Why do we care about VI?

- Releases and spills of chemicals to the environment
- Basic exposure pathways to environmental contamination
  - Touch it
  - Ingest it
  - Breathe it
    - Outdoor air
    - Indoor air
- Vapor intrusion: Movement of contaminated vapors into occupied spaces
Conventional Approach

1) Groundwater
2) Soil gas
3) Sub-slab
   Indoor Air
   Outdoor Air

Modified from ITRC, 2007
VI Risk Management Decisions

Easy and good
• Sub-slab < SL
• Indoor air < SL

Easy but not so good
• Sub-slab 10x or more > SL
• Indoor air > SL

The grey zone
• Indoor air > SL, Sub-slab < SL
• Indoor air < SL, Sub-slab > SL

I’ve got a bad feeling about this …
Challenges …

• What are some common challenges?
  – Low / Conservative Screening Levels
  – Background Sources
  – Preferential Pathways
  – Spatial Variability
  – Temporal Variability

• What can we do?
  – Use multiple lines of evidence … but which ones?
  – Not just re-sampling
... and Solutions

**Challenges**

- Low / Conservative Screening Levels
- Background Sources
- Preferential Pathways
- Spatial Variability
- Temporal Variability

**Solutions**

- *Building-specific attenuation factors*
Low / Conservative Screening Levels

**Drinking Water:**
Assume 2 L/day

- MCL TCE: 5 µg/L
- MCL Benzene: 5 µg/L

**Indoor Air:**
Assume 20,000 L/day

- IA SL TCE: 0.00048 µg/L (0.48 µg/m³)
- IA SL Benzene: 0.00036 µg/L (0.36 µg/m³)
Low / Conservative Screening Levels

• Generic VI screening levels are intended to be conservative to avoid false negative decisions
  – Sub-slab & soil gas screening levels are based on conservative attenuation factors (e.g., USEPA 0.03)

• Generally used to identify if further investigation is warranted – not intended to be cleanup requirements

• Can lead to unnecessary sampling and remediation
  – Exceedance of soil gas screening level does not mean corrective action is necessary
Data from
- 15 States
- 41 Sites
- 913 buildings (mostly residential)
Figure 11. Cumulative probability plots summarizing subslab soil gas attenuation factor distributions after application of various database screens. (Data sets and screens are summarized in footnotes to Table 6 and described in Sections 4.1 through 4.4.)

USEPA, 2012, EPA’s Vapor Intrusion Database
Site-Specific Attenuation Factors

- USEPA empirical AF assessment approach can be replicated if there are sufficient site data

\[ \alpha_{\text{empirical}} = \frac{C_{\text{indoor}}}{C_{\text{subsurface}}} \]

- Account for background sources in evaluation

\[ \alpha_{\text{empirical}} = \frac{C_{\text{indoor VI}} + C_{\text{indoor background}}}{C_{\text{subsurface}}} \]

Site-specific screening levels can be orders of magnitude higher than generic values
## Challenges and Solutions

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</table>
• Many VOCs are frequently detected in indoor air

• Some commonly at concentrations that exceed screening levels

Values in parentheses are reporting limits in µg/m³

Dawson and McAlary, 2009
IA – indoor air    SS – sub-slab    OA – outdoor air    $\text{AF}_{\text{bldg}}$ – building specific attenuation factor
Building Pressure Cycling

- **Turn “VI on” by depressurizing**
  - IA > baseline
- **Turn “VI off” by pressurizing**
  - IA < baseline

Dawson, 2016
Challenges and Solutions

Challenges
• Low / Conservative Screening Levels
• Background Sources
• Preferential Pathways
• Spatial Variability
• Temporal Variability

Solutions
• Building-specific attenuation factors
• Background studies
• Compound ratio analysis
• Building pressure cycling
• Portable mass spectrometers
• Tracers, surrogates, indicators
• Stable isotope analysis
Types of Preferential Pathways

• **Typical**
  – Diffusion-dominated mass transport
    • Usual utility connections
    • Usual cracks in foundations
  – All buildings have these

• **Atypical**
  – Advection-dominated mass transport
  – Pathway connects a VOC source area to a building

Johnson et al., 2015
Challenges and Solutions

**Challenges**
- Low / Conservative Screening Levels
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**Solutions**
- Building-specific attenuation factors
- Background studies
- Compound ratio analysis
- Building pressure cycling
- Portable mass spectrometers
- Tracers, surrogates, indicators
- Stable isotope analysis
- *High volume sampling*
Sub-Slab Spatial Variation

Johnson et al., 2012

38,000 ug/m³

0.81 ug/m³
High Volume Sampling

38,000 ug/m³
0.81 ug/m³
HVS Results and Trends
Extra Benefits of HVS

• ID of preferential pathways and subsurface features

• Building-specific attenuation factors independent of chemical data
  – ES&T Article – Fluid Flow Model for Predicting the Intrusion Rate of Subsurface Contaminant Vapors into Buildings (June 2018)

• SSD pilot testing and design
Challenges and Solutions

**Challenges**
- Low / Conservative Screening Levels
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- Temporal Variability

**Solutions**
- Building-specific attenuation factors
- Background studies
- Compound ratio analysis
- Building pressure cycling
- Portable mass spectrometers
- Tracers, surrogates, indicators
- Stable isotope analysis
- High volume sampling
- Differential pressure
- Passive sampling
- Continuous real-time monitoring
- Mass flux monitoring
When Should We Sample?

Johnson et al., 2012
Pressure Differentials

- Cross-building and cross-slab
- Cost-effective, reliable, micro-manometers with data-logging capabilities
Advances in Passive Sampling

• New generation of passive samplers
  – Verified uptake rates
  – Differences in size, sorbents, diffusive interface, uptake rates
Waterloo Membrane Sampler

Correlation Between Waterloo Membrane Sampler and Conventional Samplers

7 orders of magnitude of concentration

10 minutes to 12 day samples

Dozens of different VOCs

Several different media

Most results are within typical variability
Benefits of Passive Samplers

- Not limited by sample volume
- Sample duration dictated by DQOs
- Dedicated, unlike Summa canisters
- Simple sampling protocols
- Small
- Depending on type
  - Hydrophobic (good for soil vapor monitoring)
  - Insensitive to high wind velocity (good for outdoor and vent-pipe)
  - Small diameter (easy to put in vent-pipes or sub-slab probes)
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Conclusions

• VI is a complex pathway that our basic CSMs may not accurately depict

• Guidance is the starting point for risk management decisions

• When results don’t fit the CSM
  – Answer likely not to be found by re-sampling
  – Consider multiple lines of evidence beyond standard guidance that evaluate environmental and building dynamics
Questions?

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