Lecture 12: In Situ Air Sparging and Vacuum Extraction

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Faculty of Engineering & Applied Science
12.1 Introduction

- In situ air sparging

- A remediation technique has broad appeal since about 1985 due to its projected low costs relative to conventional approaches.

- For the remediation of volatile organic compounds (VOCs) dissolved in the groundwater, sorbed to the saturated zone soils, and trapped in soil pores of the saturated zone.

- Often in conjunction with vacuum extraction systems to remove the stripped contaminants.
Schematic of Air Sparging with Vacuum Extraction

Source: Hardisty, 2005
12.2 Applicability

- In order for air sparging to be effective $\Rightarrow$ the VOCs must transfer from the groundwater into the injected air, and oxygen present in the injected air must transfer into the groundwater to stimulate biodegradation.

- The criterion for defining contaminant strippability $\Rightarrow$ Henry’s law constant being greater than $1 \times 10^{-5}$ atm-m$^3$/mol.

- Compounds with a vapor pressure greater than 0.5 to 1.0 mmHg $\Rightarrow$ can be volatilized easily.
## Examples of Contaminant Applicability for In Situ Air Sparging

<table>
<thead>
<tr>
<th>Contaminant</th>
<th>Strippability</th>
<th>Volatility</th>
<th>Aerobic biodegradability*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benzene</td>
<td>High ( H = 5.5 \times 10^{-3} )</td>
<td>High ( V_P = 95.2 )</td>
<td>High ( t_{1/2} = 240 )</td>
</tr>
<tr>
<td>Toluene</td>
<td>High ( H = 6.6 \times 10^{-3} )</td>
<td>High ( V_P = 28.4 )</td>
<td>High ( t_{1/2} = 168 )</td>
</tr>
<tr>
<td>Xylenes</td>
<td>High ( H = 5.1 \times 10^{-3} )</td>
<td>High ( V_P = 6.6 )</td>
<td>High ( t_{1/2} = 336 )</td>
</tr>
<tr>
<td>Ethylbenzene</td>
<td>High ( H = 8.7 \times 10^{-3} )</td>
<td>High ( V_P = 9.5 )</td>
<td>High ( t_{1/2} = 144 )</td>
</tr>
<tr>
<td>TCE</td>
<td>High ( H = 10.0 \times 10^{-3} )</td>
<td>High ( V_P = 60 )</td>
<td>Very low ( t_{1/2} = 7704 )</td>
</tr>
<tr>
<td>PCE</td>
<td>High ( H = 8.3 \times 10^{-3} )</td>
<td>High ( V_P = 14.3 )</td>
<td>Very low ( t_{1/2} = 8640 )</td>
</tr>
<tr>
<td>Gasoline constituents</td>
<td>High</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Fuel oil constituents</td>
<td>Low</td>
<td>Very low</td>
<td>Moderate</td>
</tr>
</tbody>
</table>

*Note: \( H \) = Henry's law constant (atm·m\(^3\)/mol); \( V_P \) = vapor pressure (mmHg) at 20°C; \( t_{1/2} \) = half-life during aerobic biodegradation, hours.*

*It should be noted that the half-lives can be very dependent on the site-specific subsurface environmental conditions.*

Source: Suthersan, 1997

- Removal of fuel oil \( \Rightarrow \) aerobic biodegradation
Qualitative presentation of potential air sparging mass removal for petroleum compounds

Source: Suthersan, 1997
12.3 Description of the process

(1) Air injection into water-saturated soils

(2) Mounding of water table

- Air injected into the saturated zone $\rightarrow$ groundwater necessarily be displaced $\rightarrow$ the displacement of groundwater will have both a vertical and lateral component
- Water table mounding $\rightarrow$ a local rise in the water table caused by the vertical component
- Mounding $\rightarrow$ an indicator of the “radius-of-influence” of the sparge well during the early stages of air sparging
- The magnitude of mounding $\rightarrow$ depends on site conditions and the location of the observation wells relative to the sparge well $\rightarrow$ vary from a negligible amount to several feet in magnitude
The first transient behavior after initiation of air injection into the saturated zone.

The second transient behavior before reaching steady state during air sparging.
(3) Distribution of airflow pathways

a) Homogeneous geology, low air flow.

b) Homogeneous geology, moderate to high air flow.

c) Heterogeneous geology, low air flow.

Subtle geologic changes

d) Heterogeneous geology, moderate air flow.

Subtle geologic changes

Source: Suthersan, 1997
(4) Groundwater mixing

- may significantly reduce the diffusion limitation for mass transfer during air sparging without generating any changes in the bulk groundwater flow

- is important during air sparging to effectively transport dissolved oxygen for in situ Bioremediation

- can be effective if it occurs at the pore scale as well as over site-scale distances
12.4 Enhanced air sparging technologies

(1) Horizontal trench sparging

- Trench sparging ➔ developed to apply air sparging under less permeable (the hydraulic conductivities (in the horizontal direction) are less than $10^{-3}$ cm/s) geologic conditions when depth of contamination is less than 30 ft

- Generally applicable ➔ where there is a shallow depth to groundwater and the formation is fine grained
Horizontal trench sparging (Plan view)

GW FLOW

MULTIPLE TRENCHES TO ACCELERATE CLEAN UP

Horizontal trench sparging (Section view)

GW FLOW

Air Extraction

Pea Gravel

Nutrients

Extracted Air

Air Injection
(2) In-well air sparging

- to use air as the carrier of contaminants → to overcome the difficulties of injecting air into “non-optimum” geologic formations

- Injection of air into the inner casing → induces an “air lifting effect” → water column inside the inner casing lifted upward and overflow over the top → contaminated water drawn into the lower screen and continuously “air lifted” in the inner tube → strippable VOCs captured for treatment
In-well air sparging
(3) Biosparging

- To remediate a dissolved plume of contaminant, which is a nonstrippable but extremely biodegradable compound

- Injection of air at very low flow rates (0.5 cfm to less than 2 to 3 cfm per injection point) into water-saturated formation to enhance biodegradation

(4) Vapor recovery via trenches

- A minor modification to conventional air sparging that involves the recovery of stripped vapors from fine-grained formations of a shallow depth to groundwater
Air sparging with vapor recovery through trenches
(5) Pneumatic fracturing for vapor recovery

- Using pneumatic fracturing to enhance vapor recovery
- Applicable to sites with fine-grained formations that extend below the water table and depths to water that prohibit trenching
- Increased hydraulic and vapor flow conductivity near the top of the water table and in the overlying unsaturated zone → allowing stripped contaminants to be collected without spreading out laterally
Air sparging combined with pneumatic/hydraulic fracturing