NEWMOA Northeast Waste Management Officials' Association
Technical Training for Waste Site Cleanup Professionals

Vapor Intrusion

Data Collection & Interpretation: State of Practice & Lessons Learned

Wednesday, September 26, 2018	Thursday, September 27, 2018	Friday, September 28, 2018
Fireside Inn and Suites	Westford Regency Inn and Conference Center	Quinebaug Valley Community College
25 Airport Road	219 Littleton Road	742 Upper Maple Street
Lebanon, NH	Westford, MA	Danielson, CT

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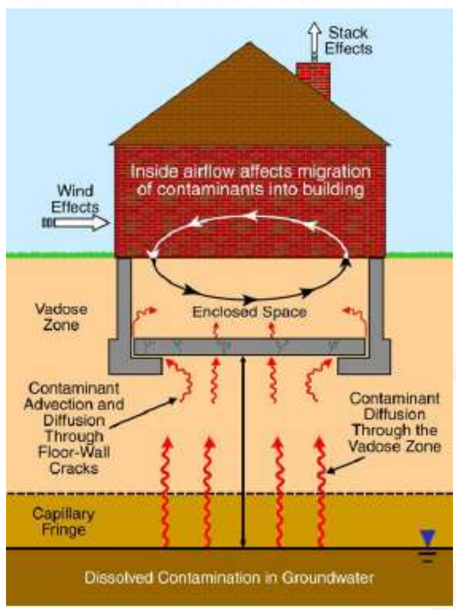
Topics:

- 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



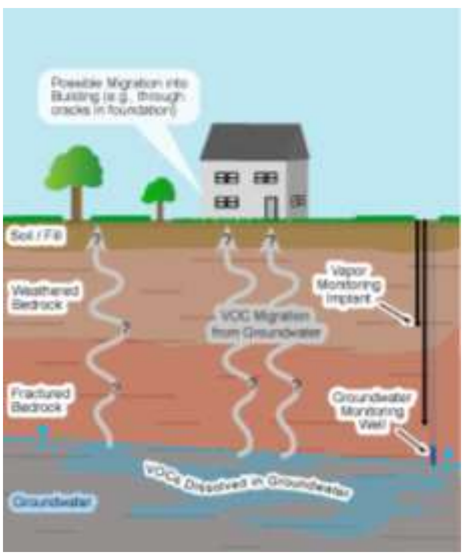
ITRC (2014)

NEWMOA-member States' VI Guidance

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

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

Conceptual Site Model to evaluate VI pathway

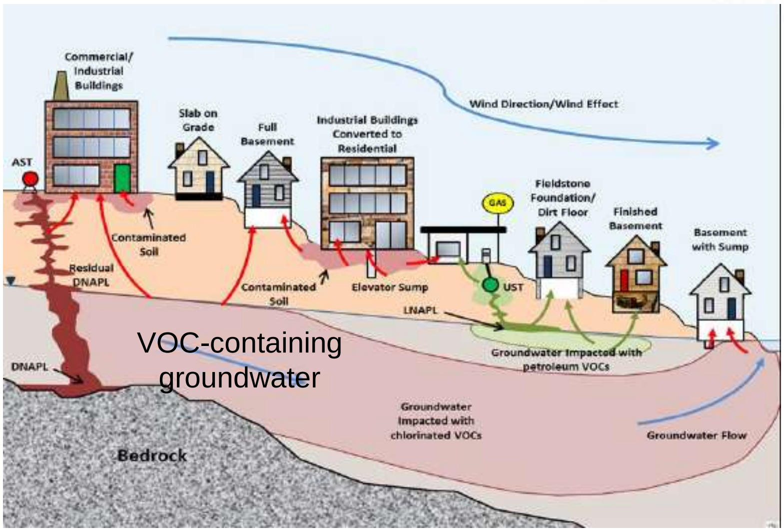


Vapor intrusion requires:

- 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

VOC-containing soil



VOC-containing groundwater

NAPL

Mass DEP VI Guidance, 2016, Fig 2.1

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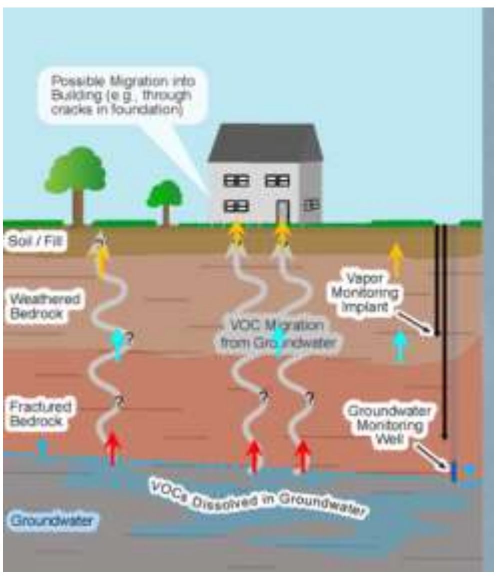
Transport mechanisms related to VI



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)

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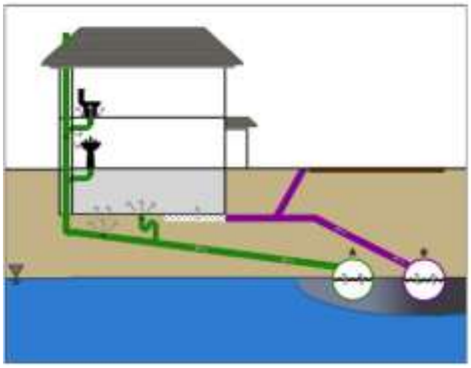
Other transport mechanisms - Preferential Pathways



From McHugh and Beckley, 2017
ESTCP Project ER-201505

- 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

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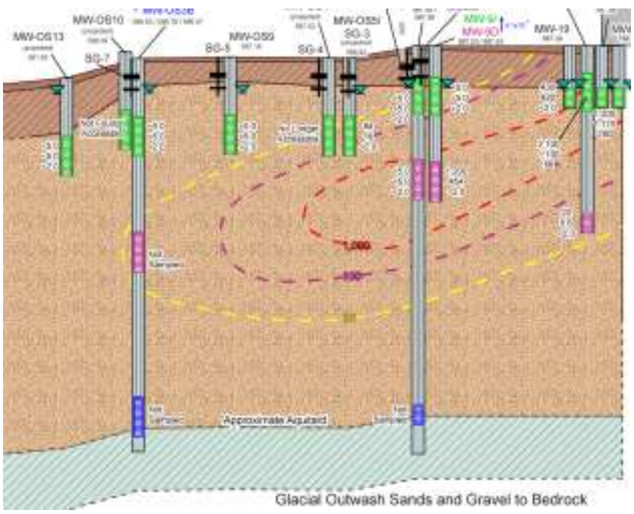
Example of building a CSM to rule out off-site VI – No Pathway



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

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Screening distances for VI assessment – Massachusetts example

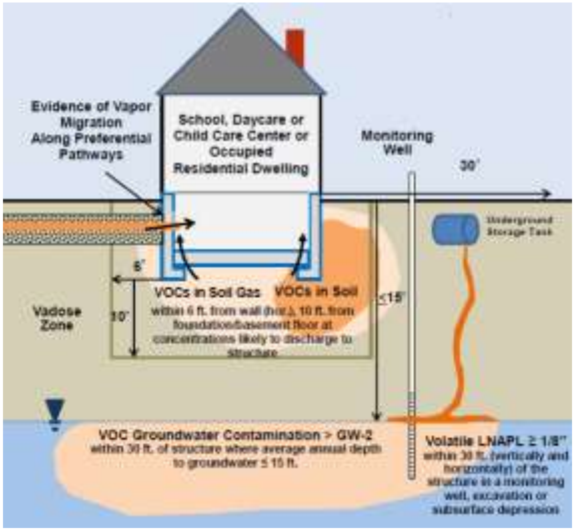

Fig 4-1 of MADEP VI Guidance, 2016

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

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

Example – VI residential screening values for TCE

Media	Units	CT	MA	ME	NJ	NH	NY	RI	VT	USEPA
Indoor Air	ug/m^3	5	0.4	2.1	3	0.4	2	None	0.5	0.48
Soil Gas*	ug/m^3	38,000	28	63	27	20	Varies	None	5 (< 5 ft) 50 (>5 ft)	16
Groundwater	ug/l	219	5	None	2	20	None	None	1.19	1.2

*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

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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

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Exterior soil gas sampling probe – single event equipment

Retractable drive point connect to flexible tubing through hollow rod

Hand-driven tools

Hydraulic push tools

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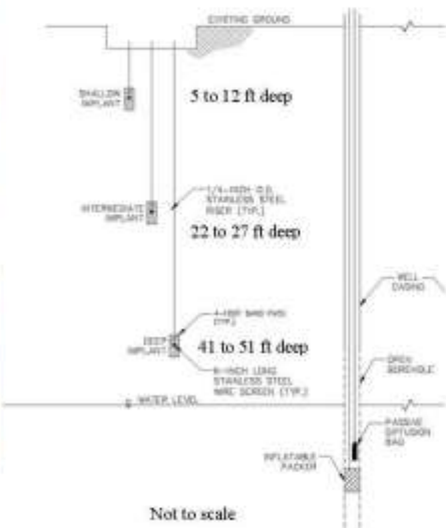
Exterior soil gas sampling probe – permanent monitoring



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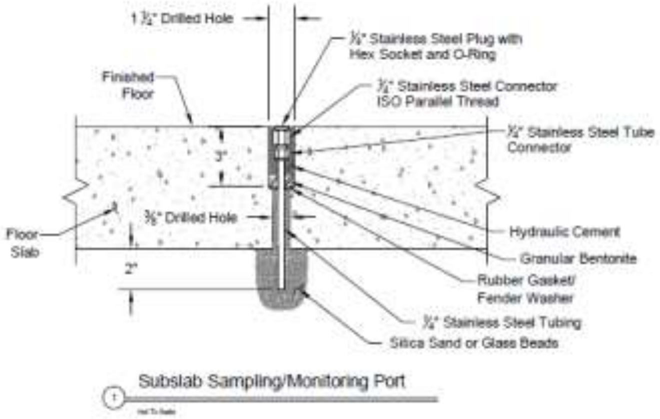
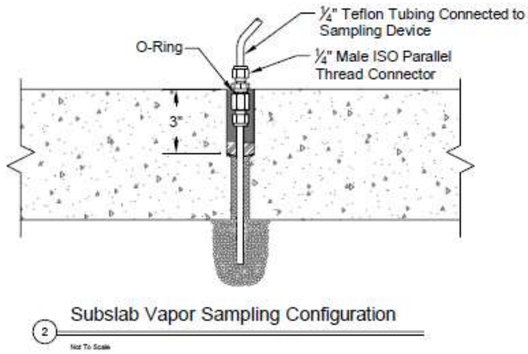
Subslab Sampling Port – permanent installation used for:

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





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Subslab port installation





Commercial product

VaporPin®

https://www.vaporpin.com/

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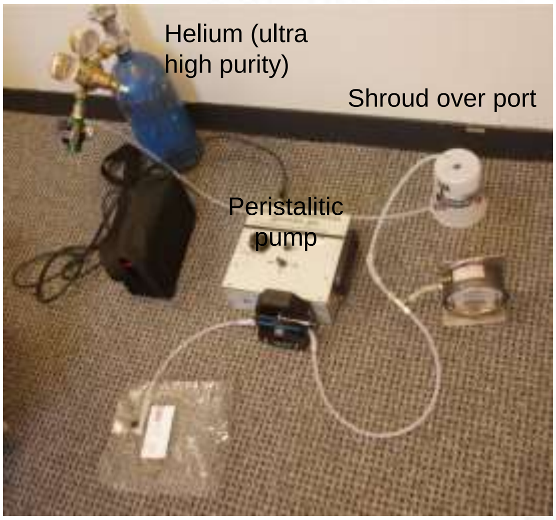
Subslab sampling

Integrity/leak testing of port construction

Sampling into Summa canister

Collection of primary and field duplicate samples



Tedlar bag for screening for helium

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Subslab sampling – single event

Temporary hole drilled through slab and sealed with hot beeswax

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How many subslab samples?

State	# of subslab samples for typical residence
Mass	2 to 4, including one from the center; 1 to 2 events
NH	3, including one from the center
NJ	Minimum of 2

For larger residential or commercial/industrial buildings

Table 3-2
Recommended Minimum Number of Sub-Slab Soil Gas Samples

Square footage of building footprint	Number of SSSG Samples
Up to 1,500	2
1,501 to 5,000	3
5,001 to 10,000	4
10,001 to 20,000	5
20,001 to 50,000	6
50,001 to 250,000	8
250,001 to 1,000,000	10
>1,000,000	12+

NJDEP VI Guidance, 2018

"cannot be based on area alone…based on professional judgment to determine the number of subslab samples"

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Subslab and soil gas sampling

Sources of Error or Bias	QA/QC Measures	Lessons Learned
Sample dilution due to leaky surface seal drawing in ambient air	Conduct integrity/tracer testing; maintain sample rate <200 ml/min	Use ultra-high purity helium as tracer; avoid sulfur hexafluoride (SF_6) – greenhouse gas
Sample dilution due to leaky tube fittings/connections	Conduct "shut-in" test (see NJ VI guidance for details)	Use gas-tight fittings (no quick-connect fittings)
VOCs react with or absorb/desorb from tubing material	Use stainless steel or Teflon tubing	Discard flexible tubing after each sample. No Tygon, LDPE, or vinyl tubing
Tedlar bags – bag may contain VOCs; bag allows VOC diffusion in and out over a period of days	Analyze ASAP (< 3 hrs) to avoid VOC loss through bag	Use Tedlar bags for "screening" only; Kynar bags are more robust but not readily available
Summa canister sampling	See separate table on indoor air sampling	

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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

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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

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Sampling with Summa canisters

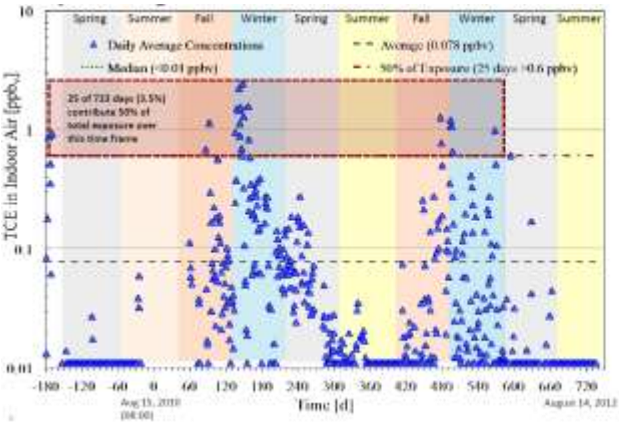
Sources of Error or Bias	QA/QC Measures	Lessons Learned
Contaminated canisters or controllers from lab	Order individually certified clean canisters/controllers and obtain lab QA/QC report	Batch certified canisters not worth the uncertainty in cleanliness
Faulty equipment – low canister vacuum on receipt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

How many indoor air sampling events?

State	Guidance
Maine	4 successive "clean" rounds spaced 3 mos. apart to conclude no VI pathway
Mass	Multiple rounds across several seasons, including worst-case (Tbl 2 of VI guidance); At least 2 to 4 rounds to conclude no VI pathway
NH	1 round in late winter/early spring
NJ	1 round in the heating season (Nov 1 to Mar 31) assuming no other contradictory lines of evidence
NY	Multiple rounds across several heating seasons

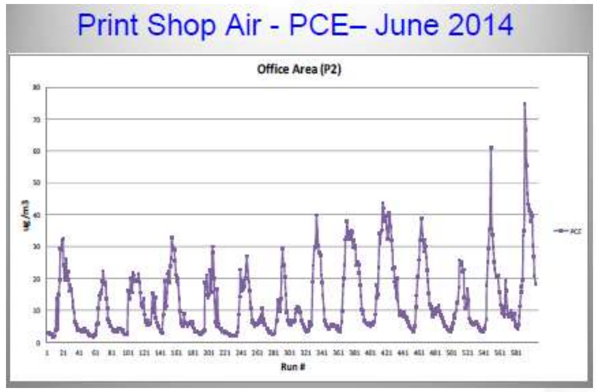
Indoor Air Sampling – Sources of Error & Bias

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



Arizona State U. Research House, Layton, UT

Holton et al., ES&T, 2013, 47, 13347-13354

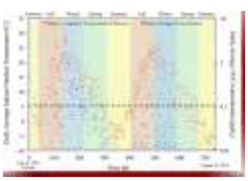


Hartman et al, AEHS San Diego, March 2018

Methods to address temporal variability

Longer-term passive samples

Real-time and/or continuous monitoring



Guided samples (by temperature, radon, ΔP)

Passive Sampling Devices

Courtesy of Heidi Hayes eurofins

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Waterloo Membrane Sampler

Radiello passive sampler

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

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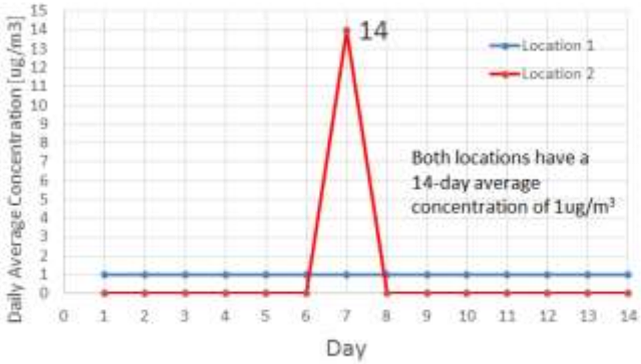
Assessing short-term peaks using passive sampler results



Max. Daily Avg [ug/m^3] = Passive result x (# days of deployment)

Max Daily Threshold / # days = Passive Result Threshold

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

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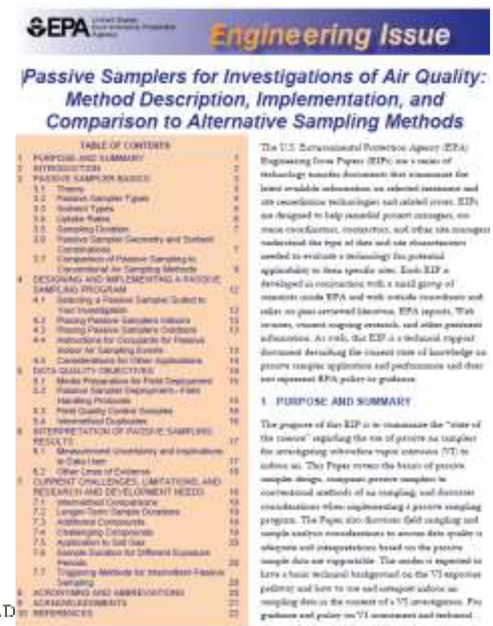
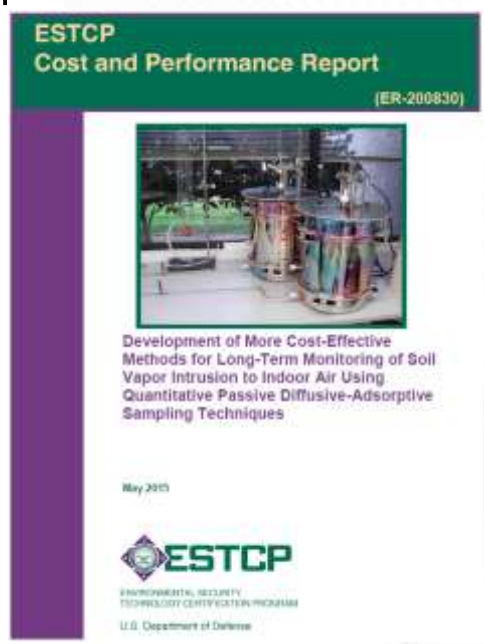
For more information on passive samplers…





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Real-time indoor air monitoring

HARTMAN ENVIRONMENTAL GEOSCIENCE

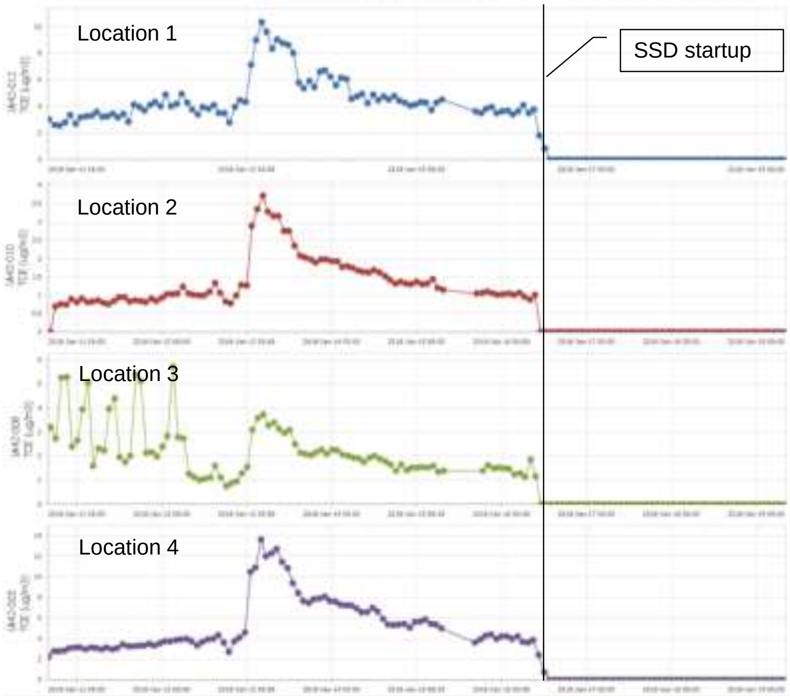
INFICON HAPSITE

Defiant Technologies FROG 5000

HARTMAN ENVIRONMENTAL GEOSCIENCE

- 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



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Inficon HAPSITE Portable GC-MS

Pros

- Detects VOCs to ~1 µg/m^3 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)

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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

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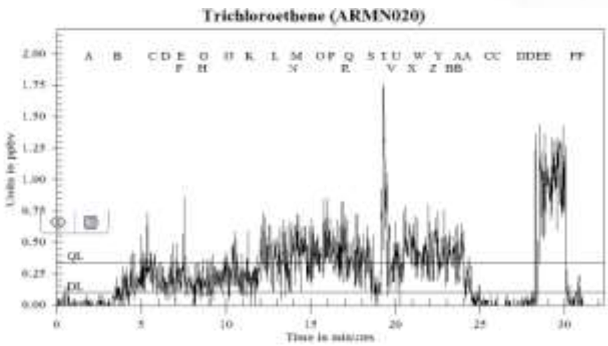
Real-time continuous VI sampling using EPA's Trace Atmospheric Gas Analyzer (TAGA) Mobile Laboratories



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

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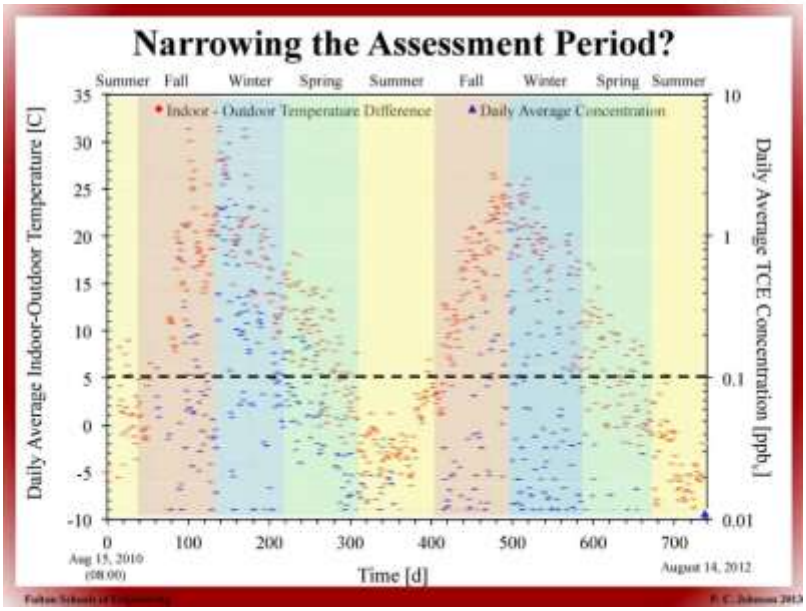
Guided Sampling: New US EPA initiative to use indicator parameters such as temperature, pressure, and radon to sample indoor air when worst-case VI is most likely



Sun Devil Manor, UT

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

- RME is defined as >90th percentile and <98th percentile, typically 95th percentile, of 24-hour average indoor air exposure distribution in a particular structure.
- RME is the "worst case" not the chronic, long-term average
- 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
- Can statistical methods be used to guide the timing of samples to increase the odds of capturing the RME level?

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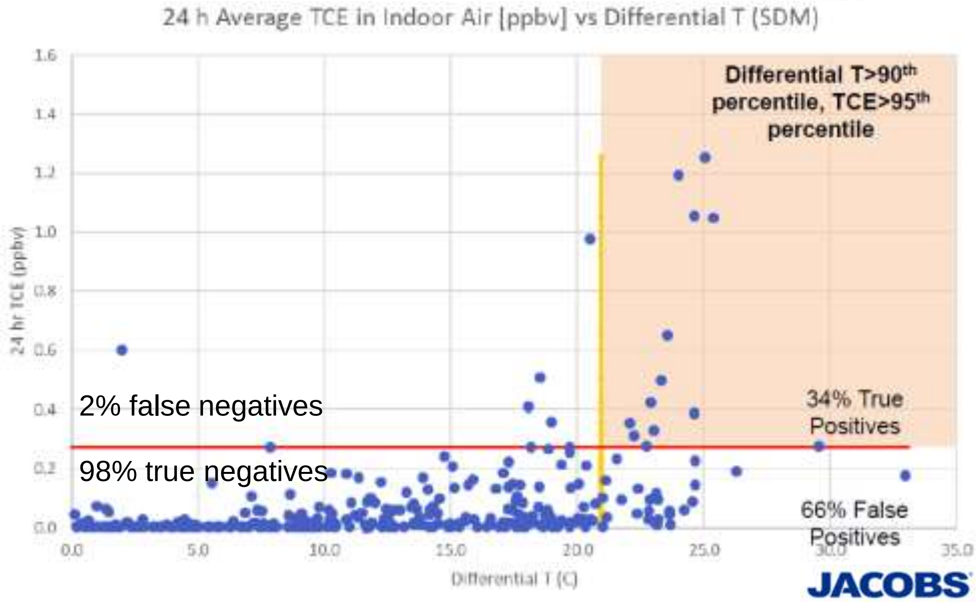
Temperature differential as a VI indicator at Sun Devil Manor, UT



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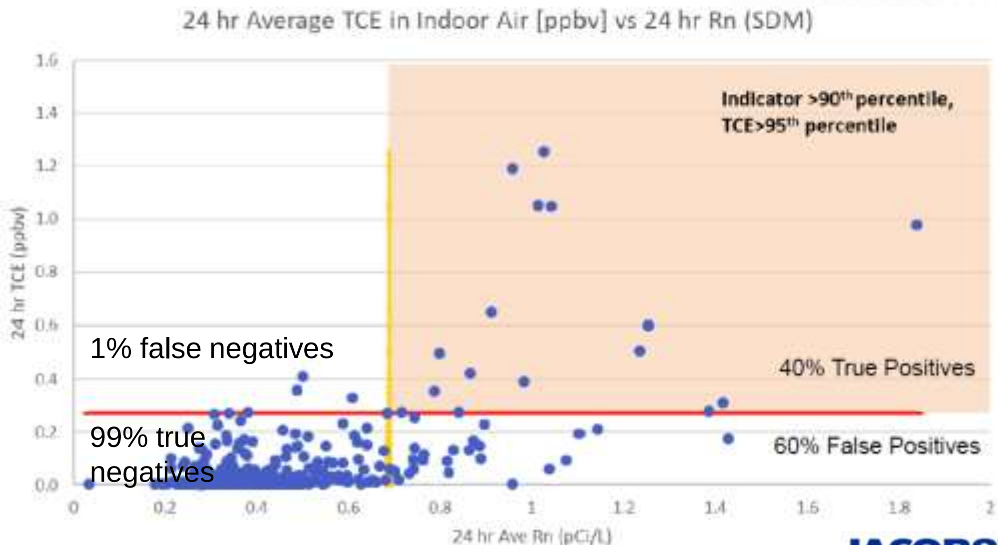
Radon as a VI indicator at Sun Devil Manor, UT



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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

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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 97^{th} 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

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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

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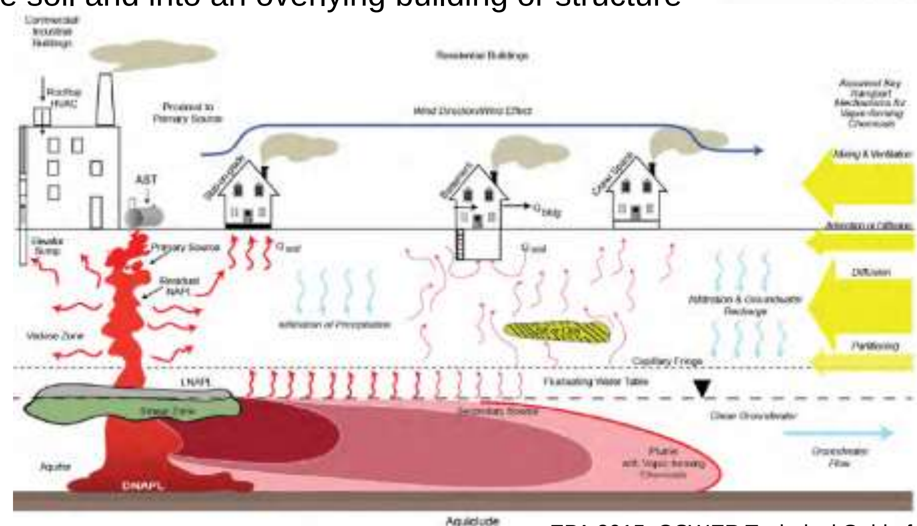
Vapor intrusion (VI) is the general term given to migration of hazardous vapors from any subsurface vapor source, such as contaminated soil or groundwater, through the soil and into an overlying building or structure



EPA 2015, OSWER Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Sources to Indoor Air

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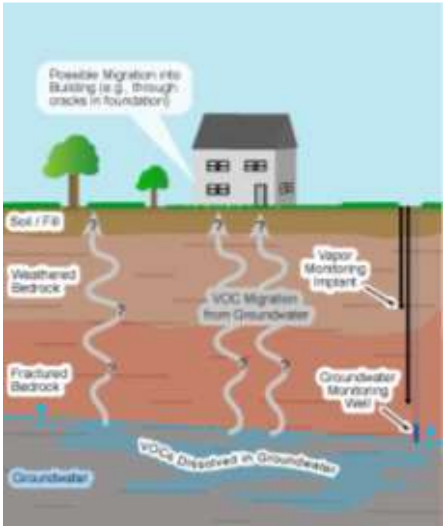
Value of a working Conceptual Site Model (CSM) to inform sampling strategy and build multiple lines of evidence – typically an iterative process



<u>Need to Evaluate</u>

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

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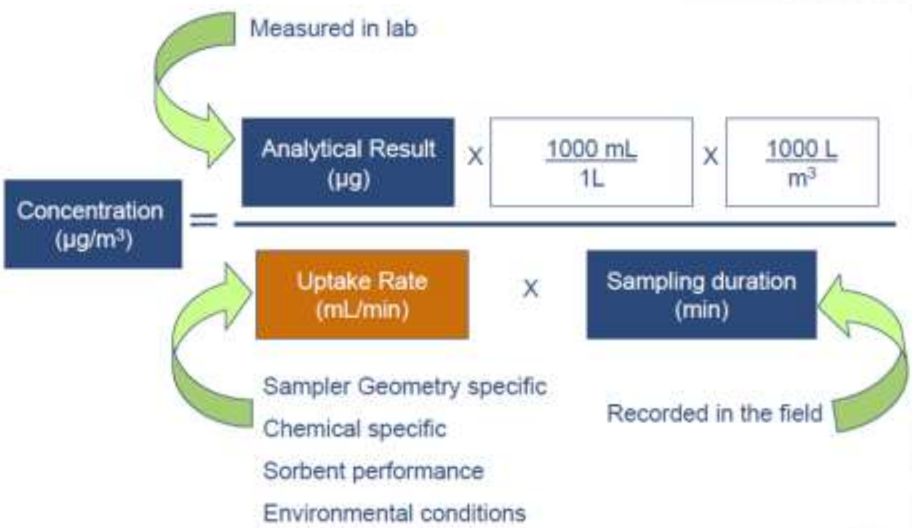
Passive Sampling Concept



Courtesy of Heidi Hayes eurofins | Air Toxics

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