

BIOVENTING



Air-Based Remediation Technologies

Presentation Objectives

- Describe various configurations of in-situ bioremediation technologies
- Describe applicability of bioremediation technologies
- Identify data needs for technology selection/design
- Recommend pilot testing approaches
- Provide design considerations
- Discuss operational strategies
- Compare closure strategies



Air-Based Remediation Technologies

Bioventing

- Operating principles
 - Air injected at low rates (can be extraction in some cases)
 - Increase oxygen content - oxygen limited conditions
 - Minimize mobilization of vapors
 - Enhance existing natural bioremediation
 - May be able to use passive air injection
- May prevent intrusion of hydrocarbons vapors
- Passive bioventing
 - Use of barometric changes to inject air
 - Need barrier to vapor exchange to surface



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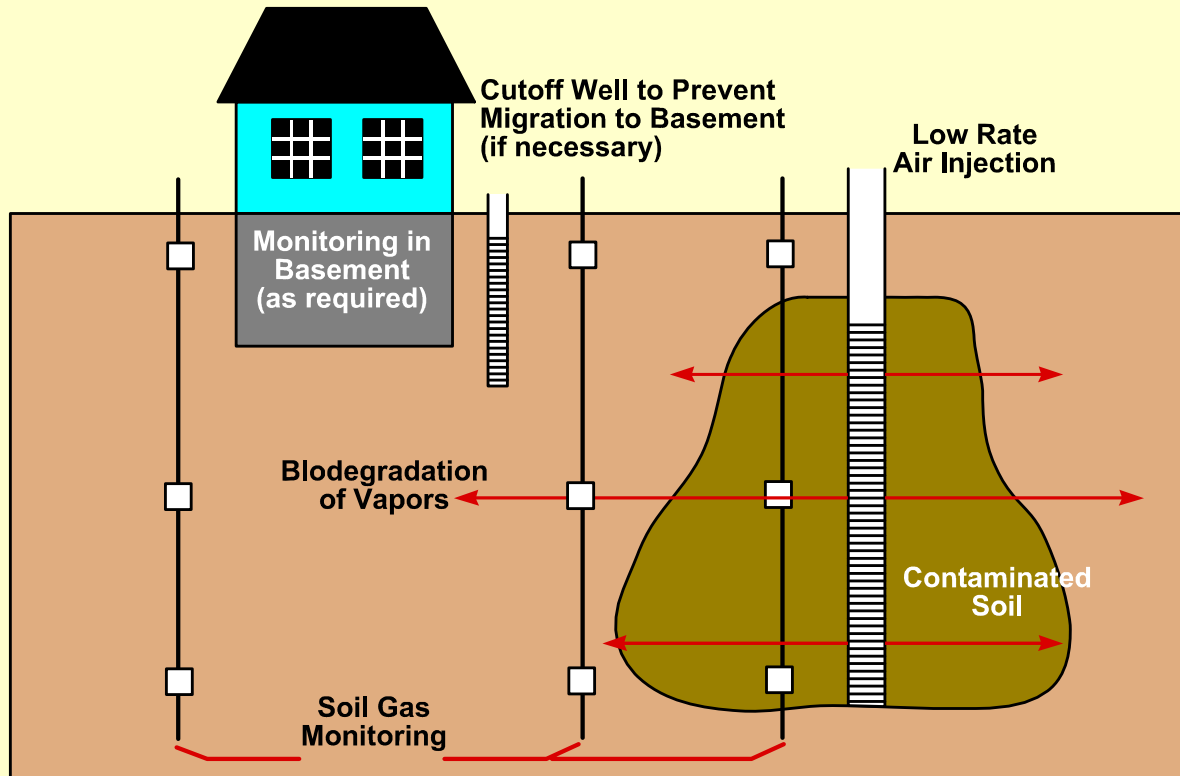
Other Bioventing Configurations

- Can inject other gases to promote degradation of chlorinated solvents
 - Comatabolic bioventing
 - Methane, propane injection (at <LEL)
 - Create enzymes to destroy TCE
- Creating reducing conditions to treat metals, others?
 - Inject N₂, carbon source, induce anaerobic conditions



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Bioventing (Injection)

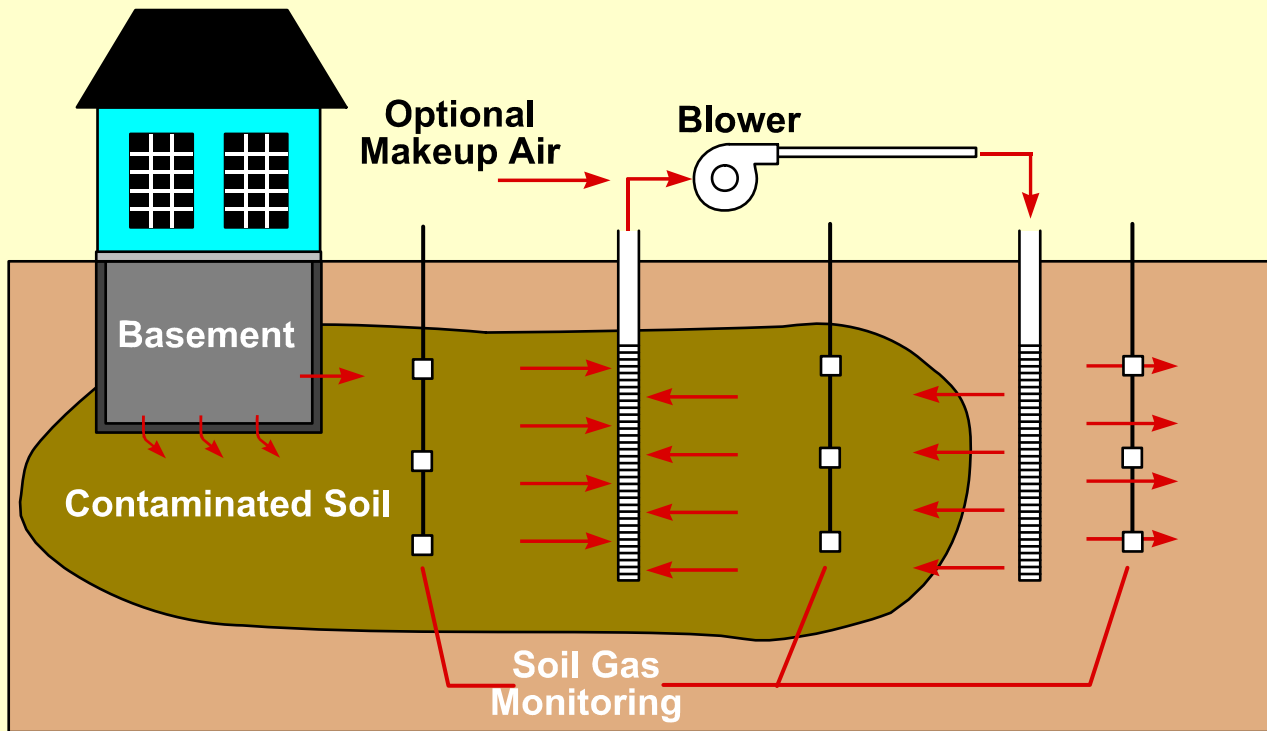


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Bioventing (Extraction)



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Bioventing Applicability

- By nature, an aerobic process
 - Aerobically degradable hydrocarbons
 - Co-metabolic degradable chlorinated organics
- Require adequate air permeability
 - Similar site applicability as SVE
- Often effective for light hydrocarbons, but very slow for heavier hydrocarbons
 - May achieve limits for benzene, etc., But not for total petroleum hydrocarbons
 - Does remove more mobile contaminants



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Bioventing Limitations

- Moisture/nutrient control
 - May be needed in dry areas
 - Some researchers claim nutrients not needed
 - Other studies suggest nutrients may help
 - Nutrient, moisture addition by liquid, vapor



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BV Data Needs

BV Design Consideration

- Needs type, quantity, and 3-D distribution of contaminants and free products for locations of injection, extraction, and monitoring wells
- Determine biodegradation vs. abiotic processes (e.g., dilution / dispersion / volatilization)
 - Mass balance of O₂, CO₂, and contaminants if extractive BV
 - Compound Specific Isotope Analysis (CSIA) – stable isotope ratios change and serve as unique “signatures” (www.epa.gov/ada/pubs/reports/600r08148/600r08148.pdf)



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BV Data Needs

- Soil gas oxygen, carbon dioxide content
- Stratigraphy
- Moisture content
- Nutrient availability
- Site features (utilities and basements)
- Air permeability
- Water table fluctuations, floating product
- Enumeration studies



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Bioventing Pilot Studies

- Air permeability testing, step testing
- Respiration tests
 - Verify oxygen depletion
 - Aerate portion of contaminated site
 - Can use aeration part of test to determine air permeability
 - Use of helium - determine diffusive losses
 - Aerate background site – assess natural oxygen demand



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Bioventing Pilot Studies

- Respiration tests, continued
 - Sample soil gas in multi-depth probes over time
 - Monitor carbon dioxide, oxygen levels, he
 - Look at oxygen uptake, use stoichiometry to estimate mass destroyed
 - Estimate respiration rate
 - Subtract background rate, diffusive losses



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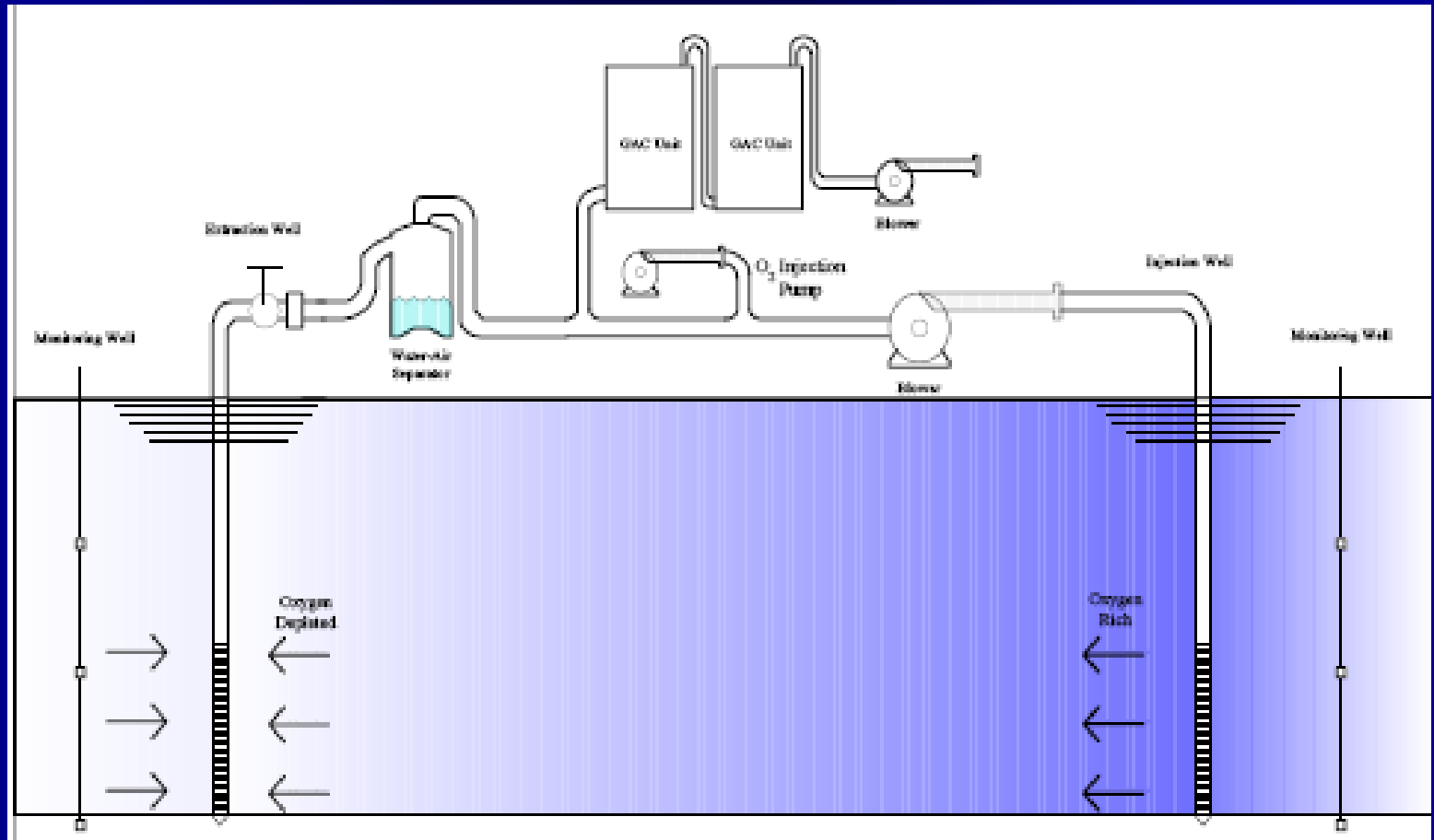
Bioventing Design

- Well spacing and screen placement
 - Air delivery obviously critical
 - Space wells, choose air injection to achieve one air exchange throughout treatment volume in 2 to 4 days
 - Consider contaminant distribution in choosing screened interval
- Well design: similar to SVE wells, injection rates low
- Monitoring system: multi-depth probes, in areas near and far from injection points
 - Assess vapor intrusion at occupied buildings



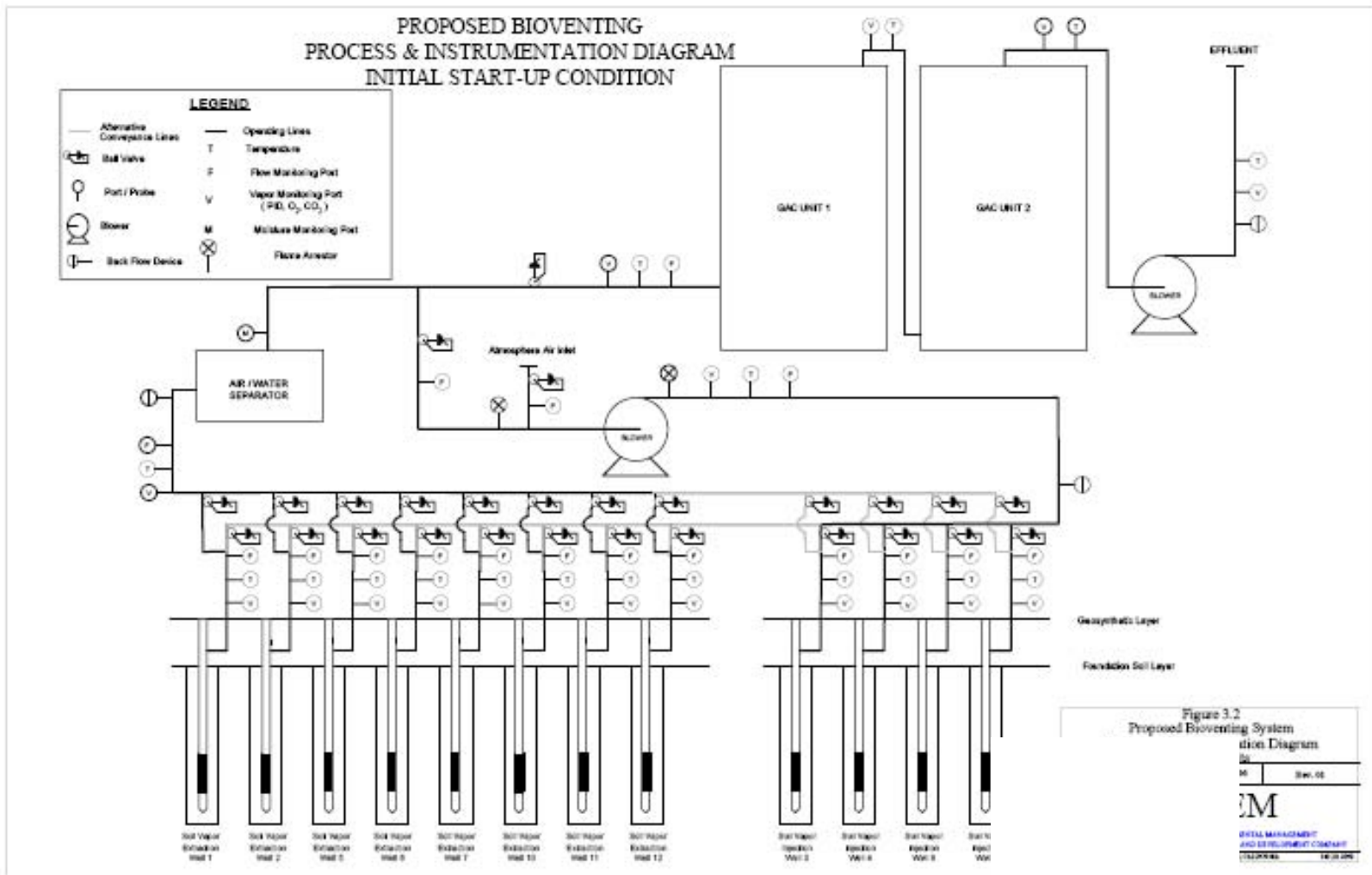
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Bioventing Piping



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PROPOSED BIOVENTING
PROCESS & INSTRUMENTATION DIAGRAM
INITIAL START-UP CONDITION



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BV Piping Design

- Piping:
 - Similar considerations as for SVE piping
 - Consider pressure drop along piping
 - Address potential for condensation



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Blower Design

- Types: typically regenerative, positive displacement (rotary lobe)
- Identify necessary flow, predict wellhead pressure/vacuum
- Match blower performance curve to system conditions, including the losses in piping
- Minimize energy use, maximize speed, need flexibility - variable speed drive motors



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Monitoring System Design

- Permanent probes, small diameter, good seal
 - Multiple depths - use to confirm design
 - Choose representative locations based on geology, contaminants
- Flow control valves, sample port
- Flow measurement device for each wellhead
 - Pitot tubes, orifice plate, rotometers, anemometer
- Temperature, vacuum/pressure measurement before/after blower



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Other Components

- Condensate handling
 - Insulate, heat tracing
 - If extracting, address as would for SVE
- Particulate filters
 - Dust at intake
 - Filters: ~10 um paper cartridge, others
 - Measure pressure drop across filter



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BV Off-gas Treatment

- Offgas Treatment (if operating in extraction mode)
 - Carbon Adsorption, Resin Adsorption
 - Thermal Destruction
 - Catalytic Oxidation
- Considerations similar to SVE



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Control System

- Control system
 - Well suited to unattended operation
 - Typically modest level of automation
 - Auto-dial for shut-down condition
 - Thermal cut-off on blower motor, high condensate tank level, high vacuum/low pressure
 - Pressure relief valves, bleed valve



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Off-site Considerations

- Noise < 120 dB
- VOC vapor migration (in injection mode)
 - Utility corridors
 - Basements
 - Vapor discharge to atmosphere
 - Ambient air sampling may rarely be needed



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Bioventing Construction and Operations

- Bioventing remediation in months to years
- Construction:
 - Weeks to months
 - Installation of wells, piping
 - Above-ground equipment
 - Often leased
 - Concrete pad, temporary building
- Safety
 - If extraction, similar to SVE
 - Rotating machinery
 - Unexpected vapor migration



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Bioventing Start-up And Operations

- Start up
 - Similar to SVE
 - Baseline oxygen uptake in new wells
- Operations
 - Balance air flow to wells
 - Match oxygen demand in area
 - Maintain blower
 - SVE - to - bioventing conversion
- Optimization



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BV System O&M Monitoring

- Monitoring – contaminant concentrations in vapor, O₂, CO₂ levels
 - Portable meters typically used
- Periodic respiration tests
- Monitor flow rates, pressures at each well
- Possibly sample soil periodically to assess progress



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Bioventing Operations and Closure

- Duration - Longer than SVE, Still Few Years
- Monitoring - Contaminant Concentrations in Vapor, O₂, CO₂ Levels, Air Injection Rates
- Periodic Respiration Tests
- Subsurface Performance Evaluation Checklist
- Verification Sampling and Closure Criteria
 - Based on Respiration Rates: If No O Demand, Done All You Can Do
 - Soil Sampling



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References

- Soil Vapor Extraction and Bioventing EM
- EPA/AF Principles & Practices Manual available
<http://www.afcee.af.mil/shared/media/document/AFD-070926-074.pdf>
- Air Force Bioventing Design Tool
<http://www.afcee.af.mil/resources/technologytransfer/programsandinitiatives/bioventing/resources/index.asp>



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Bioventing Case Study

Battle Creek, Michigan USA

- Fire-training area
- Contaminants
 - 280,000 L of fuels, solvents
 - Benzene, related contaminants to 15,000 mg/kg total petroleum hydrocarbons
- Hydrogeology
 - Sand and gravel



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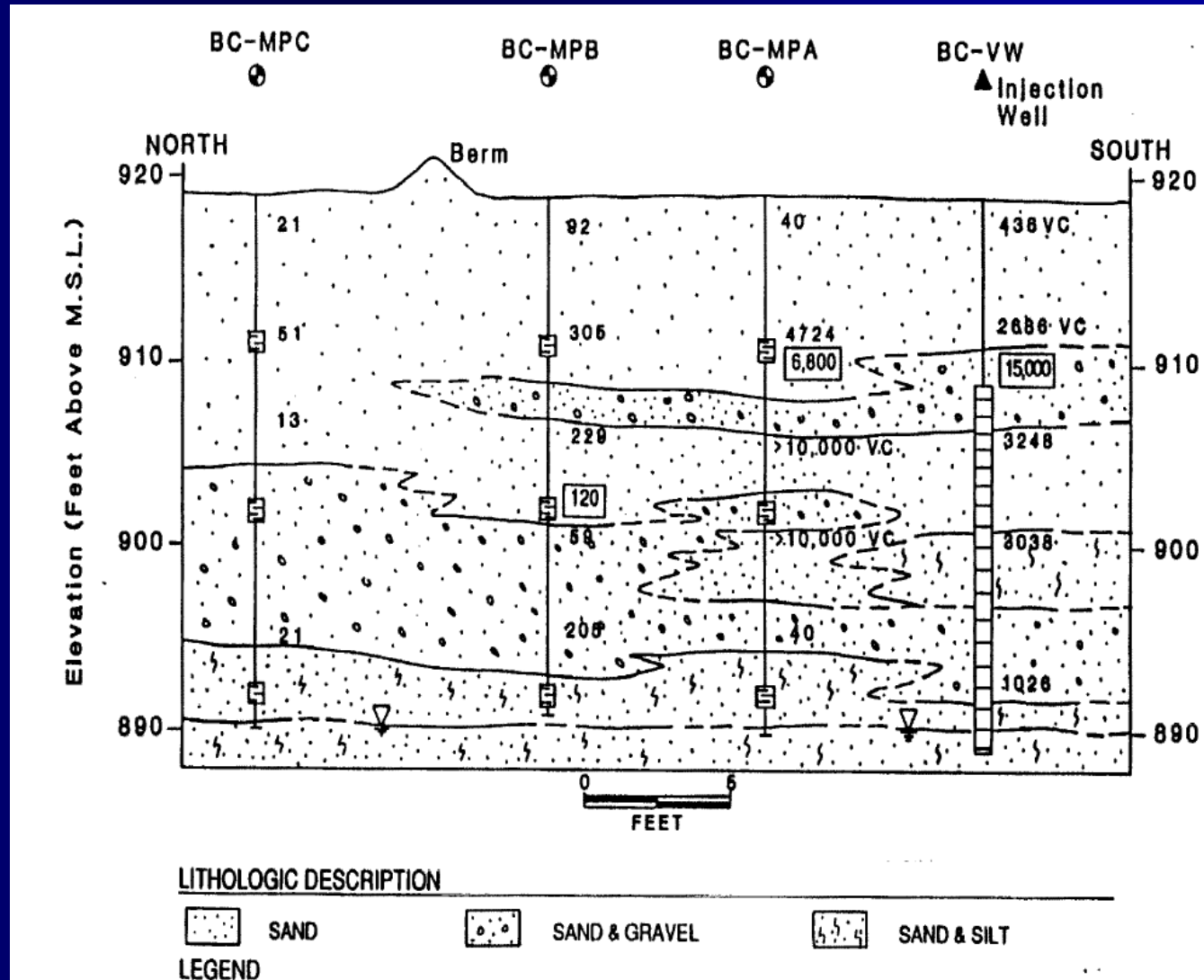
Bioventing Case Study, Continued

- Technology Implemented
 - Air injection, small 1 HP regenerative blower
 - Large area of influence per well (>15 m)
 - Monitored soil gas concentrations
 - Final soil sampling



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Site Conditions

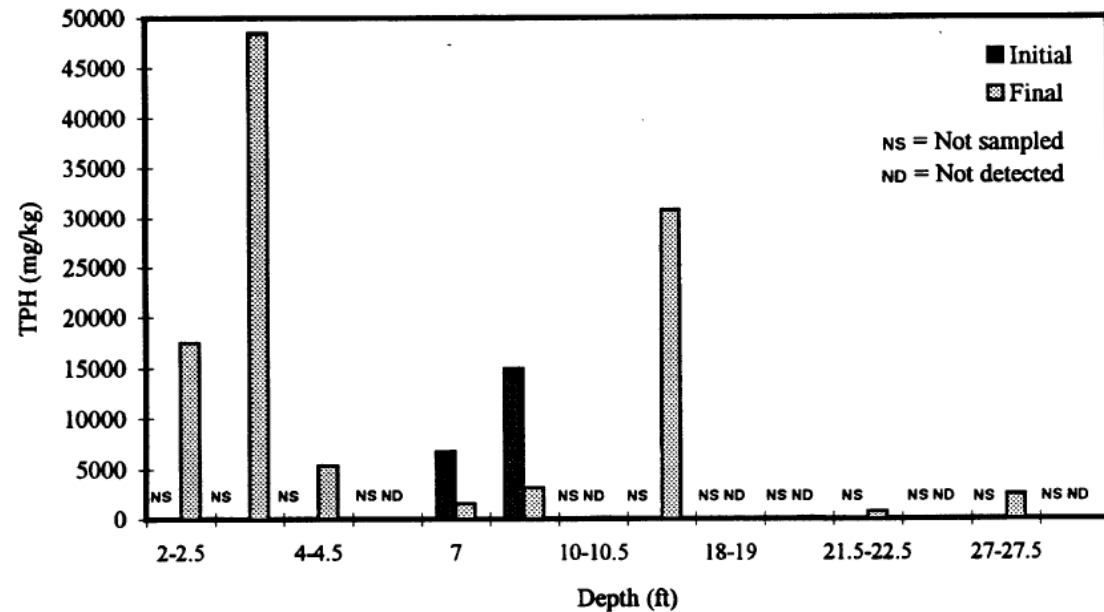
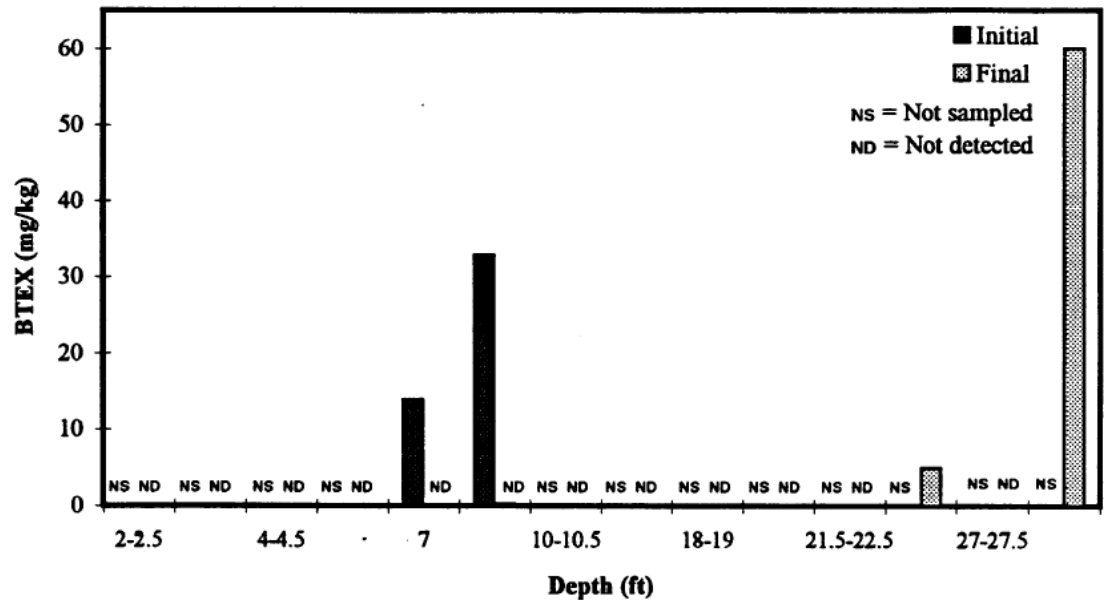


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Results

- Benzene, other constituents largely removed
- Less effective for other hydrocarbons



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Presentation Summary

- Bioventing for aerobic degradation of organics
 - Look for oxygen limiting conditions
 - Do respiration testing
 - Design aeration system
 - Assess performance by periodic respiration tests
- Variations tailored to biodegradation of chlorinated organics
- Passive bioventing is potentially sustainable option



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