Bioventing (is Still Bioventing)

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Principles of Bioventing

• Subsurface injection or withdrawal of air to stimulate biodegradation of contaminants in the vadose zone

• Similar to soil vapor extraction, but with significantly different objectives
  – maximize biodegradation
  – minimize volatilization

• Applicable to any aerobically biodegradable compound

• Demonstrations established bioventing as preferred conventional technical option for remediation of petroleum hydrocarbons

• Inexpensive, safe, easily implemented technology
Schematic Diagram of a Typical Bioventing System
Applicability of Bioventing
Positive Indicators

• Oxygen content is initially less than 5%
  – Indicates aerobic biological activity consumed oxygen
  – If not, identify potential limiting factors, such as nutrient limiting, toxic substances, lack of moisture and determine if these factors can be overcome through engineering controls

• Result of respiration test greater than 0.1% oxygen per day
  – Confirms aerobic biological activity
  – If not, identify potential errors in test procedures or limiting factors as discussed above

• Soil permeability high enough to maintain >5% oxygen over radius sufficient for cost effective system (i.e. greater than 0.01 Darcy)
  – Indicates bioventing will be effective
  – If not, consider fracturing
Key Technology Considerations

• Most Important Factor
  – Oxygen (petroleum hydrocarbons and other aerobically degraded compounds)

• Long-term Technology
  – Several years may be required to achieve remedial goals

• Other Factors
  – Temperature
  – Moisture
  – Nutrients
Flowchart for Determining Bioventing Applicability

1. **Data and Site History Review**
   - **Soil Gas Survey**
     - Oxygen Concentration <5%*
       - **In Situ Respiration Test**
         - Respiration Rates >0.1% Q/day*
           - **Soil Gas Permeability Test**
             - $R_s < \text{Length of Screen or Permeability <0.01 Darcy}$
               - **Intrinsic Bioremediation or Alternative Technology**
             - $R_s > \text{Length of Screen or Permeability >0.01 Darcy}$
               - **Full-Scale Design and Installation**
           - **Intrinsic Bioremediation or Alternative Technology**
         - **Techniques Look Good**
           - Techniques Look Good
             - **Intrinsic Bioremediation or Alternative Technology**
           - **Limiting Factor Identified**
             - Implement Treatment Option
         - **Evaluate Field Sampling Procedures**
           - **No Limiting Factors Can Be Identified**
             - **Limiting Factor Identified**
               - Implement Treatment Option
     - **Low Respiration Rates <0.1% Q/day**
       - **Identify Limiting Factors**
         - **No Limiting Factors Can Be Identified**
           - **Limiting Factor Identified**
             - Implement Treatment Option
Hydrocarbon Biodegradation and Volatilization Rates as a Function of Flowrate
Health and Safety

- Vapors can migrate into buildings
- Vapors may be carcinogenic (benzene)
- Vapors and/or in within the explosive range
  - gasoline sites
  - Sites containing “fresh” contaminants
Components of a Bioventing System - Vent Well

- Spacing typically 1.5 to 1.7 times the radius of influence
- Typically, 2- to 4-inch-diameter PVC
- Screen should extend through as much of the contamination as possible, with bottom corresponding to lowest historical water table level
Components of a Bioventing system - Monitoring Points

- Locate in contaminated soil
- Position considering soil-gas permeability test: minimum 3 locations from vent well
- Generally, 3 depths
  - Deepest, at bottom of contamination
  - Shallowest, 3 to 5 ft below ground surface
## Monitoring Point Spacing

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Depth to Top of Vent Well Screen (ft)</th>
<th>Spacing Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coarse sand</td>
<td>5</td>
<td>5-10-20</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>10-30-50</td>
</tr>
<tr>
<td></td>
<td>&gt;15</td>
<td>20-30-70</td>
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<tr>
<td>Medium sand</td>
<td>5</td>
<td>10-20-30</td>
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<td></td>
<td>10</td>
<td>15-25-45</td>
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<tr>
<td></td>
<td>&gt;15</td>
<td>20-40-70</td>
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<tr>
<td>Fine sand</td>
<td>5</td>
<td>10-20-40</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>15-30-50</td>
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<td></td>
<td>&gt;15</td>
<td>20-40-60</td>
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<tr>
<td>Silts</td>
<td>5</td>
<td>10-20-40</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>15-30-50</td>
</tr>
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<td></td>
<td>&gt;15</td>
<td>20-40-60</td>
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<td>Clay</td>
<td>5</td>
<td>10-20-30</td>
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<tr>
<td></td>
<td>10</td>
<td>10-20-40</td>
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<tr>
<td></td>
<td>&gt;15</td>
<td>10-25-50</td>
</tr>
</tbody>
</table>
Air Delivery Systems

• Air injection
  – Actively inject air via blower system

• Air extraction
  – Air treatment may be required
  – Mounding may occur

• Passive venting
  – Capitalize on natural barometric pressure fluctuations or tidal influences to aerate contaminated areas
Radius of Influence During Air Injection and Air Extraction

![Graph showing the radius of influence during air injection and air extraction. The graph plots log pressure (inches of water) against distance from the vent well (ft). Two lines are present: one for injection mode and another for extraction mode. The data points are marked with circles and triangles, respectively.](image-url)
Bioventing by Air Extraction

If air injection is better why would anyone use extraction for bioventing

Because we must in order to:

• Prevent migration of vapors into subsurface structures, which could cause indoor air issue or worse yet, an...

• Prevent excessive surface emissions

• Alleviate concerns over contaminant migration
Basic Air Extraction System
Alternatives to Direct Extraction with Emission

- Isolation of subsurface structure
- Reinjection
Passive Bioventing

- Barometric pressure changes
  - Drive natural air exchange in subsurface
- Simple and inexpensive
- Alternative for remote sites
- May be applied at sites with:
  - Large soil-gas reservoir
  - Porous media
  - Substantial temperature or barometric pressure fluctuations
  - Low permeability layer near ground surface
- Installed at MCAGCC 29 Palms
  - Depth to groundwater ~70 m
  - Deeper wells produced greater flowrates
Oxygen Concentrations During and Following Passive Aeration

Date of Recording

Oxygen Concentration (%)

30 ft

50 ft

40 ft

Start Passive Bioventing 10/11/96

End Passive Bioventing 10/30/96
Bioventing Monitoring

• In situ respiration test
  – Year 1 - Semi-annually
  – Year 2 to closure - annually

• When oxygen utilization approaches 0, initiate final sampling

• No periodic soil sampling needed!!
Cleanup Times and Costs are Site Specific

In General: 2 to 10 years for TPH
1 year for BTEX

Factors:

• Soil characteristics
• Contaminant location and distribution
• Soil moisture content
• Contaminant concentration
• Desired cleanup time
• Air emissions
Comparison of Costs for Soil Treatment

- 2 Years Bioventing
- Soil Vapor Extraction
- Land Farming
- Excavation and LTT
- Biopile Treatment

Costs are presented per cubic yard of soil, with varying costs depending on the cubic yards of soil treated.
Key Factors to Success

• Sufficient site characterization
• Field testing (extensive pilot not always necessary but quick field test is important)
• Set realistic budget and schedule
• Design review by experienced personnel; this does not always happen even at firms having such experienced personnel
• Project planning and construction management
• Establish site-specific monitoring and optimization plan
Bioventing Design Tool (BVDT)

- Developed by Battelle to help analyze field data, construct tables, and construct charts that will help with full-scale design. Sections include:
  - Data collection
  - In situ respiration test
  - Permeability and radius of influence
  - Blower design
  - Vent well and monitoring point spacing
  - Soil gas monitoring
Bioventing Example – Jet Fuel Cleanup

• 100,000 liters spilled
  – About 8,000 L free product recovered
  – 3,800 m³ contaminated soil, up to 20 m deep
  – TPH up to 10,200 mg/kg

• Converted SVE to bioventing
  – Removed off-gas treatment system – saved $13,000/month
  – 15 months operation
  – Biodegraded more than 40,000 kg fuel
  – Cleanup and regulatory closure achieved