Vapor Intrusion: Investigating Sites for the Protection of Public Health

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Vapor Intrusion: Investigating Sites for the Protection of Public Health

www.michigan.gov/vaporintrusion
Source of Vapor + Migration Route + Receptor = Completed Pathway ➔ HEALTH RISK!!!!!!

EPA 2015
Vapor Source

A concentration that above which a hazardous substance may form vapors that have the potential to migrate to a structure and cause an unacceptable human health risk.

- Groundwater
- Soil contamination
- NAPL (at or above the water table surface)
- Vapor

USEPA, 2012
Vapor Intrusion (VI) is the process by which chemicals in soil or groundwater migrate to indoor air.

Not a pathway!

Groundwater that is a source of vapors
Types of Vapor Intrusion

**Petroleum vapor intrusion (PVI)** is a subset of VI that deals exclusively with releases from a petroleum source.

**Chlorinated Vapor Intrusion (CVI)** is a subset of VI that deals with chlorinated hydrocarbons includes mixed releases that may also contain a petroleum source.

![Diagram showing PVI and CVI](ITRC 2015)
Lateral Inclusion Zone

The horizontal distance beyond a vapor source that may make a property or structure vulnerable to the migration of vapors.

Adapted from ITRC 2015
Vapor Intrusion (VI) - A Complex Pathway

Why some buildings are less affected
- Soil type and foundation
  - Sandy soil can allow vapors to easily migrate through.
  - Clay soil does not allow easy passage for vapors.
  - Buildings with slab foundations are less likely to be affected.

Source of contamination
- May be from a previous owner a long time ago. Buildings or businesses may not exist anymore.

Moved by groundwater
- Chemicals can dissolve into groundwater and be spread by its natural flow.

Pipe pathways
- Chemical vapors sometimes move along porous soil surrounding utility pipes.

Backfill pathways
- Sand or gravel fill around foundations can be easier for vapors to migrate through.

Getting through the foundation
- Soil vapors migrate through cracks in the foundation and gaps where the pipes enter the basement.

MPCA, 2016
Potential for an Unacceptable Risk

- **High concentrations and/or NAPL (VOCs)**
- **Coarse-grained soils and/or vertically uniform media**
- **Releases with chlorinated hazardous substances does not biodegrade**
- **Low air exchange rates, open pits, sumps, dirt floors**
- **Shallow water table, large water table fluctuations**
- **Potential risk from a single exposure**

- **Low source concentrations, no NAPL (VOCs)**
- **Finer grain that is horizontally and laterally extensive**
- **Petroleum based hazardous substance will biodegrade**
- **High air exchange rates, continuous floor**
- **Deep water table**
- **Long term chronic risk**

Hyde-Environmental, 2017
Multiple Lines of Evidence are Important!

P.C. Johnson, 2014
An Acute Situation May Look Like This

Sites with VI have no odors or observed effects
DEQ and DHHS are Partners

✓ DEQ and DHHS have a data sharing agreement

✓ DEQ provides information to DHHS on sites that may have accelerated or immediate risks

✓ DHHS completes its own analysis of the data and may take its own response and/or notice actions
Volatilization to the Indoor Air Pathway (VIAP)

Criteria and Screening Levels

• Pathway in a state of flux

• SVICC and GVICC considered unprotective but still promulgated

• Site-Specific Evaluation and Criteria May be Required

• RIASL’s (Recommended Interim Action Screening Levels) and MSSL’s (Media Specific Screening Levels) to be used to determine when interim action required
Principles of Vapor Movement

- Partitioning to vapor phase
- Diffusion in vadose zone
- Advection near building
- In order to investigate VI, you must understand how contaminants move from the source to...
Factors That Affect Vapor Movement: Sub-Surface

**Porosity:** Open spaces in rocks/soils

**Permeability:** How connected the pore spaces are

**Soil Moisture:** Pores filled with moisture displace gas

*ITRC, 2015*
Diffusion

Contaminants in the vapor phase migrate slowly in the pore space by diffusion

- But much faster (~100x) than in water

Vapor phase chemicals move in response to a concentration gradient

- From high concentration areas to low concentration areas

Highest concentration is point of origination
Advection: Much Faster than Diffusion

Pressure driven gradient

- Wind speed
- Barometric pressure changes
- HVAC (Heating, ventilation, air conditioning) and fan operations
- Stack effect

Generally shallow affect (w/in 5 ft. of structure or ground surface)
Common Soil Vapor Profiles

Surface Source

Deep Source

Surface and Deep Sources
Attenuation Factor Concept

\[ \alpha_{sg} = \frac{C_{\text{indoor}}}{C_{sg}} \]

- Alpha = 15/500
- Alpha = 0.03 (shallow soil gas)

Indoor Air
15 \( \mu g/m^3 \)

Soil Gas (shallow)
500 \( \mu g/m^3 \)
Vapor Intrusion Investigations
Investigation Work Plan

- Conceptual Site Model
- Data Gaps
- Locations of Samples
- Background
- Sampling and Analysis Plan
- Community Outreach
- Access
- Implementation & Scheduling
Conceptual Site Models

A written or illustrative representation, or both, of the surface and subsurface conditions. Includes the physical, chemical, and biological processes that control the migration to a human receptor.

- Facility Information
- Source/Release History
- Hydrogeologic Conditions
- Building/Receptor Characteristics
Key Elements of a CSM

Source
• Can be soil, groundwater, vapor, or NAPL, or any combination

Route
• How does it travel and what media does it go thru to get there

Receptor
• Who is around and where they are in relation to the source
Vapor Intrusion Investigations
Site Investigation Flowchart – Iterative Process

1. Develop Conceptual Site Model/Select Investigative Strategy
2. Design Investigation Work Plan
3. Implement Work Plan
4. Evaluate Data

- Is Additional Investigation Needed?
  - Yes → Refer to Step 2
  - No → Is Mitigation Needed?
    - No → No Further Action
    - Yes → Mitigation

Ref: ITRC, January 2007, Vapor Intrusion Pathway: A Practical Guide
Preferential Pathways

Site conditions that result in significant lateral transport, enhanced convective flow, or a source within a building

- Large subsurface utilities (e.g. storm drains)
- Consider fill material
- Basement sumps
- Elevator shafts

Models typically assume soil gas convection

- Contaminants of concern enter into building through cracks is considered common
Residential vs. Nonresidential Buildings

Better predictability for residential structures than for bigger buildings

- Variability of construction methods for nonresidential
- Various air exchange rates for nonresidential structures
- Multiple exchange rates possible for same structure
- Other influences
Sampling Methods for the VIAP

Based on ITRC, 2016
Vapor Intrusion Investigations

Types of Samples - Soil

Soil samples from under building enclosure, typically used to identify extent of release in vadoze zone for design of soil remedy.

Uncertainty with using partitioning coefficients

EPA 2015
Researchers have not found a good correlation between soil and soil gas sample results.

Typically used as a screening tool or secondary line of evidence.

EPA 2015
Vapor Intrusion Investigations

Types of Samples - **Groundwater**

Provides indirect information though predictive modeling (groundwater to soil gas to indoor air)

Typically not used as stand-alone investigative technique for vapor intrusion

EPA 2015
Groundwater

**PROs**
Commonly collected during the course of an investigation

Helps assess potential down-gradient impacts

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
Types of Samples
Vapor Intrusion Investigations

Types of Samples – Soil Gas

Sample typically collected at a depth of 5 feet

Common approach for VI pathway

Temporal and spatial variability

There are available screening values for soil gas data. These values are usually higher than indoor air screening levels – assumed attenuation factor has some uncertainty
Soil Gas

**PROs**
- Identifies concentrations in the vapor phase
- Can be performed without entering a structure or without buildings
- More reliable that estimating from soil or groundwater concentrations
- Large empirical data

**CONs**
- Grab sample; lateral and vertical spatial variability
- Results may not be representative of vapor concentrations under a building!
- Is not representative of sources shallower than the collection point
- May not reflect how concentrations will change if a building is built on it in the future
Types of Samples
Sub-Slab

**PROs**
Can provide measure of vapor directly below the structure

Closest subsurface sample to receptors

Less variability than indoor air

**CONs**
Intrusive

Cannot be performed at properties having no existing buildings

Can be influenced by indoor air

Grab sample; lateral and vertical spatial variability

**EDR**
Types of Samples
Indoor Air

Highly variable
- Seasonal

Time-Weighted Average vs. grab

Expensive
- Relocation
- Prep/post

Expect detections!
Mitigation
Purpose of Mitigation: Make Buildings Safe!
Is Mitigation Warranted?

Review all evidence to conclude:

- Is exposure pathway relevant?
- Indoor air concentrations above RIASL and/or sub-slab concentrations above MSSL?
- Risk management decision
- Monitoring vs mitigation system installation
- Presumptive remedy?
- Presence of developmental toxicants
Common Mitigation Methods
Existing Structures

Active

• Sub-slab depressurization (SSD)
• Sub-membrane depressurization (SMD)
• Aerated Floors using a Structural Forms*

Passive Mitigation Systems:

• Floor Sealants
• Liner with venting system*
Common Mitigation Methods
Existing Structures

Installation of mitigation systems easier, less expensive and easier for new structures as compared to existing structures

Performance monitoring required to document system operating as required

- Indoor Air Sampling
- Pressure Gradient Evaluation
- Other
Questions?
VI Public Health Perspective

What We Have Learned
Use Screening Levels to Evaluate Potential Exposures

How are screening levels developed and used?

- Review the scientific literature
- Identify key studies
- Use screening levels to evaluate exposures
- Translate information into screening levels for humans, using reasonable worst-case assumptions
- Update screening levels as new science emerges
Screening Levels were developed using:

• 1 in 100,000 cancer risk

• Hazard Quotient of 1 for acute hazards
Screening Levels

Exceed RIASL – take action within days to lower level

Exceed TSRIASL – take immediate action
Health interpretation of indoor air screening levels

Exposure < the screening level

- No significant increased risk of health effects for sensitive individuals who have been exposed under reasonable worst-case conditions

Exposure > screening level

- Indicates contamination poses a health hazard
- **Does not indicate** health effects will necessarily occur
Health interpretation of indoor air screening levels

Development of health effects depends on personal factors

- Level and duration of exposure
- Individual sensitivity
- Genetics
- Existing health conditions
- Lifestyle factors
- Exposure from other sources
Completed Exposure Pathway

1. Source of contaminants
2. A pathway to move contaminants in the environment (groundwater, air)
3. A place where people contact the contamination
4. Route of exposure (inhalation, touching)
5. People have to be present
What we have learned
Pair indoor air samples with sub-slab
Before indoor air samples are taken – remove chemicals.
Not every chemical in the house is a problem
Beware of Grandpa’s Chemical Collection
Unusual Hobby Chemicals
California Proposition 65

[WARNING]

This product can expose you to chemicals, which are known to the State of California to cause cancer. For more information, visit www.P65Warnings.ca.gov.
Power equipment stored in house
### Chloroform from Chlorinated Water Supply

<table>
<thead>
<tr>
<th>Parameter Detected</th>
<th>Your Water Results</th>
<th>Regulatory Requirements</th>
<th>Likely Source</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Highest Level Detected</td>
<td>Results Range</td>
<td>EPA LIMIT MCL, TT, or MRDL</td>
</tr>
<tr>
<td>Bromate</td>
<td>3.8 ppb $^1$</td>
<td>ND – 10.6 ppb</td>
<td>10</td>
</tr>
<tr>
<td>Chloramines $^3$</td>
<td>2.4 ppm $^1$</td>
<td>0.17 – 3.4 ppm</td>
<td>MRDL: 4</td>
</tr>
<tr>
<td>Haloacetic Acids (HAA5) $^3$</td>
<td>5.0 ppb $^1$</td>
<td>ND – 8.0 ppb</td>
<td>60</td>
</tr>
<tr>
<td>Total Organic Carbon (TOC)</td>
<td>57% removed $^1$</td>
<td>49 – 64% removed</td>
<td>TT: 25% minimum removal</td>
</tr>
<tr>
<td>Total Trihalomethanes (TTHM)</td>
<td>3.9 ppb $^2$</td>
<td>1.4 – 4.7 ppb</td>
<td>80</td>
</tr>
</tbody>
</table>

$^1$: Data from a specific source or method.
$^2$: Calculated from other parameters.
$^3$: Chlorination by-product.
Vapor Intrusion Problems

What we have found during investigations
No plumbing vent stack
Missing Sewer Traps
Basement Drywells
Cracks between the wall and floor
No slab under bathtub
HVAC systems need fresh air
HVAC needs air balance
Questions?