Topics:

- Assessing the VI pathway
  - Conceptual site model development
  - Screening distances and concentrations

- Sampling methods and QA/QC
  - Soil gas
  - Subslab gas
  - Indoor air

- Techniques to address variability
  - Passive samplers
  - Real-time sampling
  - Guided sampling

ITRC (2014)
# NEWMOA-member States’ VI Guidance

<table>
<thead>
<tr>
<th>State</th>
<th>Department</th>
<th>Status of VI Guidance (Data collection)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connecticut</td>
<td>Dept of Energy and Environmental Protection</td>
<td>Concurrence (Oct 2017) with ITRC VI Guidance (2007); Remediation Standard Regulations – Volatilization Criteria</td>
</tr>
<tr>
<td>Maine</td>
<td>Dept of Environmental Protection</td>
<td>Supplemental VI guidance (Feb 2016) to USEPA VI guidance (2015)</td>
</tr>
<tr>
<td>Massachusetts*</td>
<td>Dept of Environmental Protection</td>
<td>Oct 2016 VI guidance</td>
</tr>
<tr>
<td>New Hampshire</td>
<td>Dept of Environmental Services</td>
<td>July 2006 VI guidance w/Feb 2013 revision</td>
</tr>
<tr>
<td>New Jersey*</td>
<td>Dept of Environmental Protection</td>
<td>Jan 2018 VI guidance (ver 4.1)</td>
</tr>
<tr>
<td>New York</td>
<td>Dept of Environmental Conservation</td>
<td>2006 VI Guidance</td>
</tr>
<tr>
<td>Rhode Island</td>
<td>Dept of Environmental Management</td>
<td>No stand-alone VI guidance (VI addressed in remediation regs)</td>
</tr>
<tr>
<td>Vermont</td>
<td>Dept of Environmental Conservation</td>
<td>No stand-alone VI guidance (July 2017 background doc); VI covered under Investigation and Remediation of Contaminated Properties (IROCP) rule</td>
</tr>
</tbody>
</table>

*MA and NJ most recent and detailed on VI data collection methods

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## Conceptual Site Model to evaluate VI pathway

Vapor intrusion requires:

- **Source** of VOC vapor
- Mechanism for sufficient **transport** from source to building space
- A **receptor** (a person) and an exposure point (an enclosed space).
Potential VOC sources to drive VI

Partitioning:
Transfer from water to gas
Transfer from soil to gas

Diffusion:
Transfer driven by a concentration gradient

Advection:
Bulk vapor flow driven by pressure gradients (created by heating, wind, barometric conditions, others)
Other transport mechanisms - Preferential Pathways

- VOC entry through plumbing fixtures connected to sanitary or storm sewers
  - Sewer intersects VOC-containing groundwater or non-aqueous phase liquid
  - VOC discharge into sewer
  - Sewer in vadose zone above VOC-containing groundwater
- VOC entry through utility penetrations
  - Sumps, elevator pits
  - Sewer, water, gas, electric, etc.
  - Backfill may act as a preferential pathway

From McHugh and Beckley, 2017
ESTCP Project ER-201505

Example of building a CSM to rule out off-site VI – No Pathway

Multiple physical and chemical lines of evidence:
- Downward hydraulic gradients
- VOC profiling consistent w “diving plume” overlain by clean water lens
- Shallow silt- and clay-rich soils with high water saturation
- TCE not detected in subsurface gas
Screening distances for VI assessment – Massachusetts example

VOC Proximity to Building | Horizontal | Vertical
--- | --- | ---
VOCs in soil or soil gas | 6 ft | 10 ft
VOCs in dissolved phase plume > GW-2 standard | 30 ft | 15 ft
VOCs in dissolved phase plume > 10X GW-2 standard | 100 ft | 15 ft
LNAPL | 30 ft | 30 ft

Fig 4-1 of MADEP VI Guidance, 2016

VOC screening thresholds typically used to determine if additional investigation of the vapor intrusion pathway is required

**Example – VI residential screening values for TCE**

<table>
<thead>
<tr>
<th>Media</th>
<th>Units</th>
<th>CT</th>
<th>MA</th>
<th>ME</th>
<th>NJ</th>
<th>NH</th>
<th>NY</th>
<th>RI</th>
<th>VT</th>
<th>USEPA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indoor Air</td>
<td>ug/m³</td>
<td>5</td>
<td>0.4</td>
<td>2.1</td>
<td>3</td>
<td>0.4</td>
<td>2</td>
<td>None</td>
<td>0.5</td>
<td>0.48</td>
</tr>
<tr>
<td>Soil Gas*</td>
<td>ug/m³</td>
<td>38,000</td>
<td>28</td>
<td>63</td>
<td>27</td>
<td>20</td>
<td>Varies</td>
<td>None</td>
<td>5 (&lt; 5 ft)</td>
<td>16</td>
</tr>
<tr>
<td>Groundwater</td>
<td>ug/l</td>
<td>219</td>
<td>5</td>
<td>None</td>
<td>2</td>
<td>20</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>1.19</td>
</tr>
</tbody>
</table>

*Preference for subslab soil gas over exterior soil gas*
Sampling and Screening 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 preferential pathways
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

Not to scale
Subslab Sampling Port – permanent installation used for:

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

Subslab port installation

Commercial product

https://www.vaporpin.com/
Subslab sampling

- Sampling into Summa canister
- Collection of primary and field duplicate samples
- Tedlar bag for screening for helium

Integrity/leak testing of port construction
- Helium (ultra high purity)
- Shroud over port
- Peristaltic pump

Subslab sampling – single event

- Temporary hole drilled through slab and sealed with hot beeswax
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 react with or absorb/desorb from tubing material</td>
<td>Use stainless steel or Teflon 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

Indoor Air Sampling – Potential Error & Bias

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
- Conduct interior VOC screening with PID/FID/portable GC
- Collect outdoor air sample upwind of building or near HVAC intake
- Collect subslab samples for comparison
### Sampling with Summa canisters

<table>
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<tr>
<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>

### 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>
Indoor Air Sampling – Sources of Error & Bias

Temporal variability – a 24 hr sample represents neither the worst-case short-term nor the long-term average.

Methods to address temporal variability

- Longer-term passive samples
- Real-time and/or continuous monitoring
- Guided samples (by temperature, radon, ΔP)
Passive Sampling Devices

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 passive sampler results

Max. Daily Avg \([\text{ug/m}^3]\) = Passive result \times (\# \text{ days of deployment})

Max Daily Threshold / \# days = Passive Result Threshold

For example:
To meet TCE daily max threshold of <6 \(\text{ug/m}^3\), then 14-day passive result must be <0.43 \(\text{ug/m}^3\)

For more information on passive samplers…
Real-time indoor air monitoring

- Can Reach Low Levels (<1 ug/m3) for TCE, PCE, Vinyl Chloride & others
- <10 min Analysis Time for TCE & PCE
- Multiple Sample Locations (16 to 30)
- Very Stable - holds calibration for months
- Real-Time Data - Groundswell Dashboard
- Can be used to analyze grab samples (e.g. Tedlar bags)
Real-time continuous air monitoring

Pros
• Detects VOCs to ~1 µg/m³ levels
• Portable – excellent for sleuthing VI entry pathways
• Approx. 10 mins per sample, and up to 30 - 40 samples per day

Cons
• Functional reliability
• Requires training and experience
• Accuracy for certain compounds (e.g., dichloroethene, dichloroethane, vinyl chloride)
Real-time VI Assessment with HAPSITE portable GC-MS

In 2 days of real-time assessment:

- Obtained and analyzed ~75 samples using the portable GC-MS
- Established baseline indoor air VOC conditions throughout the bldg
- Confirmed that baseline conditions were due to vapor intrusion, not indoor sources
- Identified the VOC entry pathways to inform mitigation

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
Guided Sampling: New US EPA initiative to use indicator parameters such as temperature, pressure, and radon to sample indoor air when worst-case VI is most likely

For residential structures, how should indoor air sampling programs be designed to determine the Reasonable Maximum Exposure (RME) level?

1. RME is defined as >90\textsuperscript{th} percentile and <98\textsuperscript{th} percentile, typically 95\textsuperscript{th} percentile, of 24-hour average indoor air exposure distribution in a particular structure.

2. RME is the “worst case” not the chronic, long-term average

3. A 24-hour average sample is still the “standard” – but it represents neither the worst case short-term (RME), nor the long-term average exposure

4. Can statistical methods be used to guide the timing of samples to increase the odds of capturing the RME level?
Temperature differential as a VI indicator at Sun Devil Manor, UT

2% false negatives
98% true negatives

Radon as a VI indicator at Sun Devil Manor, UT

1% false negatives
99% true negatives
Guided sampling: preliminary findings based on a few structures

- Highly confident “negative” predictive value of temperature differential, pressure, 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 monitoring of ΔT, ΔP, and radon levels to select conditions favorable for sampling to capture short-term, worst-case VI

Another approach based on statistical analysis of the Sun Devil Manor data set

- Collect 3 winter samples (not on same day)

- Calculate 95% Upper Confidence Level of the arithmetic mean (95 UCL)

- For small data sets with wide variability, the calculated 95 UCL will represent the 97th percentile of the underlying data set, which will capture the RME

Contact for more information:
Henry Schuver  schuver.henry@epa.gov
US EPA – Office of Research Conservation & Recovery, Wash, DC
Upcoming workshop at AEHS Conference at UMASS-Amherst on October 16, 2018
Wrap-up Messages

• Develop a working Conceptual Site Model to inform VI investigation scope – typically an iterative process.

• Work towards multiple lines of evidence to support a determination of no VI risk.

• Screening distances and values are commonly used to assess continuance of a VI investigation.

• Typical VI sample media are exterior soil gas, subslab vapor, and indoor air – sampling procedures are well-established to avoid error & bias.

• Real-time analytical tools can fast-track and streamline VI assessment.

• 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
dshea@sanbornhead.com

Vapor intrusion (VI) is the general term given to migration of hazardous vapors from any subsurface vapor source, such as contaminated soil or groundwater, through the soil and into an overlying building or structure

EPA 2015, OSWER Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Sources to Indoor Air
Value of a working Conceptual Site Model (CSM) to inform sampling strategy and build multiple lines of evidence – typically an iterative process

Need to Evaluate

Nature and extent of potential VOC presence (source):
- Non-aqueous phase liquid (NAPL)
- Dissolved-phase plume
- Vadose zone VOCs

Geology/Hydrogeology (transport):
- Groundwater depth and flow directions
- Vadose zone profile (high and low permeability lenses/layers, water saturation)

Preferential pathways (transport)
- Sewers
- Subgrade utilities

Buildings potentially affected and their characteristics (receptors)

Media to sample:
- groundwater
- soil
- exterior soil gas
- subslab gas
- indoor air

Passive Sampling Concept

Measured in lab

Analytical Result

Concentration

Uptake Rate

Sampler Geometry specific
Chemical specific
Sorbent performance
Environmental conditions

1000 mL
1L

Sampling duration

Recoded in the field

1000 L
m³

Courtesy of Heidi Hayes - Eurofins Air Toxics