Geosyntec consultants

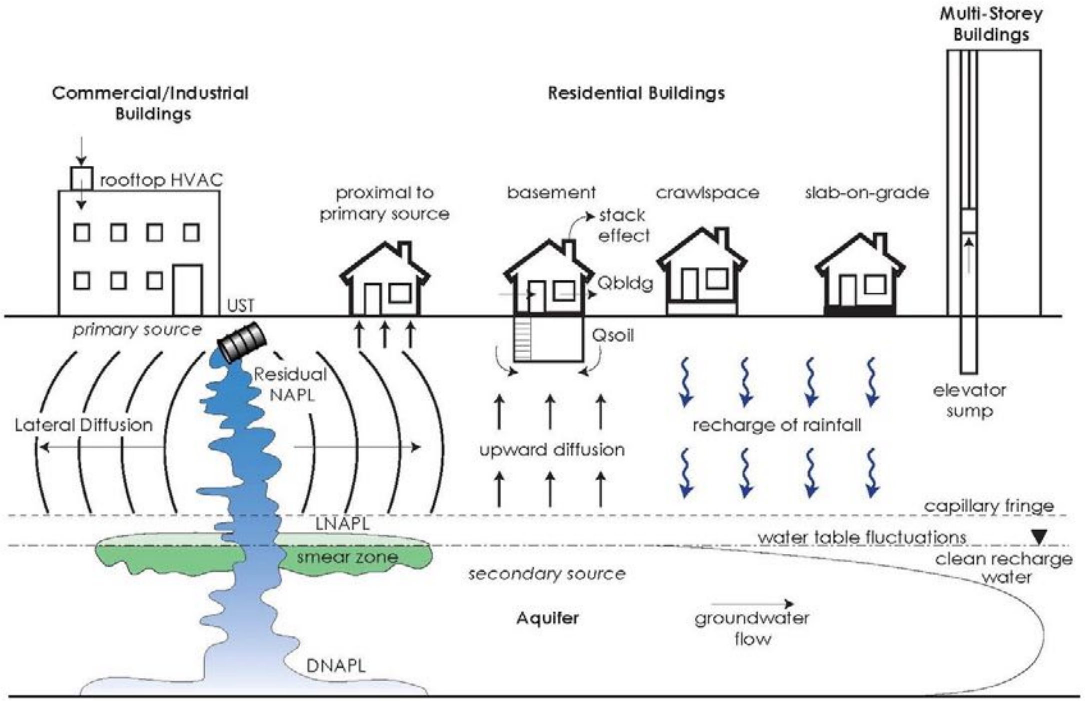
New Tools for the Assessment of Vapour Intrusion into Buildings

Yorkshire Contaminated Land Forum

Authors: Nick Roe & Jim Wragg 30th June 2022

Context – building specific vapour intrusion assessment

Vapour forming compounds present in the subsurface



e.g. Trichloroethene Benzene

BPC

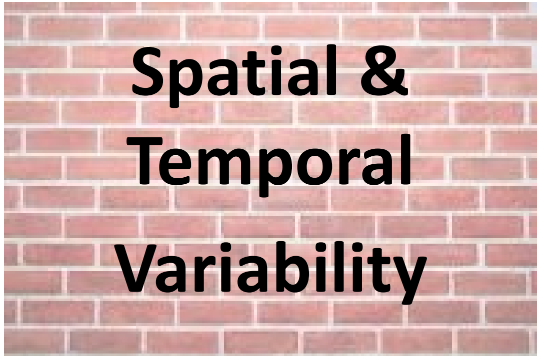
HVS

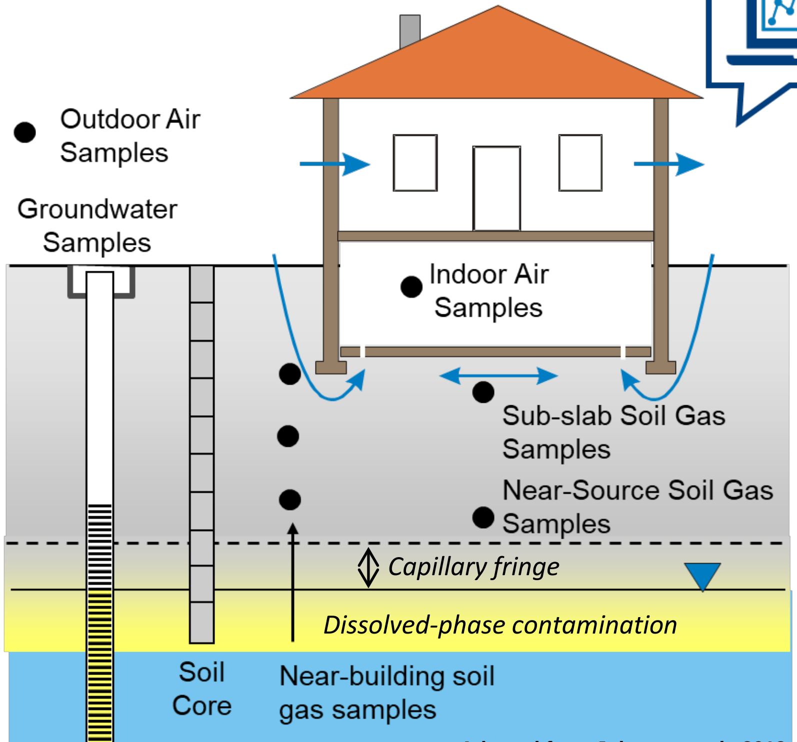
Reducing uncertainty in VI assessment

Better VI Investigation Approaches

- Vapour CSM - iterative
- Data collection – measure it!
- Multiple lines of evidence including non-concentration based

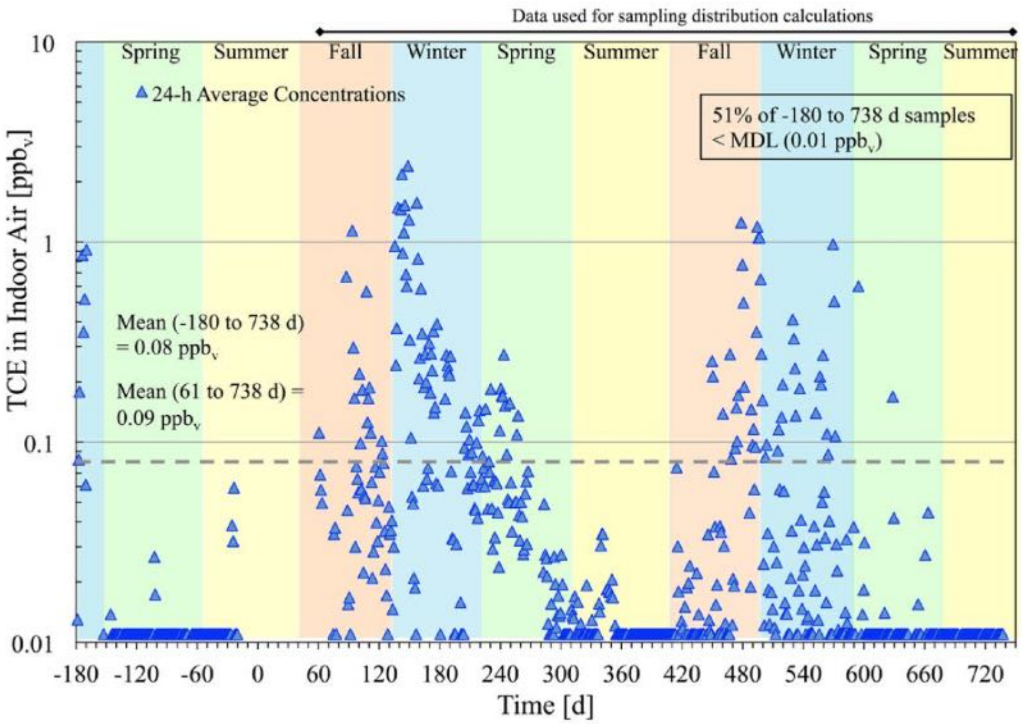
What's the problem?





Adapted from Johnson et al., 2013

Temporal Variability of Indoor Air



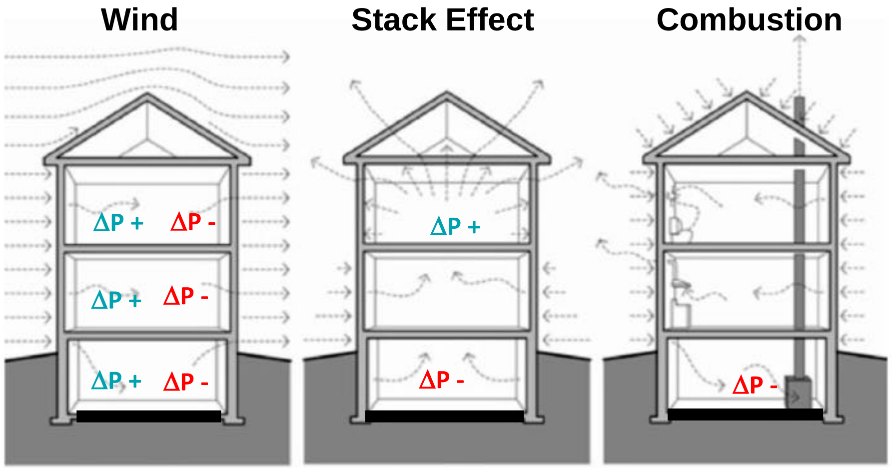
Indoor air quality can be highly variable over time

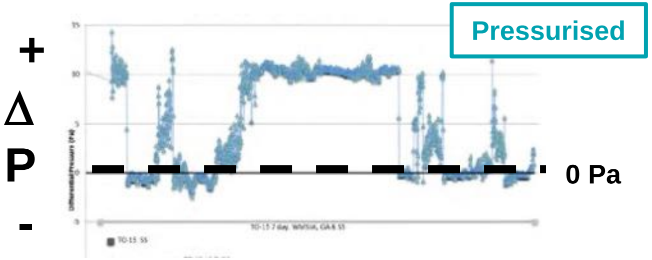
In this example, seasonal variations over 3 orders of magnitude

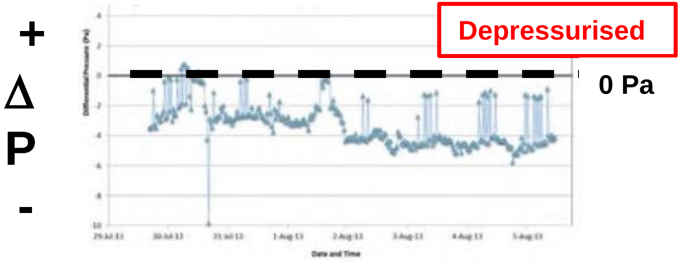
A key limitation of using spot samples to assess VI

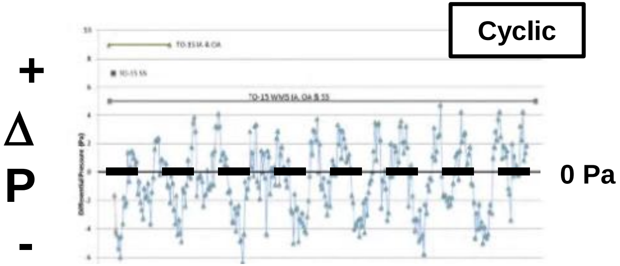
•Reference: Chase Holton, Hong Luo, Paul Dahlen, Kyle Gorder, Erik Dettenmaier, and Paul C. Johnson
Temporal Variability of Indoor Air Concentrations under Natural Conditions in a House Overlying a Dilute Chlorinated Solvent Groundwater Plume *Environ. Sci. Technol.* 2013, *47* (23), 13347-13354

Causes of Temporal Variability





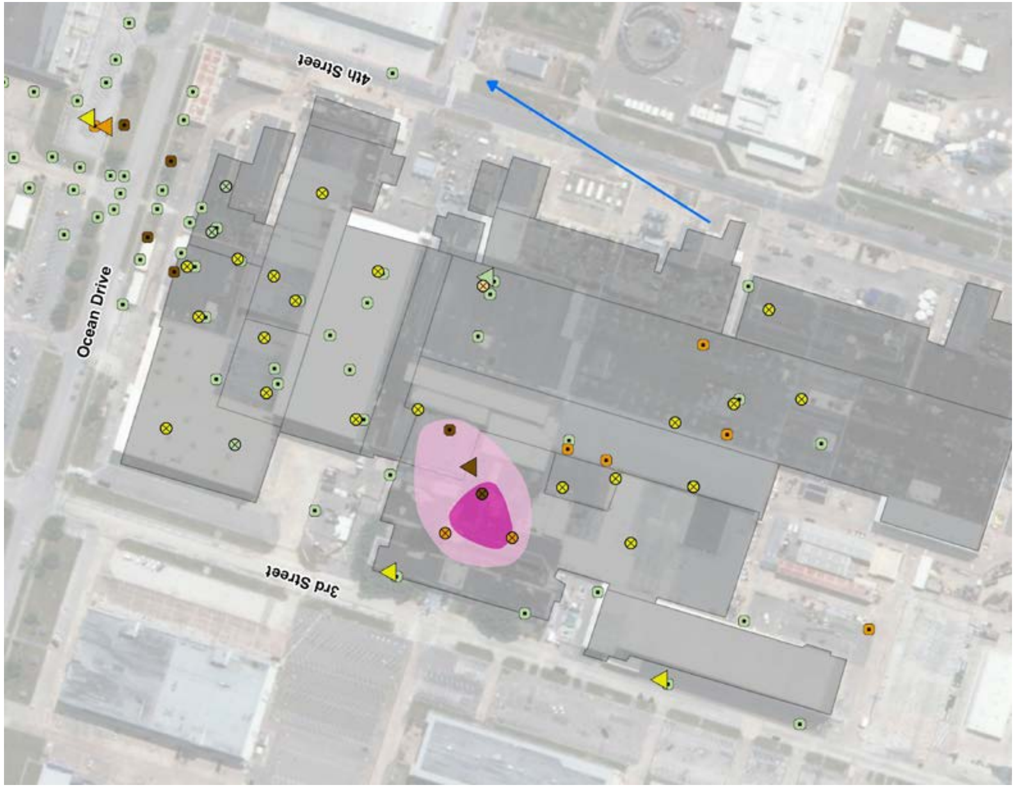




$\Delta P_{Building}$ = Building Pressure - Exterior Pressure

$\Delta P_{Subslab}$ characterizes building susceptibility to subsurface vapour entry ($-\Delta P_{Subslab}$ = vapour intrusion)

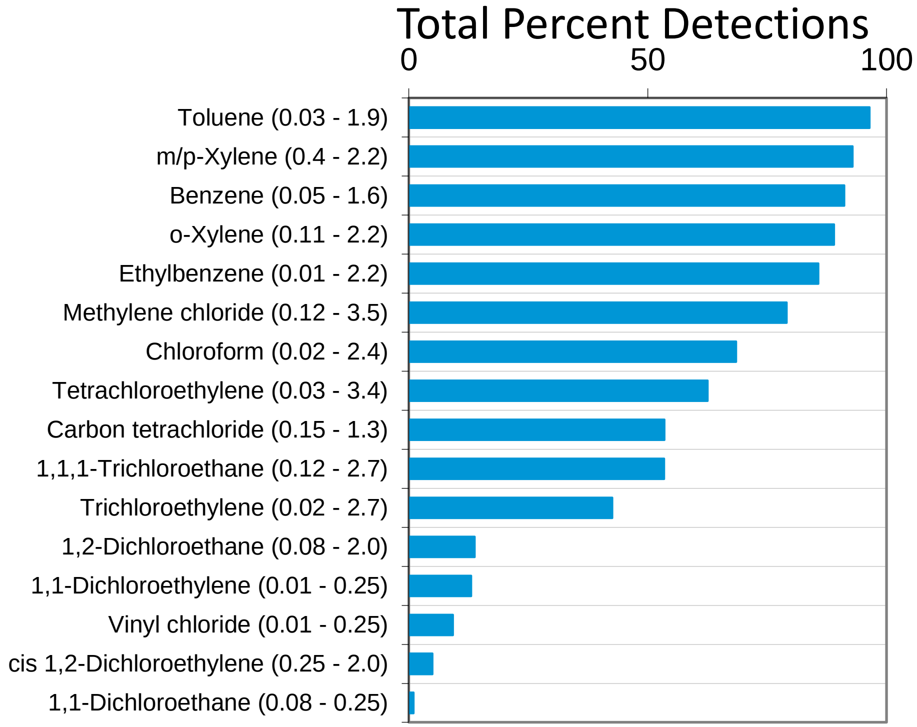
Spatial Variability



A generic example of a TCE plume in groundwater, driving vapour risks in the overlying buildings.

Consider the VI investigation stage for this example. Vast difference in VI potential from one end of the building to the other.

Consider Background Sources



Values in parentheses are reporting limits in µg/m³

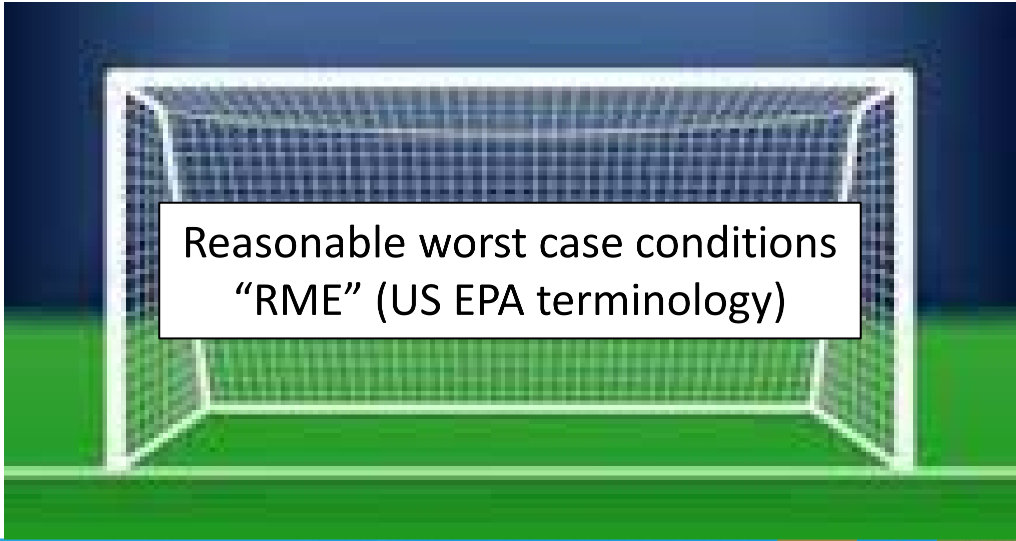
Reference: Dawson and McAlary, 2009

Advanced VI approaches

There are ways to address the temporal and spatial variability in vapour concentrations within VI assessments:

- Passive sampling - diffusion based vapour sample collection
- Building Pressure Control (BPC)
- High Volume Sampling (HVS)

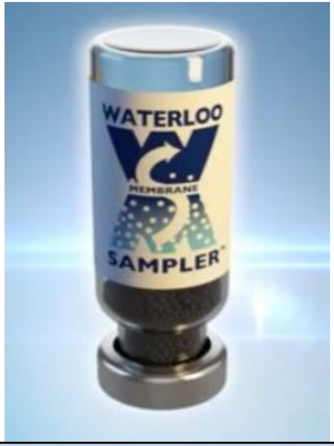
❖ Other lines of evidence



VI assessment methods – Passive Sampling

- Sorbent media. Many varieties.
- Sample collection over days to months.
- Time weighted average concentrations.

Representative long-term average concentrations

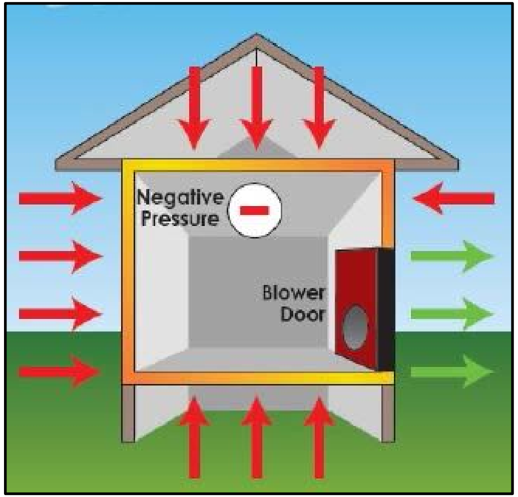


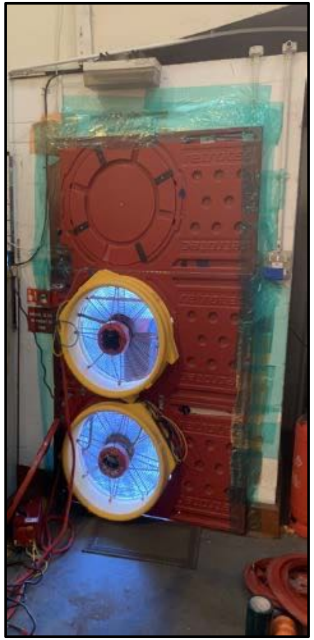
Waterloo Membrane Sampler (WMS)

- A passive permeation type sampler. VOCs permeate through the uptake-rate limiting membrane before they are collected by the sorbent.
- Concentration is a function of deployment time, sampler dimensions, membrane thickness and known (calibrated) chemical specific uptake rate.

VI assessment methods - BPC

Building Pressure Control





Manipulate building pressure

- Turn VI on or off

Monitor changes in:

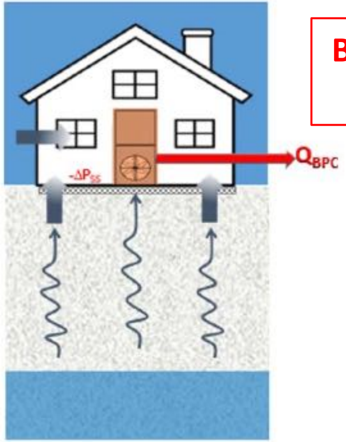
- Indoor, outdoor, sub-slab vapour
- Cross-slab differential pressure

Determine:

- Background contributions
- Reasonable worst case conditions

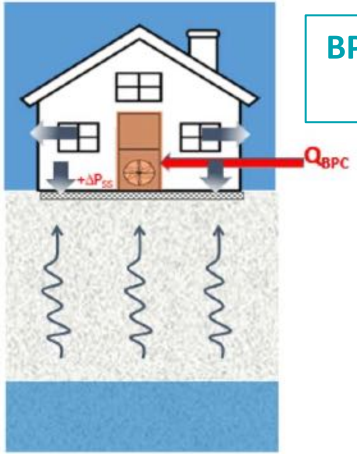
Building Pressure Control - BPC

Induce vapour intrusion by depressurising and sample to characterise induced vapour intrusion impacts



BPC Depressurised Conditions

Inhibit vapour intrusion by pressurising and sample to characterise background source emissions

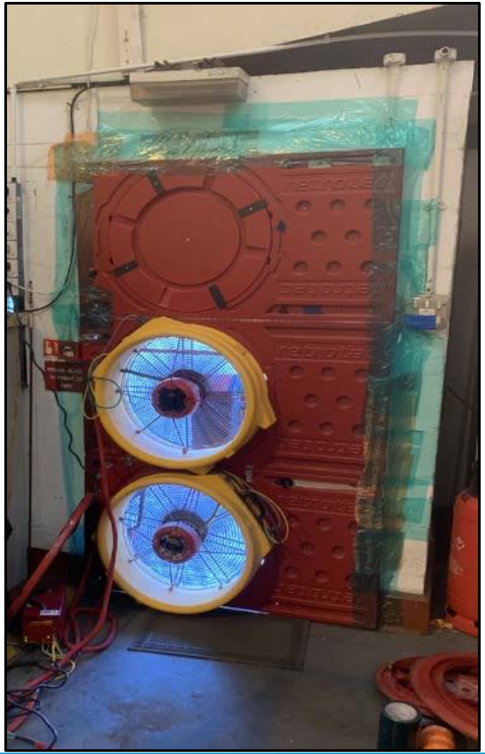


BPC Pressurised Conditions

BPC – Blower doors

Baseline - ambient

Depressurisation / Pressurisation



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BPC Case Study – UK, 2020

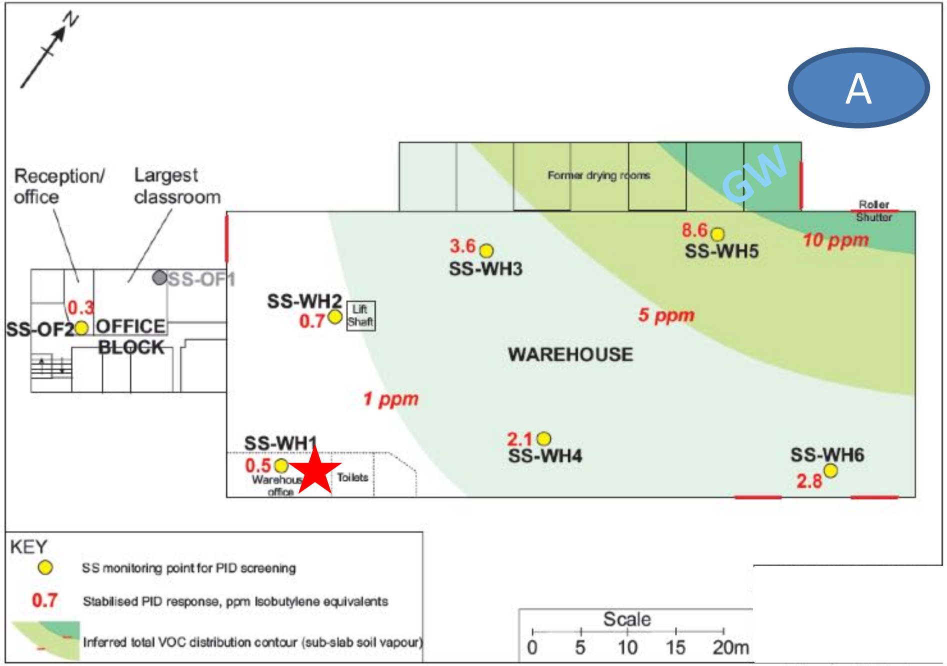
- BPC testing of warehouse and adjoining offices (occupied, third party)
- Up-gradient historical source of chlorinated solvent TCE (A)
- Impacted groundwater flow beneath the building, potential for VI

BPC Case Study - Site work

- Initial sub-slab survey undertaken for screening purposes
- Large apertures in warehouse envelope sealed – allow negative pressure steps up to -30 Pa – building leakage curve
- Building pressure control tests completed
    - Ambient pressure
    - Negative pressure - steps
    - Positive pressure
- Warehouse and Office Block tested separately
- Indoor, outdoor and sub-slab samples collected

BPC Case Study - Results

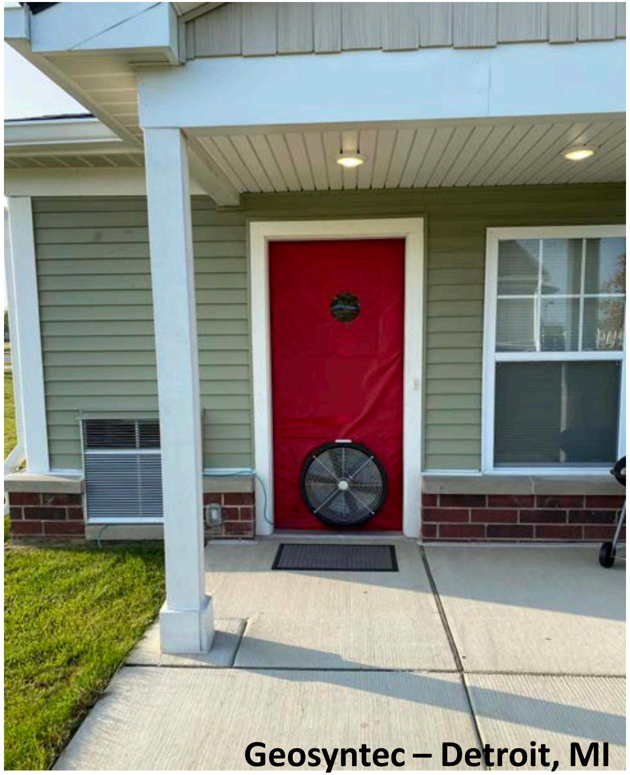
- Indoor air measurements identified VI by TCE (ambient and negative pressure steps), greatest in confined warehouse offices. Not in office block.
- All outdoor air and positive pressure step data was non-detect, no background sources.
- Sub-slab vapour, nearby groundwater quality and induced VI in the vicinity of the Warehouse offices were consistent
- BPC testing completed over 2 nights



Benefits of Building Pressure Control

- Conservative assessment of RWC
- Rapid decision-making
- Identifies background contributions
- Physical CSM data for no added cost
- Calculate site-specific targets

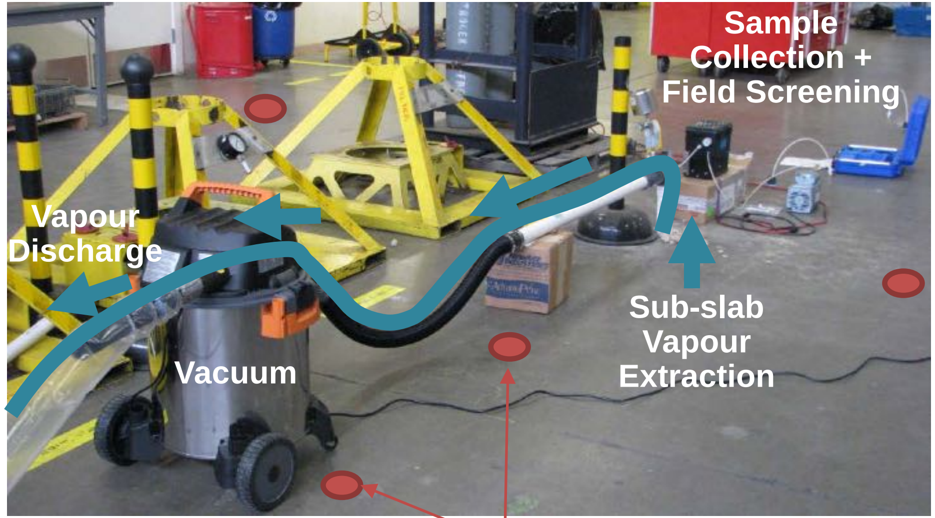
Robust VI assessment can be conducted in a single day



Geosyntec – Detroit, MI

VI assessment methods - HVS

High Volume Sampling



Communication test points

Large volume soil vapour extraction

Replace many spot samples with <<test points

Field screening and sampling:

- Spatially integrated sub-slab vapour
- PID, and ground gas response
- Sub-slab vacuum propagation
- Helium tracer testing
- Transient vacuum testing

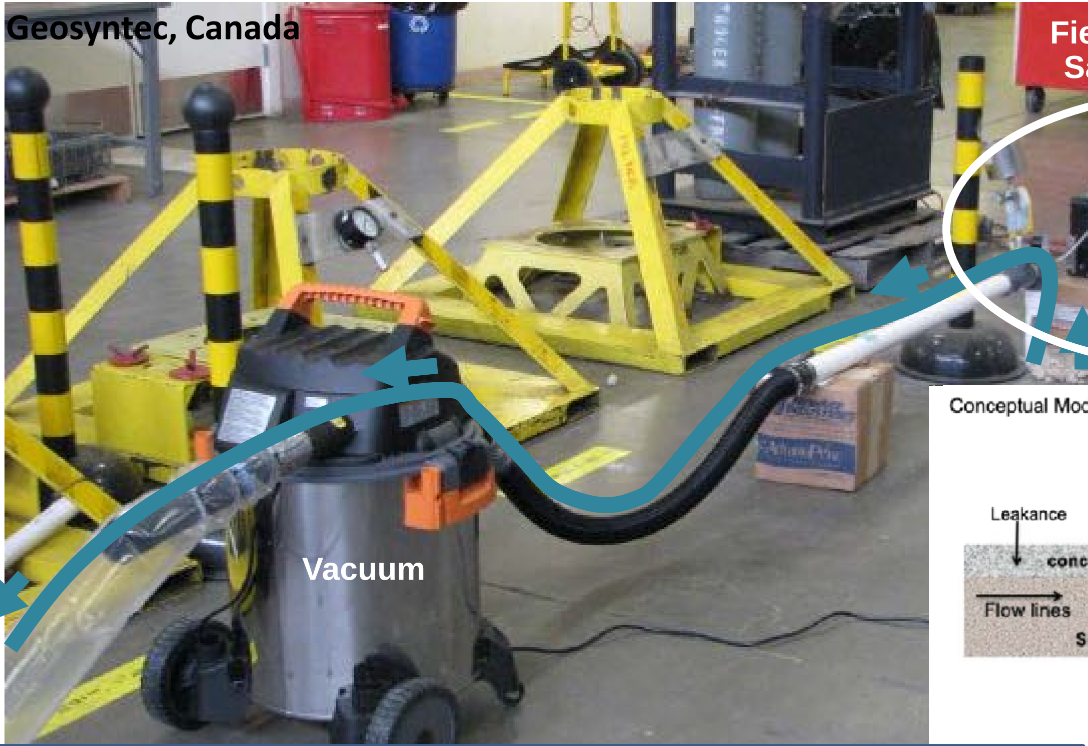
Characterise:

- Sub-slab vapour distribution
- Building specific attenuation factors
- Sub-surface pneumatic properties

High Volume Sampling (HVS)

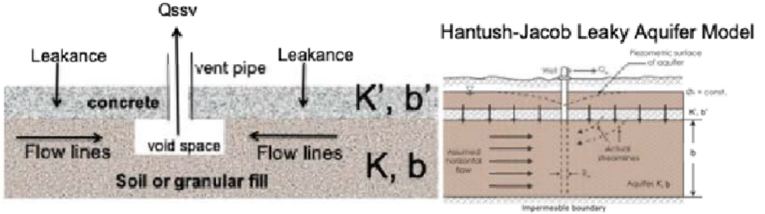
- Sub-slab soil gas quality can be very heterogeneous beneath large buildings
- Traditional soil vapour surveys looking to identify the location of contamination sources must be undertaken using many closely spaced sampling points
- High Volume Sampling employs a vacuum pump to collect integrated soil gas samples over a larger area.
- Faster, less expensive investigations to find sources.
- Also collects pneumatic data - building specific attenuation factor and VI mitigation design.

High Volume Sampling Setup



Vapour Discharge

Conceptual Model of Sub-slab Venting



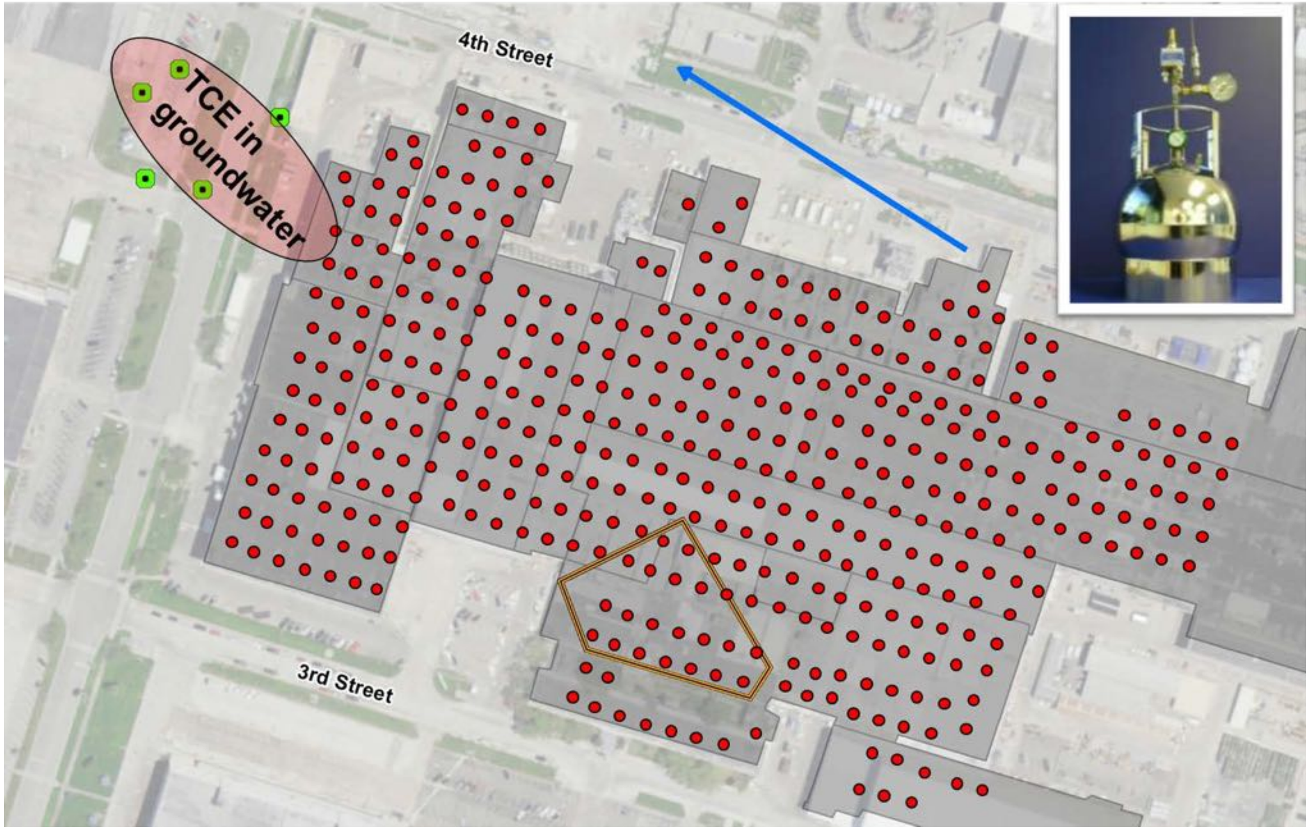
$T = Kb$ (T) = Transmissivity below the floor (ft^2/day)
(K) = gas conductivity (ft/day)
(b) = thickness (ft)

$B = \sqrt{\frac{Tb'}{K'}}$ (B) = Leakance (ft) (this parameter simplifies equations)

McAlary T. A., Nicholson P. J., Yik L. K., Bertrand D. M., and Thrupp G., 2010, High Purge Volume Sampling – A New Paradigm for Subslab Soil Gas Monitoring. Groundwater Monitoring & Remediation: 20091006-0047R.

...ob, 1955. Non-steady radial flow in an infinite leaky aquifer, Am. Geophys. Union Trans., vol. 36, pp. 95-100.

Accounting for Spatial Variability the Hard Way



A Better Way – High Volume Sampling

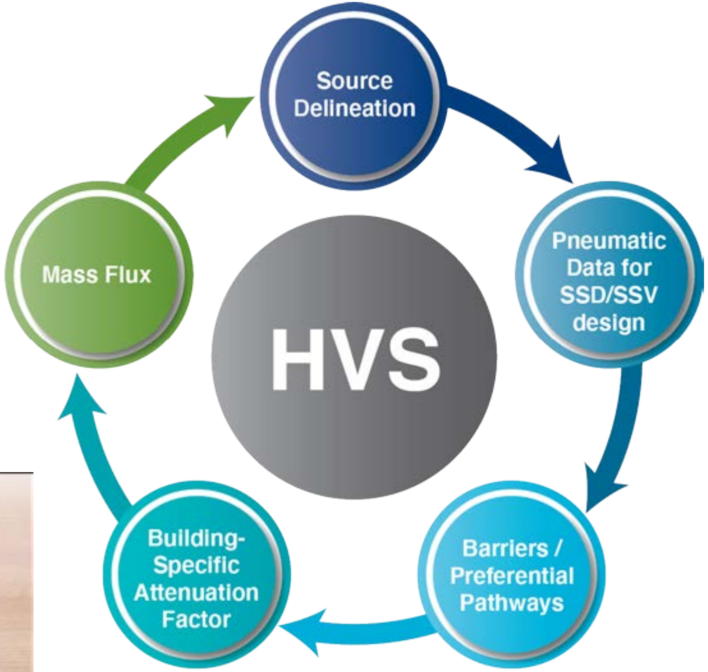
- Vapour distribution
- Preferential pathways
- Subsurface and floor slab properties
- BSAF

HVS Case Study, 2020

- Active industrial site. Highly restrictive space and operations.
- Characterise distribution of sub-surface vapour and sources
- 1 week, no impacts to production operations
- Delineated source beneath building which was not directly accessible
- Demonstrated absence of sources elsewhere

Benefits of High Volume Sampling

- Fewer required samples
- Clarify source geometry
  - works with restrictions to access
- Demonstrate absence of other sources
- Minimise risk of failing to identify significant source
- Calculate BSAF
- Collect mitigation design parameters



Conclusions

Vapour Intrusion is a widely encountered issue at re-developed sites on or near former industrial facilities

There is a broader toolbox available to overcome the inherent difficulties in

- Investigating VI occurrence
- Assessing VI risks and
- Designing cost effective mitigation measures

These approaches provide greater certainty and can save time and money

Thankyou

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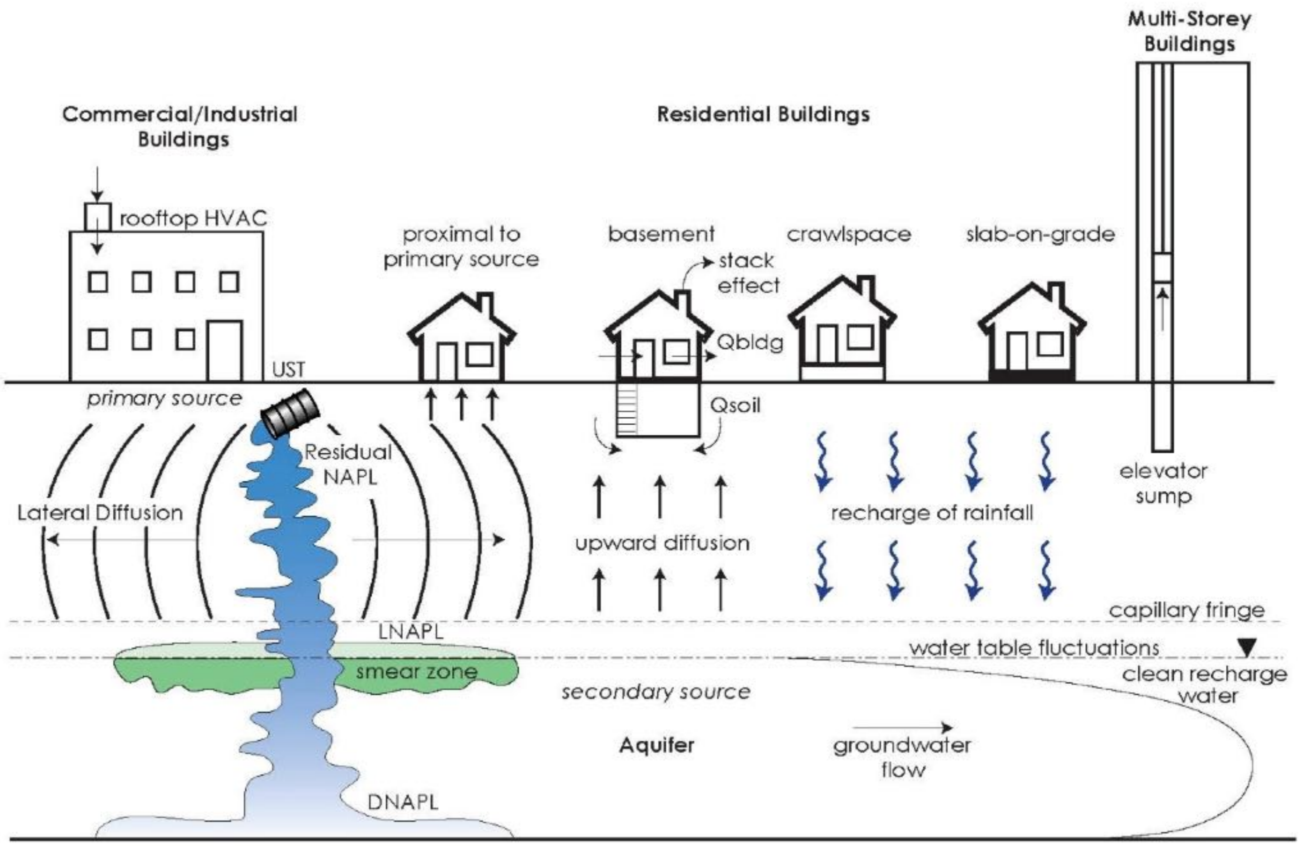
Vapour Intrusion Conceptual Site Model



Vapour Intrusion - what is it?

Vapour Intrusion (VI) is the migration of volatile organic compounds (VOCs) from a subsurface source into the indoor air of an overlying building.

Many former industrial sites have soil and groundwater impacted by volatile organic compounds (VOCs).

These include:

- Degreasing agents such as Chlorinated solvents e.g. Trichloroethene (TCE),
- Aromatic compounds e.g., BTEX, found in petrol, paint thinners

VI can affect existing or future buildings on the contaminated site and those on neighbouring properties down gradient