FET Seminar
Wisconsin’s Vapor Intrusion Guidance
Part 1
Vapor Intrusion Basics
Terry Evanson
Theresa.Evanson@wisconsin.gov
March 2 and 16, 2011
Conceptual Movement of Vapors in the Subsurface
Vapor movement from a VOC source
Vapors from a Release Directly Beneath Building & Vapor Movement Through Soils

- Contamination Source
- Vapor Movement away from Source
- Groundwater Contamination
Source Beneath Building & Lateral Vapor Migration: Saukville Cleaners
Saukville DC – Sub-slab PCE Vapor Concentrations

Vacant - 3,324 µg/m³

DC - 2,513,600 µg/m³

Laundry - 934,020 µg/m³

Sandmasters - 95 µg/m³

Dominos - 102,330 µg/m³

Studio₁ - 1,841 µg/m³

Studio₂ - 100,960 µg/m³

Studio₃ - 14,079 µg/m³
Saukville DC – Indoor Air

26,753 µg/m³

3,599 µg/m³

2,186 µg/m³

403 µg/m³

Tetrachloroethylene levels in indoor air
Vapors Migrating from Contaminants Located at the Groundwater Table
Vertical Movement of Vapors from groundwater to surface
Soil Vapor Profile: TCE in Groundwater Beneath Building
Site in SE WI – TCE in Groundwater

Extent of TCE in soil and groundwater
SE WI Site – vapor migration off groundwater table

TCE (ug/m3)
7/2006 - 11
2/2007 - 5.8

TCE (ug/m3)
7/2006 - 820
2/2007 - 1100

Groundwater TCE
7/2006 - 23 ppb

TCE (ug/m3)
7/2006 - 22,000
2/2007 - 30,000

Groundwater TCE
7/2006 - 2400 ppb
Stable/Receding Groundwater Plumes & VI Pathway

• “Stable or receding” may describe the groundwater plume behavior, but this is NOT sufficient evidence for closure unless vapor intrusion has been ruled out or adequately investigated and addressed.
Vapors Migrating Through Preferential Pathways in Soil/Utility Lines

Off-site Contaminant Source in Soil

Utility Lines
PCE in Sewer - Gunderson DC
Sewer as PCE source
Contaminated Groundwater Entering a Building

VOC contaminated source

Sump Pump

Foundation Drain

Contaminated Groundwater
Contaminated groundwater entering building - Reedsburg
### Table 1: Volatile Organic Compounds in Sump Water
Reedsburg Fire Station
131 S. Park Street, Reedsburg, Sauk County, Wisconsin
March 2007

All concentrations in micrograms per liter (μg/L)

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Sump Water Crock Locations</th>
<th>Wisconsin Groundwater Enforcement Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Floor Hole NE</td>
<td>Sump East</td>
</tr>
<tr>
<td>Petroleum VOCs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Benzene</td>
<td>890*</td>
<td>450*</td>
</tr>
<tr>
<td>Ethylbenzene</td>
<td>230</td>
<td>110</td>
</tr>
<tr>
<td>Naphthalene</td>
<td>32</td>
<td>20</td>
</tr>
<tr>
<td>Toluene</td>
<td>570</td>
<td>300</td>
</tr>
<tr>
<td>1,2,4-Trimethylbenzene</td>
<td>59</td>
<td>40</td>
</tr>
<tr>
<td>Total Xylenes</td>
<td>250</td>
<td>177</td>
</tr>
<tr>
<td>Dry Cleaning VOCs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chloromethane</td>
<td>ND</td>
<td>2</td>
</tr>
<tr>
<td>cis-1,2,-Dichloroethylene (DCA)</td>
<td>180*</td>
<td>54</td>
</tr>
<tr>
<td>Tetrachloroethylene (PCE)</td>
<td>ND</td>
<td>1</td>
</tr>
<tr>
<td>Trichloroethylene (TCE)</td>
<td>17*</td>
<td>7</td>
</tr>
</tbody>
</table>
## Table 2: Volatile Organic Compounds in Indoor Air

**Reedsburg Fire Department**  
131 S. Park Street, Reedsburg, Sauk County, Wisconsin  
January 2009

All concentrations in micrograms per cubic meter (µg/m³)

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Indoor Air Sample Locations</th>
<th>Non-Residential Indoor Air Action Level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Basement</td>
<td>Office First Floor</td>
</tr>
<tr>
<td><strong>Petroleum VOCs</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Benzene</td>
<td>52.0*</td>
<td>8.4</td>
</tr>
<tr>
<td>Ethylbenzene</td>
<td>14.0*</td>
<td>2.7</td>
</tr>
<tr>
<td>Toluene</td>
<td>73.0</td>
<td>17.0</td>
</tr>
<tr>
<td>1,2,4-Trimethylbenzene</td>
<td>6.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Total Xylenes</td>
<td>36.9</td>
<td>10.6</td>
</tr>
<tr>
<td><strong>Dry Cleaning VOCs</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chloromethane</td>
<td>1.0</td>
<td>1.1</td>
</tr>
<tr>
<td><em>cis</em>-1,2-Dichloroethylene (DCA)</td>
<td>9.2</td>
<td>ND</td>
</tr>
<tr>
<td>Tetrachloroethylene (PCE)</td>
<td>13.0</td>
<td>ND</td>
</tr>
<tr>
<td>Trichloroethylene (TCE)</td>
<td>17.0</td>
<td>ND</td>
</tr>
</tbody>
</table>
Questions?
Aerobic Degradation of Petroleum VOCs vs. Chlorinated VOCs in Soils
Petroleum VOCs
Chlorinated VOCs
Background VOCs – Indoor Air
Frequency of Detection in Residential Background Indoor Air

- Nearly always detected due to background sources: BTEX, PCE, methylene chloride, chloroform, carbon tetrachloride
- Very rarely in background IA: 1,1-DCE and cis-1,2-DCE
- Almost never in background IA: trans-1,2-DCE and 1,1-DCA
- Recent GWMR article: 1,2-DCA & VC may have indoor air sources
Background vs. Risk Screening Levels

- Typical background contaminant concentrations will be less than the applicable $10^{-5}$ Risk Screening Level for most compounds. The main exception is Benzene.
- Background PCE will exceed RSL approximately 10% of the time.
- Recognize that contaminants can exceed RSL without vapor intrusion.
Background Indoor Air (Residential)
Background Indoor Air (Residential)
Background Indoor Air (Residential)

Trichloroethylene

Indoor Air Concentration ($\mu g/m^3$)


Study Start Date

10-5 Risk SL

50%

90%
Attenuation Factors and Vapor Intrusion
Definition of Attenuation Factor

• Vapor intrusion attenuation factor ($AF_{VI}$) is defined as:

$$AF_{VI} = \frac{C_{IA-VI}}{C_{SV}}$$

The ratio of the indoor air concentration due to vapor intrusion ($C_{IA-VI}$) to the subsurface vapor concentration ($C_{SV}$) at a point or depth of interest in the VI pathway.

• Greater attenuation = lower AF value
• Less attenuation = higher AF value
AF = 0.001 at 95th percentile
Background Screened Soil Gas Attenuation Factors

Much greater variability, AF = 1 at 95th Percentile
Background Screened Subslab Attenuation Factors

AF = 0.1 at 95th Percentile
Background Screened Crawlspace Attenuation Factors

AF = 1 at 95th Percentile
Soil Gas vs. Sub-slab Data (EPA’s Conclusion from Database)

• Very poor overall correlation of sub-slab and soil gas concentrations from 6 sites with paired data
• May be a function of varying soil gas sampling depths and methods
• Recommend using 95\textsuperscript{th} percentile sub-slab attenuation factor for exterior soil gas samples (i.e., 0.1) – at least for shallow samples
Affect of Buildings on Vapor Intrusion
3 Major Factors Affect VI

- **Sub-surface factors**
  - Collect sub-surface samples (groundwater, soil matrix, soil gas, sub-slub) to define

- **Building factors**
  - Collect indoor air samples to define

- **Above ground factors (weather)**
Building Factors

• Great deal of spatial and temporal variability in all 3 factors
• Effect of an individual building on vapor migration is **not** predictable (one reason why modeling this pathway is inappropriate)
• Therefore, when sub-slab vapor concentrations indicate vapor intrusion is likely, mitigation should be installed or long-term indoor air monitoring should be conducted.
Effect of changes to a building on Radon concentration

Porch was added to a home and radon concentrations increased by 5x. Similar studies not available for chemical VI, but the processes are the same.
Questions?
Sample Collection to Identify the Vapor Migration Pathway
Sub-slab vapor samples

- Density of sample
  - 3 samples for ~5,000 ft² and 1 additional sample for each additional 2,000 ft²
  - Target areas where release has occurred
- Flow reduction to ~200 ml/min (30 min fill time).
- Method TO-14a or TO-15 for VOCs
Sub-slab vapor samples

• Quality Control
  – Vacuum testing of lines
    • Requires a vacuum gage & connection to pull a pressure of ~50 – 100 inches of water column on the sampling line & maintain vacuum for 1 min.
  – Leak Detection – ensure effective seal of probe
    • Several tracers available, most are detectable only AFTER sample collection
    • Recommend He so that leak can be detected BEFORE sample collection
Soil Gas Samples

• Many approaches (implants, post-run tubing, vapor wells, etc.)
• Collect 1-2 ft above water table, if groundwater is vapor source
• If groundwater >30 ft bgs, collect ½ way to water table
• Collect at least 5 ft bgs, where possible.
• Collection method - Tedlar bags or Summa canisters
Indoor/Outdoor Air Sampling

- Residential – 24 hr Summa canister sample
- Industrial – 8 hr Summa canister sample
- One (1) outdoor sample when collecting indoor air samples
- Method TO-14a or TO-15
- Focus on contaminant of concern
Vapors from a Release Directly Beneath Building & Vapor Movement Through Soils

- Pizza
- Dry Cleaner & Laundry
- Drug Store

Contamination Source

Vapor Movement away from Source

Groundwater

Groundwater Contamination
Sampling at a vapor source beneath building

- Sub-slab samples are the primary sampling methodology, both for soil matrix and soil vapor migration.
- Groundwater monitoring wells placed outside the building (but occasionally inside large buildings).
Example: Soil concentration vs. Sub-slab vapor concentration (PCE)

<table>
<thead>
<tr>
<th>Soil Matrix (ug/kg)</th>
<th>Sub-slab vapor (ug/m³)</th>
<th>Vapor Risk Screening Level (ug/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,500</td>
<td>2,500,000</td>
<td>210</td>
</tr>
<tr>
<td>450</td>
<td>900,000</td>
<td>210</td>
</tr>
</tbody>
</table>
Sampling for vapors migrating laterally through soils

• Depending on the proximity of the building to the source:
  – Sub-slab samples are the preferred method if source and building of interest are fairly close
  – Soil vapor samples useful for buildings that may be at a distance from the source. Follow-up with sub-slab & indoor air samples where necessary.

• Nested vapor wells recommended to identify lateral vapor movement
Vapors Migrating from Contaminants Located at the Groundwater Table

- Wind Effects
- Stack Effect
- Utility Line
- Air Streaming
- Sub-base Material
- Silt
- Dissolved Contamination
- Cracks
- Foundation
Sampling for vapors migrating off the water table

- Soil vapor samples can be collected above the water table. If near a building, sample above water table may be indicative of sub-slab concentrations.
- Follow-up with sub-slab and indoor air samples where necessary.
If soil gas samples collected, should be taken just above the water table & as close to building as possible.
Screening groundwater for vapor migration

\[ C_{gw} = \frac{C_{IA}}{(H \times AF_{gw} \times 1000 \, \frac{L}{m^3})} \]

H (dimensionless), OSWER Method at 7º C

http://www.epa.gov/athens/learn2model/part-two/onsite/esthenry.html

<table>
<thead>
<tr>
<th>Contaminant</th>
<th>( C_{IA} ) (Residential)</th>
<th>H (at ~7º C) dimensionless</th>
<th>( C_{gw} ) (µg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCE</td>
<td>4.1</td>
<td>0.276</td>
<td>15</td>
</tr>
<tr>
<td>TCE</td>
<td>12</td>
<td>0.174</td>
<td>69</td>
</tr>
</tbody>
</table>
Vapors Migrating Through Preferential Pathways in Soil/Utility Lines
Sampling for Migration through Sewer Laterals (inside building)

• Are there floor drains in the buildings? Cover them with something sealed to the floor, draw a gentle vacuum on it, and see if you get a sustainable flow of soil gas, if so, the floor drain is not air-tight (very common).

• Screen the incoming soil gas with a PID (PCE responds very favorably). If you get high readings (>10 ppmv), there is a good chance you have a candidate for sub-slab venting. If less, collect a sample for lab analysis.
Contaminated Groundwater Entering a Building

VOC contaminated source

Contaminated Groundwater

Sump Pump

Foundation Drain
Sampling for contaminated groundwater entering building

• If possible, sample the groundwater
• Seal and sample air above sump
• Sample indoor air
END Part 1
Questions?