VAPOR INTRUSION

State Bar of Michigan
Environmental Law Section

September 18, 2014
Vapor Intrusion!
Objectives

• Introduce VI concepts and issues
• Sampling Media
• Issues that affect VI
• Helpful hints
• Installing a soil gas point
Terms

Concentrations in the soil, soil gas, and groundwater that generate vapors = **Vapor Source**

Migration of vapors from contaminated groundwater or soil *into* an overlying building = **Vapor Intrusion**
Figure 1. Migration of Soil Vapors to Indoor Air

- Stack effects
- Wind effects

- Vapor intrusion through cracks in foundation slab
- Vapor intrusion through floor-wall cracks
- Soil vapor migration
- Water table
- Soil contaminated with VOCs
- Groundwater plume of VOCs

*EPA, 2012*
Screening Distances

- PVI = Petroleum
- CVI = Chlorinated VOCs

PVI – 30’ from all sources

CVI – 100’ from all sources

CAN IMPACT ADJACENT PROPERTIES!
Typical VI Scenarios
# How do we investigate VI?

## Advantages and Disadvantages Associated with Sampling Media

<table>
<thead>
<tr>
<th>Media</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groundwater sampling</td>
<td>Commonly collected during the course of an investigation</td>
<td>May not accurately represent vapor concentrations when sources are present in the vadose zone</td>
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<tr>
<td></td>
<td>Helps assess potential downgradient impacts of VI</td>
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<tr>
<td></td>
<td>Can be performed at properties having no existing buildings</td>
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<tr>
<td>Soil sampling</td>
<td>Commonly collected during the course of an investigation</td>
<td>VOC loss on sampling may be significant, which can mean vapor concentrations may be significantly underestimated</td>
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<tr>
<td></td>
<td>Can be performed at properties having no existing buildings</td>
<td>May not accurately represent vapor concentrations when sources are present adjacent to collected sample</td>
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<td></td>
<td>Detects may indicate VI issues</td>
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<tr>
<td>Soil gas sampling</td>
<td>Can provide an estimate of vapor concentrations near the source or near buildings</td>
<td>Lateral and vertical spatial variability</td>
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<td></td>
<td>Collected near buildings; can be performed without entering the structure</td>
<td>Results may not be representative of vapor concentrations under a building</td>
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<tr>
<td></td>
<td>Can be performed at properties having no existing buildings</td>
<td>May not reflect how soil gas concentrations will change if a building is subsequently built on a currently vacant property</td>
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<tr>
<td>Sub-slab sampling of vapors beneath buildings</td>
<td>Can provide measure of vapor concentration directly below indoor air space</td>
<td>Method is intrusive</td>
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<tr>
<td></td>
<td>Closest subsurface sample to receptors</td>
<td>Cannot be performed at properties having no existing buildings</td>
</tr>
<tr>
<td>Indoor air sampling</td>
<td>Can provide direct measurement of indoor air concentrations</td>
<td>Indoor contaminants and lifestyle sources may bias the data</td>
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<tr>
<td></td>
<td></td>
<td>Method is intrusive</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cannot be performed at properties having no existing buildings</td>
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<tr>
<td></td>
<td></td>
<td>Varies significantly over time</td>
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</table>
Soil Samples and VI

- “Generally” not a good predictor
- Where the sample is collected matters
Soil (cont)

• **PROs**
  – Commonly collected during the course of an investigation
  – Sampling methodology is well accepted

• **CONs**
  – May not accurately represent vapor concentrations when sources are present adjacent to collected sample
  – VOC loss on sampling may be significant
Groundwater

- **PROs**
  - Commonly collected during the course of an investigation
  - Can be performed at properties having no existing buildings

- **CONs**
  - May not accurately represent vapor concentrations when sources are present in the vadose zone
  - Modeled indoor air concentration
Soil Gas

• PROs
  – Can provide an estimate of vapor concentrations near the source or near buildings
  – Can be performed without entering the structure

• CONs
  – Results may not be representative of vapor concentrations under a building
  – May not reflect how soil gas concentrations will change if a building is subsequently built on a currently vacant property
**Subslab Soil Gas**

**PROs**
- Can provide measure of vapor concentration directly below indoor air space
- Closest subsurface sample to receptors

**CONs**
- Method is intrusive
- Cannot be performed at properties having no existing buildings
Why not indoor air?

• Highly variable
  – Seasonal
• TWA vs. grab
• Expensive
  – Relocation
  – Prep/post
• Expect indoor air concentrations
Variability of Indoor Air

![Graph showing variability of indoor air pollutants over time.](image-url)
EPA 2011 Indoor Air Study

Figure 4. Total percent detections of common VOCs in background indoor air compiled from 15 studies conducted between 1990 and 2005. Range of reporting limits is shown in parentheses.
Some are easy to figure out. . .

PCE > 95% by weight
Can also include:
- TCE
- Toluene
- Acetone
- More. . .

Can include:
- TCE
- Toluene
- Acetone
- More. . .

- PCE
Some aren’t

Contains:
- Naphthalene (31 µg/m³)
- 1,4 Dioxane (2,100 µg/m³)
- Toluene (120 µg/m³)
- Ethanol (600,000 µg/m³)
- And a bunch of others . . .

Contains:
- TCE
- PCE (up to 95% by weight)

Contains:
- Ethylbenzene (3,400 µg/m³)
- Toluene (660 µg/m³)
- TPH (390,000 µg/m³)
- And more . . .

1,2 DCA
Grilling with flavor. . .
Why not OSHA values?

• Not designed for the “non-worker”
• Requires awareness training, PPE, and/or medical monitoring
  • “Simply complying with OSHA’s antiquated PELs will not guarantee that workers will be safe.” - David Michaels, Assistant Secretary of Labor for Occupational Safety and Health
• OSHA may be acceptable
• **NOT RESIDENTIAL**
Indoor Air

**PROs**
- Can provide direct measurement of indoor air concentrations

**CONs**
- Method is intrusive
- Indoor contaminants and lifestyle sources may bias the data
- Varies significantly over time
- Cannot be performed at properties having no existing buildings
What does the data mean?

\[ \text{attenuation factor} = \frac{\text{Indoor Air Concentration}}{\text{Source Concentration}} \]

\[ \text{attenuation factor} = \alpha \]

\[ \alpha \times (\text{Source Concentration}) > \text{Indoor Air Concentration} \]

\[ \text{POTENTIAL VAPOR INTRUSION} \]
Johnson and Ettinger (1991)

\[ \alpha = \left( \frac{C_{\text{indoor}}}{C_{\text{source}}} \right) \]

\[ \alpha = \left[ \exp \left( \frac{Q_{\text{soil}} L_{\text{crack}}}{D_{\text{crack}} A_{\text{crack}}} \right) + \left( \frac{D_{\text{eff}} A_{B}}{Q_{\text{building}} L_{T}} \right) + \left( \frac{D_{\text{eff}} A_{B}}{Q_{\text{soil}} L_{T}} \right) \exp \left( \frac{Q_{\text{soil}} L_{\text{crack}}}{D_{\text{crack}} A_{\text{crack}}} - 1 \right) \right] \]

Empirical Evidence

http://www.epa.gov/oswer/vaporintrusion/vi_data.html

- Over 1,600 “paired” data points
Interpreting the Results

- Variability (spatial and temporal)
  - Construction
    - Size of structure
    - Slab-on-grade vs crawlspace
    - Heating and cooling systems
  - Precipitation and weather
  - Measurement method
Interpreting the Results (cont)

– Distance to source
  • Assumes knowledge of the extent of source of vapors
– Depth to water (if a source)
– Soil characteristics
  • bulk density, total porosity, water filled porosity, soil water content, grain size
– System temperature (north vs south)
– Air exchange rate
Building Construction

Diagram depicting indoor air, vadose zone soil gas, soil contamination, chemical vapor migration, and groundwater contamination in building construction contexts.
Building Size and Source Location

Figure 2-2. Soil gas and groundwater concentrations below a slab (Schumacher et al., 2010).
Soil Types

- Sand – 39.4%
- Loam – 36.7%
- Clay – 15.9%
- Other – 8.0%
Temperature

• Assign temp based on identified county average
  – Data based on 72 Stations
  – Daily average
  – Up to 15 years of data
Multiple Lines of Evidence

- Soil gas spatial concentrations
- Groundwater spatial data
- Building construction
- Sub-slab soil gas data
- Indoor air data
- Soil stratigraphy
- Temporal patterns
Investigate vs. Presumptively Mitigate

Extra time and cost required for investigation

vs.

Cost to presumptively mitigate the site (allowed for under Part 201)
Response Actions

- Source Area Remediation
- Institutional Controls
- Building Controls
# APPENDIX 1

## Recommended Parameters for Common Petroleum Products

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Leaded Gasoline&lt;sup&gt;1&lt;/sup&gt;</th>
<th>Unleaded Gasoline&lt;sup&gt;2&lt;/sup&gt;</th>
<th>Petro. Solv&lt;sup&gt;3&lt;/sup&gt;</th>
<th>Light Distillate Oils&lt;sup&gt;4&lt;/sup&gt;</th>
<th>Residual Oils&lt;sup&gt;5&lt;/sup&gt;</th>
<th>Used Motor Oils&lt;sup&gt;6&lt;/sup&gt;</th>
<th>Waste Oils&lt;sup&gt;7&lt;/sup&gt;</th>
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<td>X</td>
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</tbody>
</table>
PNAs with HLC > $10^{-6}$

- Naphthalene
- 2-methylnaphthalene
- Acenaphthene
- Acenaphthylene
- Fluorene

- Anthracene
- Phenanthrene
- Ethylene Dibromide (1,2-Dibromoethane)
- Fluoranthene
- Pyrene

*TO-15 can’t analyze everything . . .
Common Soil Gas Methods

- TO-15
- TO-17
- TO-13A
  - (via Low-Flow)
- NIOSH
- EPA

**NOTE:** JUST LIKE SOIL AND GROUNDWATER, MORE THAN ONE METHOD MAY BE REQUIRED!
Typical Soil Gas Concentrations

- SG concentrations can create headaches!
  - Typical Soil Gas Concentrations
    - Benzene near gasoline spill: \(>100,000 \, \mu g/m^3\)
      - TPH vapor: \(>1,000,000 \, \mu g/m^3\)
    - TCE near a degreaser: \(>75,000 \, \mu g/m^3\)
    - PCE under dry cleaner: \(>100,000 \, \mu g/m^3\)
Something else to think about. . .

- How Fast Do Vapors Move?
  - Distance = \((2 \cdot D_e \cdot t)^{1/2}\)

  where:
  
  \(D_e\) is the effective diffusivity.
  
  \(t\) is time
How Fast Do Vapors Move (cont)?

• For many vapors, the gaseous diffusion coefficient is approximately 0.1 cm²/s
• Soil porosity varies depending on the type of soil
  – Several equations are available to calculate the effect of air-filled and total porosity on the diffusivity
  – Conservative approximation is that the porosity reduces the gaseous diffusivity by a factor of 10
  – $D_e$ can be approximated as 0.01 cm²/s
How Fast Do Vapors Move (cont)?

Distance
\[ = (2 \times 0.01 \text{ cm}^2/\text{s} \times 31,536,000 \text{ s})^{1/2} \]
\[ \sim 800 \text{ cm} = \sim 25 \text{ feet per year} \]

Into and through the groundwater in a year: 3 inches

* Assumes liquid diffusion, not gaseous diffusion, coefficient for compounds is approximately 0.00001 cm\(^2\)/s
Consider when sampling:

- Site geology
- Sample volume
- Sample collection vacuum
- Sample probe purging
- Soil gas equilibration
- Sampling interval
- Sampling method
- Weather?
Quality of the Data

**GOAL** is to collect reliable data!

- **How much to collect?**
  - number of samples vs volume
    - Greater the volume, greater the uncertainty
    - More samples, better characterization

- **Where will they be collected?**
  - Closer to surface, harder to collect
    - 5’ bgs generally considered stable (building?)
Quality of the Data (cont)

• When to collect
  – Weather
  – Seasonal effects
  – Extreme temperature variations
  – Heating/cooling of structure
  – Heavy periods of rain
• New vs old vs modified
• Will it change the concentrations?
Reliable Data Requires

• Just like soil and groundwater
  – Good sampling techniques
  – Good analytical methods
  – Good CSM (where is the source)
  – Understanding what the data means

• Experience with vapor sampling
  – Have they done this before?
  – Quality/experience of field staff? Sr or Jr?
Chain of Custody...
Breakthrough. . . NOT a lab issue, a sampling issue

<table>
<thead>
<tr>
<th>Substance</th>
<th>Result</th>
<th>Units</th>
<th>Reporting Limit</th>
<th>Dilution</th>
<th>Prep Date</th>
<th>Prep Batch</th>
<th>Analysis Date</th>
<th>Analysis Batch</th>
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<tbody>
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<td>Acetone (NN)</td>
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<td>mg/L</td>
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<td>08/08/2012</td>
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<td>Benzene (NN)</td>
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<td>mg/L</td>
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<td>1,2-Dichlorobenzene (NN)</td>
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### Table 4

**SOIL VAPOR ANALYTICAL RESULTS**

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<thead>
<tr>
<th>Soil Vapor Monitoring Point</th>
<th>Screened Interval</th>
<th>Sample Date</th>
<th>Lower Explosive Limit (LEL)</th>
<th>Oxygen</th>
<th>Hydrogen Sulfide</th>
<th>Benzene</th>
<th>Toluene</th>
<th>Ethylbenzene</th>
<th>m &amp; p-Xylenes</th>
<th>o-Xylene</th>
<th>Total Xylenes</th>
<th>Total Hydrocarbons as Gas</th>
<th>Carbon Dioxide</th>
<th>Methane</th>
<th>2-Propanol</th>
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<td>NM</td>
<td>NM</td>
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<td>7.1</td>
<td>&lt;1.0</td>
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<td>&lt;16.1</td>
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<td>NM</td>
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Questions that should be asked

- What level of uncertainty is acceptable?
  - Owner
  - Consultant
  - Financial institution/Other?
- Who is doing the sampling?
- Does my site conditions currently match the future?
  - If not what can be done?
Questions that should be asked

• What are the specific chemicals of concern need to be identified?
  – What methods are necessary and available?
  – Is there more than one method?
    • Is it an air method?
    • Is there a standard available?
    • Pros/Cons
  – What analytical method reporting limits are required?
Questions that should be asked

• Am I going to sample more than once?
  – How will that impact the data?
• What, where and when of sampling...
Closing
Soil Gas Wells

Also called:
• Soil Gas Monitoring Point
• Vapor Monitoring Point
• Others

LustLine #42, 2002
Sub-Slab Monitoring Point
Questions?

Matthew Williams
Vapor Intrusion Specialist
RRD-Superfund Section
Michigan Department of Environmental Quality
Phone: 517-284-5171
Email: williamsm13@michigan.gov