with a black outline. In the bottom right corner, there is a list of topics: 'Remediation Case Histories', 'Thermal Treatment', 'Operation & Maintenance', 'Health & Safety Training', and 'Stormwater Management'.

assuming a 1:1 vertical to horizontal air channel migration ratio.

AS Injection Rate. Based on the assumption of soil porosity of 20%, the AS zone of influence for a 10 ft injection depth with a 10 ft radius of influence would contain an approximate volume of 210 ft³. The proposed AS injection rate per screen is three to five SCFM, which will provide 20 to 35 air exchanges per day for each AS screen interval.

AS Injection Pressure. Based on an AS injection depth of 10 ft, a sand and gravel fill

grade as indicated in **Figure 3**.

Each AS well was constructed of 1.25-inch diameter, stainless steel, 2 ft, 0.010 slot screens, with a 1-in. diameter black iron steel riser, in flush mounted road box. The AS well design includes 10 wells screen installed approximately 14 to 17 ft below grade (approximately 5 ft below the seasonable low groundwater table) and 10 well screens installed approximately 20 to 24 ft below grade (approximately 10 ft below the seasonable low groundwater table) as indicated in **Figure 3**. Each SVE well head was connected to schedule 40 PVC subsurface piping to a common manifold within the remediation building. Each

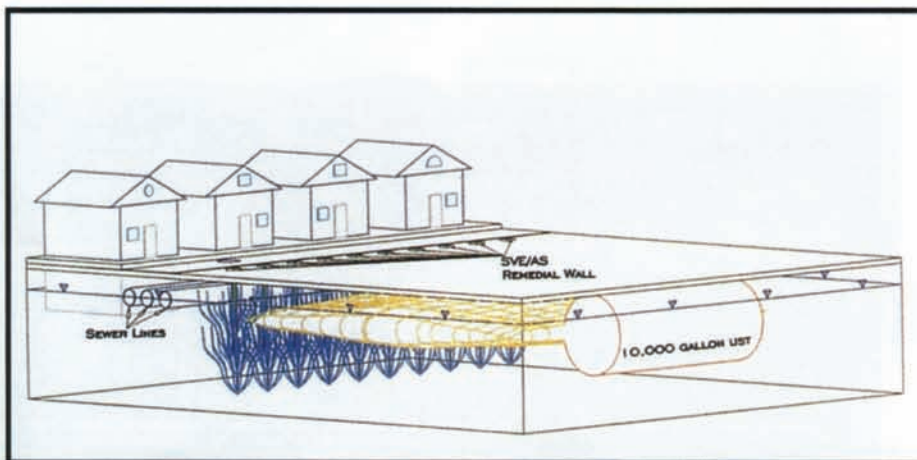


Figure 3. SVE/AS Remedial Wall

geology and the utilization of two ft stainless steel 0.010-in. slot AS screens set in filter pack, the air sparge injection pressure is calculated as set forth in **Table 1**.

The injection pressure and injection flow rates continued to be balanced during the start-up phase, with individual flow control valves allowing manipulation of rates within each AS screen interval.

SVE Extraction Rate and Vacuum. Based on the AS injection rate of three to five SCFM per screen interval and two screen intervals per AS point, the maximum injected AS air flow rate per SVE/AS well couplet would be 10 SCFM. There-

fore, the SVE extraction rate per SVE/AS well would utilize an approximate 3:1 extraction versus injection ratio per SVE/AS well, or 30 SCFM per SVE well and 10 SCFM per AS well. The estimated extraction vacuum was 30 in. of water vacuum for a 2-in. diameter SVE extraction point.

SVE/AS Remedial Wall Installation

Each SVE well was constructed of 2-in. diameter, schedule 40 PVC, 5 ft, 0.010 slot screens, in flush mounted road boxes. Each SVE well screen was installed approximately 2.5 to 7.5 ft below

AS well head was connected to 1-in. diameter HDPE subsurface piping to a common manifold at the remediation building.

The SVE/AS remedial system is housed in a skid mounted insulated shed, and consists of a positive displacement rotary lobe type vacuum extraction blower capable of 330 SCFM at 60 in. of water vacuum/pressure and a positive displace-

ment rotary lobe type AS blower capable of 110 SCFM at 9 psi. The air sparge blower included a filtered intake air, high temperature discharge switch and an integral relay to shut down the AS blower if the SVE unit shuts down. The SVE blower included a moisture separator tank with a high level float switch, filtered inlet air and dilution, high temperature discharge switch, and recirculation/flow control valve.

As a result of the elevated petroleum mass removal rate observed during operation (> 35 lbs/day), the extracted SVE vapors were treated utilizing a catalytic oxidizer capable of a 95%

destruction removal efficiency (DRE) at 330 SCFM, with an integral relay to shut down the SVE blower if the catalytic unit shuts down. A master control panel operates the remedial equipment and alert personnel upon alarm shut downs via modem. The costs of the system is set forth below:

As set forth in **Table 2**, the catalytic oxidizer is an expensive capital item, however, the catalytic oxidation is a cost effective option to treat off-gas vapors and achieve a DRE of greater than 95%. After two months of operation, it was calculated that the cost of the vapor phase carbon to treat the equivalent mass of VOCs would have equalled the capital cost of the catalytic oxidizer.

Operation, Maintenance and Monitoring Results

Over the first one to two months of operation, the SVE system extraction rate was 350 SCFM at 10 to 20 in. of water column vacuum. AS injection pressures ranged from 6 to 9 psi at the AS wellheads. The AS injection flow rate was 100 SCFM. The initial start up of the remedial system consisted of SVE only to allow for the soil vapor concentrations to equilibrate prior to AS. Upon start-up of the AS system on day 34, the extracted vapor concentrations significantly increased. Approximately 1,510 lbs of petroleum constituents have been extracted or 35 lbs per day. The installation of the remedial wall has achieved its objectives to limit the off-site migration of vapors and impacted groundwater to sensitive receptors downgradient of the property boundary.

Notes & References

- Henry's Law constants range from 5.1x 10⁻³ to 8.7 x 10⁻³ atmospheres/m³/mole and vapor pressures range from 6.6 to 95.2 millimeters of mercury at 20°C for BTEX compounds. Nyer, Evan K., "In Situ Treatment Technology," pp. 199, Lewis Publishers, New York, 1996.
- EPA, "How to Evaluate Alternative Cleanup Technologies for Underground Storage Tank Sites," EPA 150-B-95-007, May, 1995.
- Nyer, Evan K., "In Situ Treatment Technology," pp. 208, Lewis Publishers, New York, 1996.
- Nyer, Evan K., "In Situ Treatment Technology," pp. 209, Lewis Publishers, New York, 1996.

For more information, contact the authors at RAM Environmental, LLC, (508) 747-7900; e-mail: pdinockm@ramenvironmental.com.

SVE/AS Remedial Wall Design:	\$10,000
SVE/AS Remedial Wall Installation and Construction:	\$63,000
Catalytic Oxidizer:	\$40,000
One year of Operation, Maintenance, Monitoring and Reporting:	\$18,500
Total:	\$131,500

Reader Rating. Please circle the appropriate number on the Reader Service Card to indicate your level of interest in this article/topic.

High 315 Medium 316 Low 317