Vapor Intrusion Assessment:
Guidelines, Data Collection Methods, and Advancements

Presented by:
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Topics:

- Conventional sampling methods and QA/QC
  - Soil gas
  - Subslab gas
  - Indoor air

- Methods/tools to address uncertainties
  - Real-time field screening
  - Building pressure testing
  - Longer-term samples
  - Guided sampling

ITRC (2014)
Vapor Intrusion from TCE Plume, Endicott, NY

- One of the largest vapor intrusion sites in the US
- Nearly 1000 properties assessed over a 350-acre TCE plume in groundwater
- Implemented high quality technical methods that advanced the state of practice
- Successful mitigation of over 450 homes and businesses
Investigation Sampling Methods

- Exterior soil gas – temporary and permanent probes
- Subslab vapor – temporary and permanent ports
- Indoor Air
Exterior soil gas sampling

**Pros**
- Delineate VOCs in soil gas to narrow focus of buildings needing subslab and/or indoor air sampling
- Less disruptive than interior sampling
- Can be done concurrent with soil sampling and logging to identify factors that promote or hinder VI (soil type, layering, moisture content)

**Cons**
- Subslab vapor favored by most states for comparison to screening levels and indoor air samples
- Potential spatial and temporal variability, particularly for shallower exterior soil gas
- May miss exterior preferential pathways such as utility trenches and sewer lines.
Exterior soil gas sampling probe – single event equipment

Retractable drive point connect to flexible tubing through hollow rod

Hand-driven tools

Hydraulic push tools
Exterior soil gas sampling probe – permanent monitoring
Example of exterior investigation to rule out off-site VI

Multiple physical and chemical lines of evidence:

- Downward hydraulic gradients
- VOC profiling consistent with “diving plume” overlain by clean water lens
- Shallow silt- and clay-rich soils with high water saturation
- TCE not detected in subsurface gas
Subslab sampling – single event

Temporary hole drilled through slab and sealed with hot beeswax
Subslab Sampling Port – permanent installation used for:

- Multiple sampling events
- Cross-slab differential pressure monitoring to assess VI mitigation performance
Subslab port installation

https://www.vaporpin.com/

Commercial product
Subslab sampling

Sampling into Summa canister

Collection of primary and field duplicate samples

Integrity/leak testing of port construction

Helium (ultra high purity)

Shroud over port

Peristaltic pump

Tedlar bag for screening for helium
How many subslab samples?

<table>
<thead>
<tr>
<th>State</th>
<th># of subslab samples for typical residence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass</td>
<td>2 to 4, including one from the center; 1 to 2 events</td>
</tr>
<tr>
<td>NH</td>
<td>3, including one from the center</td>
</tr>
<tr>
<td>NJ</td>
<td>Minimum of 2</td>
</tr>
</tbody>
</table>

For larger residential or commercial/industrial buildings

NJDEP VI Guidance, 2018

“cannot be based on area alone...based on professional judgment to determine the number of subslab samples”
## Subslab and soil gas sampling

<table>
<thead>
<tr>
<th>Sources of Error or Bias</th>
<th>QA/QC Measures</th>
<th>Lessons Learned</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample dilution due to leaky surface seal drawing in ambient air</td>
<td>Conduct integrity/tracer testing; maintain sample rate &lt;200 ml/min</td>
<td>Use ultra-high purity helium as tracer; avoid sulfur hexafluoride (SF₆) – greenhouse gas</td>
</tr>
<tr>
<td>Sample dilution due to leaky tube fittings/connections</td>
<td>Conduct “shut-in” test (see NJ VI guidance for details)</td>
<td>Use gas-tight fittings (no quick-connect fittings)</td>
</tr>
<tr>
<td>VOCs absorb/desorb from tubing material</td>
<td>Use Teflon-lined or stainless steel tubing</td>
<td>Discard flexible tubing after each sample. No Tygon, LDPE, or vinyl tubing</td>
</tr>
<tr>
<td>Tedlar bags – bag may contain VOCs; bag allows VOC diffusion in and out over a period of days</td>
<td>Analyze ASAP (&lt; 3 hrs) to avoid VOC loss through bag</td>
<td>Use Tedlar bags for “screening” only; Kynar bags are more robust but not readily available</td>
</tr>
<tr>
<td>Summa canister sampling</td>
<td>See separate table on indoor air sampling</td>
<td></td>
</tr>
</tbody>
</table>
Indoor Air Sampling

Typical State guidelines:

- Conduct pre-sampling survey (see next slide)

- Use stainless steel canisters (Summa) for lab analysis by EPA Method TO-15

- Analyze for full TO-15 analyte list unless there is justification for narrowing list

- 24-hr time-averaged samples (8-hr acceptable for non-residential buildings in most states)

- Collect at least one sample from the likely space where VI may occur (basement or crawl space) and one sample from the lowest living level

- When collecting concurrent subslab samples, collect them after indoor air to avoid potentially cross-contamination to indoor air
## Sampling with Summa canisters

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<th>Sources of Error or Bias</th>
<th>QA/QC Measures</th>
<th>Lessons Learned</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contaminated canisters or controllers from lab</td>
<td>Order individually certified clean canisters/controllers and obtain lab QA/QC report</td>
<td>Batch certified canisters not worth the uncertainty in cleanliness</td>
</tr>
<tr>
<td>Faulty equipment – low canister vacuum on receipt</td>
<td>Check canister vacuums prior to field mobilization</td>
<td>Order extra canisters</td>
</tr>
<tr>
<td>Faulty equipment – flow controllers</td>
<td>Check canister vacuum frequently during sampling</td>
<td>Order extra controllers</td>
</tr>
<tr>
<td>Field contamination during prep/storage/shipping</td>
<td>Collect field blank using ultra high purity nitrogen</td>
<td>Order UHP nitrogen from lab – commercial gas may have trace contaminants</td>
</tr>
<tr>
<td>Leakage during return shipping</td>
<td>Close canister with 7 to 3 in. Hg vacuum remaining and record on Chain-of-Custody</td>
<td>Don’t rely on canister gauge – use separate vacuum gauge</td>
</tr>
<tr>
<td>Field imprecision</td>
<td>Collect a field duplicate sample</td>
<td>Collect duplicate where you expect to get a VOC detection</td>
</tr>
</tbody>
</table>
The major confounding factors of indoor air sampling:

1. Background/indoor sources of VOCs

2. Time variability of VI

Hartman et al, AEHS San Diego, March 2018
Examples of PCE- and TCE-containing products that can interfere with VI sampling
Indoor Air Sampling – Beware of indoor sources

Indoor sources of VOCs
• Household and commercial products
• Dry-cleaned clothes
• Building materials (paints, finishes, carpets, adhesives, etc.)
• Former chemical use absorbed in building walls and floors
• VOCs entering from outdoor air

QA/QC Measures
• Conduct pre-sampling survey including field documentation and photos
• Remove commercial products 24 to 48 hrs before sampling – not always feasible
• Collect outdoor air sample upwind of building or near HVAC intake
• Collect subslab samples for comparison
Vapor intrusion can be extremely time variable

A 24-hr sample represents neither the worst-case short-term nor the long-term average
## How many indoor air sampling events?

<table>
<thead>
<tr>
<th>State</th>
<th>Guidance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maine</td>
<td>4 successive “clean” rounds spaced 3 mos. apart to conclude no VI pathway</td>
</tr>
<tr>
<td>Mass</td>
<td>Multiple rounds across several seasons, including worst-case (Tbl 2 of VI guidance); At least 2 to 4 rounds to conclude no VI pathway</td>
</tr>
<tr>
<td>NH</td>
<td>1 round in late winter/early spring</td>
</tr>
<tr>
<td>NJ</td>
<td>1 round in the heating season (Nov 1 to Mar 31) assuming no other contradictory lines of evidence</td>
</tr>
<tr>
<td>NY</td>
<td>Multiple rounds across several heating seasons</td>
</tr>
</tbody>
</table>
Methods/tools to address indoor sources and variability

1. Real-time screening and continuous monitoring

2. Building pressure tests

3. Longer-term samples

4. Guided samples (by temperature, radon, other parameters)
Real-time VI assessment with portable analyzer

- 100,000 sq. ft. footprint
- TCE used in 1960s and 1970s
- Subsurface TCE presence indentified in 1990s
- Groundwater at depth of ~5 feet below slab
Real-time VI assessment with portable analyzer

- 62 samples during 2 days with portable GC/MS
- TCE ranged from 15 to 690 ug/m³ (median of 71)
Identifying the vapor entry pathways:

Air handler unit mechanical rooms under negative pressure

Targeted screening of interior storm drain manholes
TCE in Indoor Air (μg/m³)

- Pre-Mitigation Screening with Portable GC-MS
- Post-Mitigation Screening with Portable GC-MS
- Post-Mitigation 8-hr Summa

- Max
- Median
- Min

- N = 62
  - Max: 690
  - Median: 71
  - Min: 15

- N = 24
  - Max: 3.7
  - Median: 1.8
  - Min: <0.54

- N = 10
  - Max: 3.4
  - Median: 1.2
  - Min: 0.12
PCE and TCE in indoor air in former mill building converted to apartments (artistic residences) → Is it VI or indoor sources of chemicals?

- Analyzed ~80 samples over 2 days in 25 apartments
- Analyzed household products, art supplies, and potential VI pathways

Results:
PCE due to art supplies.
TCE due to VI through floor cracks.

Instant results using portable analyzer (HAPSITE)

Sniffing for VI from cracks under rugs

Courtesy of StoneHill Environmental
Continuous real-time air monitoring

PCE increases every night when the HVAC system is off
Continuous indoor air monitoring

Startup of mitigation system
Advantages of real-time and continuous data

- No waiting 2 weeks or more for lab results
- Lots of data offers opportunity to identify variability and patterns
- Distinguish VI from indoor chemicals
- Find VI entry locations/pathways
- Informs best mitigation strategy
- Immediately evaluate mitigation effectiveness
Real-time Monitoring of HVAC Performance Reliability

- IA18-004 TCE (µg/m³)
- IA18-005 TCE (µg/m³)

Decrease outside air (OA) damper % open position
Increase OA damper % open position
Building pressure negative relative to SS
Building pressure positive relative to subslab (SS)
Real-time continuous VI sampling using EPA’s Trace Atmospheric Gas Analyzer (TAGA) Mobile Laboratories

For more information:
Archive of Aug 29, 2018 webinar: https://clu-in.org/live/archive/
Contact: David Mickunas, US EPA, Environmental Response Team
(919) 541-4191
mickunas.dave@epa.gov
VI Diagnostic Tool: Building Pressure Tests

Negative pressure: favors VI
Positive pressure: suppresses VI
Building pressure manipulation for an industrial building (real-time VI assessment of a 10,000 ft² manufacturing space)
Initial conditions
Normal HVAC operations, room ~neutral pressure
Test conditions:
Shutdown HVAC supply air, and activate exhaust fans, neg. pressure in room

PCE/TCE increase
Response of indoor VOC levels to change in room pressure:

negative pressure = higher VOC levels
Identifying the VOC entry points:
Expansion joints in floor slab

1100 / 240

6100 / 6600

1900 / 1700

3600 / 1300

2600 / 1300

PCE / TCE ug/m³
In 1 day of real-time assessment:

- Obtained and analyzed 27 samples using the portable GC-MS
- Established baseline indoor air VOC conditions
- Without sub-slab sampling, confirmed that baseline conditions were due to vapor intrusion, not background levels
- Identified the VOC entry pathways (i.e. the expansion joints), which suggested a remedial solution (re-caulking/sealing the joints)
Hypothetical Cost Comparison*: VI assessment of 20,000 sq ft building

<table>
<thead>
<tr>
<th>Description</th>
<th>Qty</th>
<th>Unit Cost</th>
<th>Units</th>
<th>Cost</th>
<th>Description</th>
<th>Qty</th>
<th>Unit Cost</th>
<th>Units</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline Sampling</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Baseline and Focused Sampling</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Indoor Air (TO-15)</td>
<td>5</td>
<td>$450</td>
<td>sample</td>
<td>$2,250</td>
<td>GC-MS Calibration</td>
<td>1</td>
<td>$900</td>
<td>lump</td>
<td>$900</td>
</tr>
<tr>
<td>Sub-slab (TO-15)</td>
<td>5</td>
<td>$450</td>
<td>sample</td>
<td>$2,250</td>
<td>GC-MS</td>
<td>1</td>
<td>$500</td>
<td>day</td>
<td>$500</td>
</tr>
<tr>
<td>Labor</td>
<td>4</td>
<td>$1,200</td>
<td>person-days</td>
<td>$4,800</td>
<td>Labor</td>
<td>2</td>
<td>$1,200</td>
<td>person-days</td>
<td>$2,400</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Confirmatory (TO-15)</td>
<td>5</td>
<td>$450</td>
<td>sample</td>
<td>$2,250</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td>$16,200</td>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td>$6,100</td>
</tr>
</tbody>
</table>

* Cost estimates are for relative comparison and do not include other items likely common to both approaches, such as report preparation, project management, and QA/QC.
Long-term Sampling Devices (passive samplers)
Pros
• Small, unobtrusive, easy to use, easy to ship
• Total cost typically less than Summa canister samples
• Provide 1-day to 30-day (or more) composite samples that can capture longer term variability

Cons
• Requires careful selection of sampling device, sorbent material, and deployment time to achieve target analyte reporting limits – need to consult with laboratory
• Some VOCs are weakly absorbed and poorly retained (e.g., vinyl chloride, chloromethane)
• May miss short-term concentration peaks/spikes
• Not routinely accepted in place of 24-hr Summa samples for final risk decisions
Assessing short-term peaks using long-term sampler results

Max. Daily Avg \([\text{ug/m}^3]\) =
(Long-term conc) \(\times\) (# days of deployment)

For example:
To meet TCE daily max threshold of <6 \(\text{ug/m}^3\), then 14-day avg result must be <0.43 \(\text{ug/m}^3\)
For more information on passive samplers...
Guided Sampling: Recent US EPA initiative to use indicator parameters such as temperature, pressure, and radon to sample indoor air when worst-case VI is most likely
Temperature differential as a VI indicator at Sun Devil Manor, UT

24 h Average TCE in Indoor Air [ppbv] vs Differential T (SDM)

- 2% false negatives
- 98% true negatives

Differential T > 90th percentile, TCE > 95th percentile

34% True Positives

66% False Positives
Radon as a VI indicator at Sun Devil Manor, UT

24 hr Average TCE in Indoor Air [ppbv] vs 24 hr Rn (SDM)

1% false negatives
99% true negatives
40% True Positives
60% False Positives

Indicator >90th percentile, TCE>95th percentile
Guided sampling: preliminary findings based on a few structures

- Highly confident “negative” predictive value of temperature differential and radon – sampling for VI when these parameters are not “elevated” will not likely (>95% confidence) reveal short-term, worst-case VI

- Conversely, sampling when these parameters are “elevated” is more likely to find “elevated” VOC levels from VI (30-40% positive predictive value)

- This approach requires real-time monitoring of $\Delta T$ and radon levels to select conditions favorable for sampling to capture short-term, worst-case VI

Contact for more information:
Henry Schuver schuver.henry@epa.gov
US EPA – Office of Research Conservation & Recovery, Wash, DC
Wrap-up Messages

• Conventional VI sampling methods are well-established, but hindered by their “snapshot” nature and prone to error/bias (e.g. missing variability, indoor/background VOC sources)

• Tools and methods are available to reduce uncertainty inherent in conventional VI assessments:
  - Real-time and continuous field screening
  - Building pressure testing coupled with field screening/sampling
  - Long-term sampling

• Active research area: given the temporal variability in VI, can we use guided sampling to capture reasonable maximum exposure? Stay tuned…

Questions: Dave Shea, (603) 415-6130
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