GROUNDWATER SERVICES, INC.

Vapor Intrusion Investigation Methods

Petroleum Vapor Intrusion Workshop

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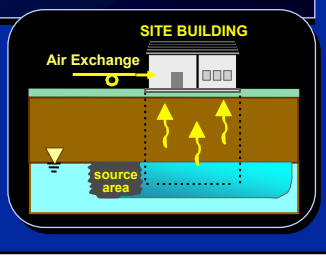
Thomas McHugh
Groundwater Services, Inc., Houston, Texas
(713) 522-6300, temchugh@gsi-net.com



Evaluation of Vapor Intrusion

Impact of Background on Vapor Intrusion Investigations

- Indoor Air as a Source of Subsurface VOCs
- Use of Non-VOC Measurements to Understand Vapor Intrusion
- Case Study: DoD Research Site

Significance of Background Effects

Source of Background Indoor Air Impacts

Key Sources of VOCs in Indoor Air

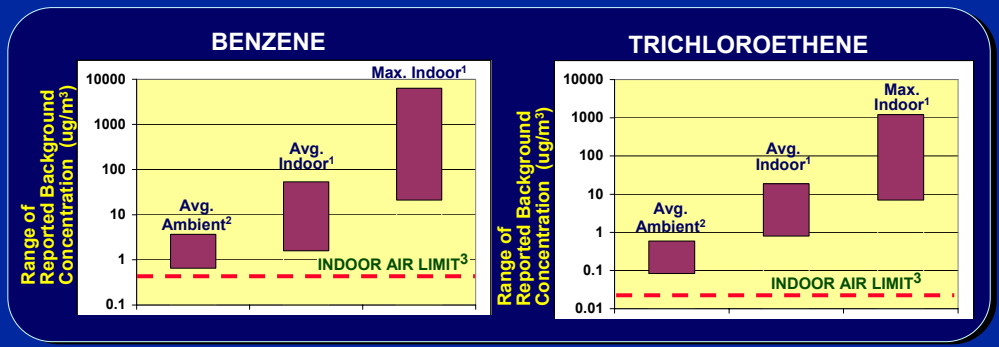
- Ambient air
- Vehicles, gasoline
- Paints, adhesives
- Cleaning agents
- Insecticides
- Tobacco smoke
- Cosmetics, etc.

REFERENCES:

- USEPA, 1991, "Building Air Quality Guide"
- OSHA, 1999, "Tech Manual for Indoor Air Investigation"

Significance of Background Effects

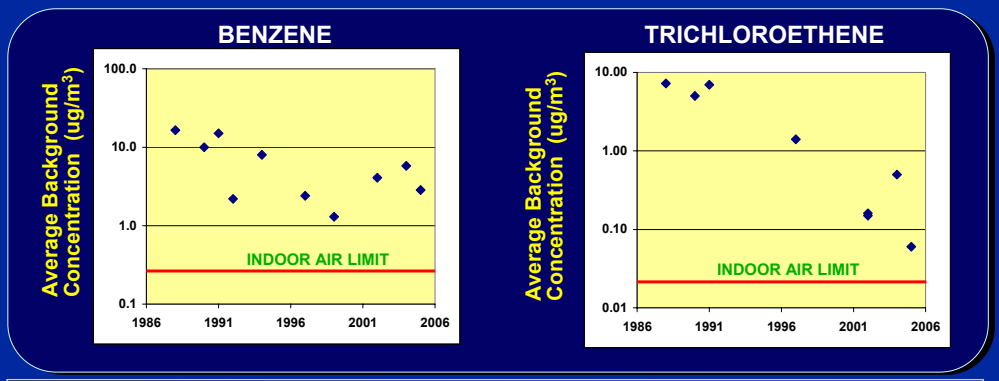
Backgrd Conc.'s vs. USEPA Risk-Based Limits



KEY POINT: Average **background** indoor and outdoor air concentrations ***EXCEED*** risk-based limits for indoor air.

1) Range of values reported in the studies reviewed in "Indoor Air Quality Data Base for Organic Compounds", USEPA, 1992
2) 5th and 95th percentile concentrations in urban areas, National-Scale Air Toxics Assessment, USEPA, 1996 data.
3) USEPA Draft Vapor Intrusion Guidance, November 2002

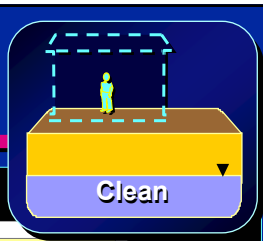
Average Indoor Air Quality Over Time

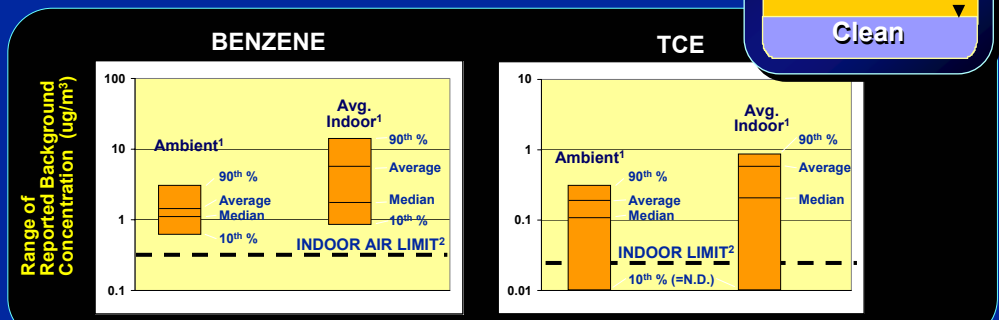


KEY POINT: **TCE concentration apparently decreasing over time. However, little change in indoor petroleum VOC concentrations.**

Note: 1) Average background indoor air concentrations reported in various studies by year of publication.
2) Indoor air limits (10^{-6}) from USEPA Draft Vapor Intrusion Guidance, November 2002.

2004 Background vs. USEPA Risk-Based Limits



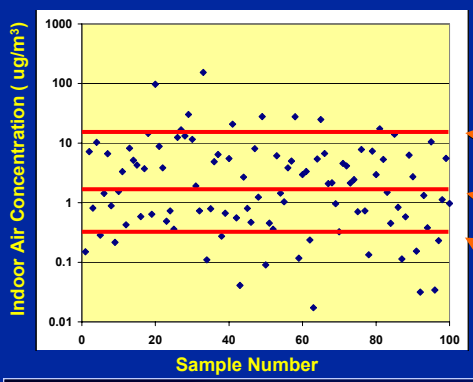


KEY POINT: **In 2004, background indoor and outdoor air concentrations still exceed risk-based limits for indoor air.**

1) Background concentrations from Sexton et al. 2004 ES&T 38(2); 423-430.
2) USEPA Draft Vapor Intrusion Guidance, November 2002

Significance of Background Effects
Is Background Correction Possible?

EXPECTED BENZENE LEVELS IN 100 HOMES WITHOUT VI IMPACTS



	Screening Value (ug/m3)	Number of Homes w/ Exceedances
90th % Backgrnd	15.3	10
Median Backgrnd	1.9	50
USEPA Limit (10^{-6})	0.31	84

KEY POINT: *Site-specific background can vary by >1000x, making site-specific correction of single measurement difficult.*

1) Indoor air limit (10^{-6}) from USEPA Draft Vapor Intrusion Guidance, November 2002
2) Median and 90th % background concentrations from Sexton et al. 2004 ES&T 38(2); 423-430.

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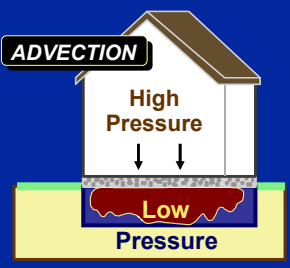
Advection / Diffusion Vapor Transport Processes

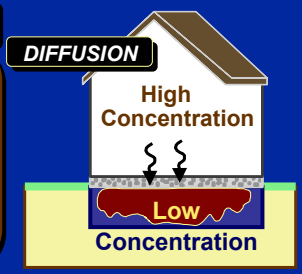
Gas flow from higher pressure to lower pressure

			EXAMPLE
If indoor higher	→	Flow Out	Commercial bldg. designed for positive pressure
If indoor lower	→	Flow In	Residence in winter (chimney effect)
Variable pressure	→	Reversible Flow	Barometric pumping

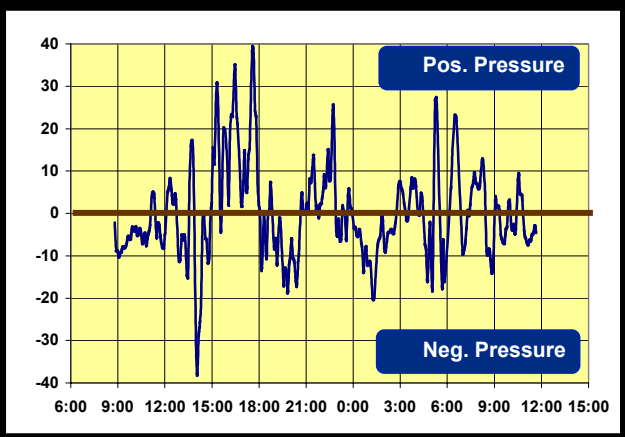


Mass flow from high concentration to low concentration

			EXAMPLE
If indoor higher	→	Flow Out	Indoor source of VOCs
If indoor lower	→	Flow In	Subsurface contamination
Variable gradient	→	Reversible Flow	Periodic release of VOCs in building (e.g., pest control)



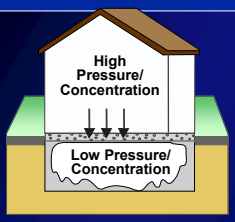
Pressure Gradient Measurements: *School Building, Houston, Texas*



KEY POINT:

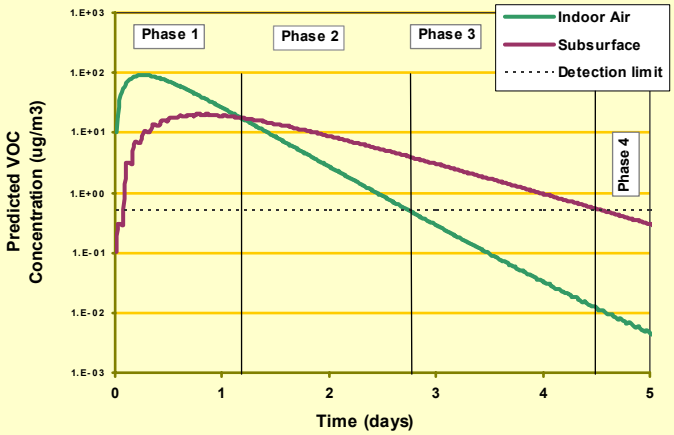
Pressure gradient frequently switches between positive and negative within a single day.

Indoor VOC Source, Reversible Flow: *Model Results*



KEY POINT:

VOCs can remain below building after dissipating from indoors.



Case Study

Downward Migration of VOCs

What

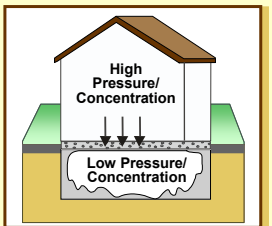
- Apartment complex located adjacent to gas station with release to groundwater.

Goal

- Evaluate potential for VI at apartment complex associated with release from gas station.

Key Issue

- Source of VOCs detected in sub-slab samples below three vacant apartments in complex.



OUTCOME: **VOCs detected in sub-slab samples attributed to local indoor VOC sources.**

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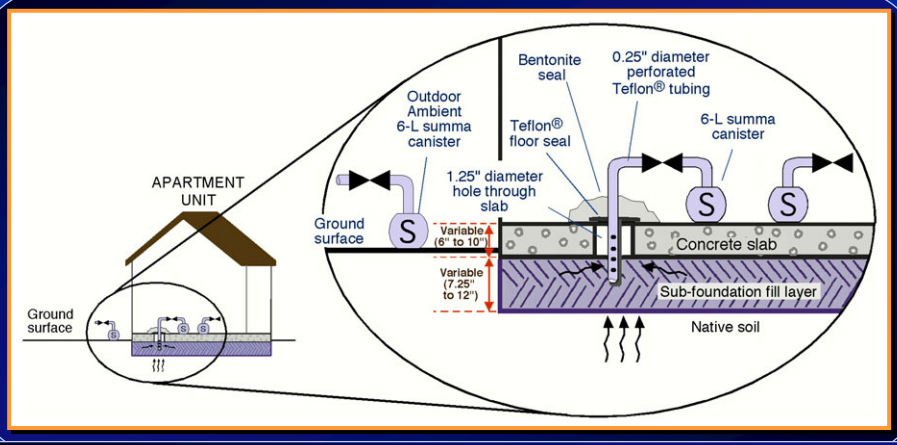
Investigation:
Outdoor, Indoor, and Sub-Slab Sampling



KEY POINT: **Concurrent sampling of sub-slab, indoor air, and outdoor air.**

Sample Collection

Sub-Slab Sampling

2 Summa Canisters (1 to purge, 1 to sample)

Outdoor Air Sampling

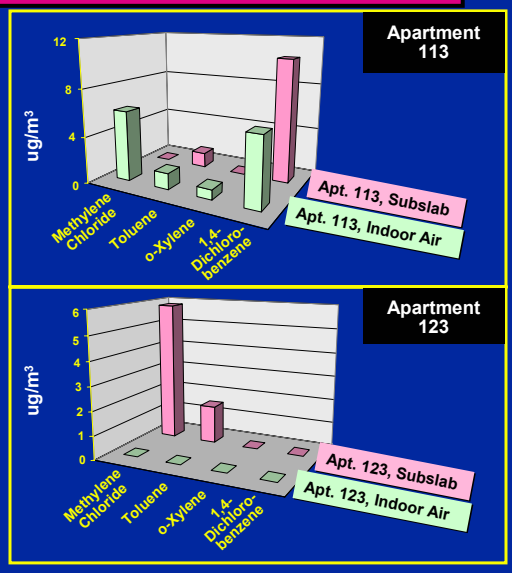
Documents ambient conditions

Vapor Sampling: *Results*

- Analyzed for 43 VOCs, detected 4.
- All 4 have common indoor sources
- Only 2 of 4 found at gas station (at low concentrations)

KEY POINT:

Indoor VOCs detected in subsurface samples.



Evaluation of Vapor Intrusion

- Impact of Background on Vapor Intrusion Investigations
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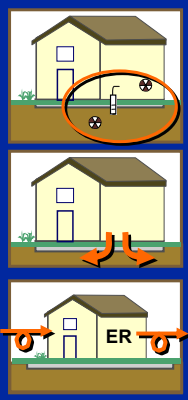
- Case Study: DoD Research Site

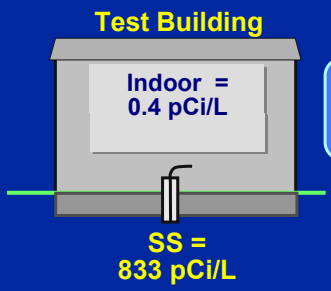
VI Investigation Methods: *Non-VOC Measurements*

Radon	Naturally occurring tracer gas used to measure attenuation through building foundation.
Building Pressure	Magnitude and duration of building pressure fluctuations: negative vs. positive building pressure.
Air Exchange	Building ventilation rates: design standards, HVAC operation, indoor tracer gas.



KEY POINT: **Non-VOC measurements used to evaluate vapor intrusion while avoiding background VOC issues.**

Radon as a Tracer for Foundation Attenuation



Sub-Slab to Indoor Air Atten. Factor:

$$= \frac{0.4}{833} = 0.00048$$

U.S. EPA Default AF = 0.1

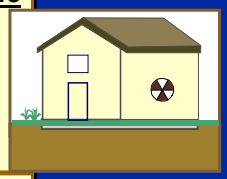
BENEFITS:

- No common indoor sources of radon.
- Lower analytical costs compared to VOCs.
- Less bias caused by non-detect results indoors.
- Can be used for long-term testing (up to 6 months).

Radon: *Measurement Options*

Indoor Air

- ***Home Test Methods:*** Charcoal Canister, electret, alpha detector — ***Cost/Sample*** $10-50
- ***Air Samples:*** Radon concentration measured at off-site lab * — $100



Sub-Foundation

- ***Air Sample:*** Radon concentration measured at off-site lab * — $100
- ***Electret?:*** Placed over hole in foundation — $25-50

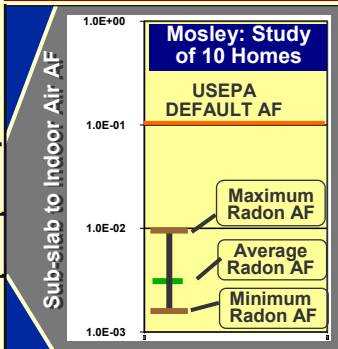
ALTERNATIVE: ■ Purchase equipment for on-site analyses: $50,000-$80,000.

* *Off-site analysis provided by Dr. Doug Hammond, University of Southern California*

Sub-Slab to Indoor Attenuation Factors: *Radon Measurements*

RADON ATTENUATION FACTORS IN RESIDENCES

Type of Attenuation Factor	*Value*
Maximum: (Mosley)	0.009
Average: (Mosley)	0.003
Representative: (Nazaroff)	0.0016



KEY POINT: ■ Measured radon attenuation factors less than defaults based on VOC data.

Radon data from: 1) Mosley et al., 2004, USEPA Vapor Attenuation Workshop, San Diego, CA, March 2004. (http://iavi.rti.org/resources.cfm?pageID=document), 2) Little, J.C., Daisey, J.M., and Nazaroff, W.M., 1992. Transport of Subsurface Contaminants into Buildings: An Exposure Pathway for Volatile Organics, Env. Sci. Tech., Vol. 26, No. 11, pp. 2058-2066.

Pressure Gradient: *Wazzat ?*

What

- Measure pressure gradient across building foundation

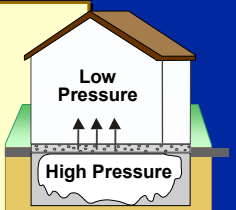
How

- Pressure transducer with ports open to building and below foundation

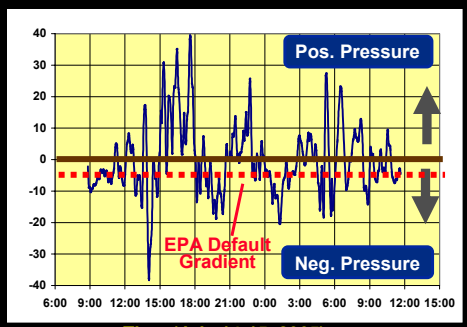
Pressure Transducer

Why

- Understand driving force for vapor transport across foundation: positive vs. negative pressure gradient.
- Document impact of ambient weather on sampling program



Pressure Gradient Measurements: *School Building*



Key Site Conditions

Atmospheric Pressure: Steady (7430 - 7460 Pascals)

Wind Speed: 0-17 mph (Avg. = 8)

Precipitation: About 1" rain

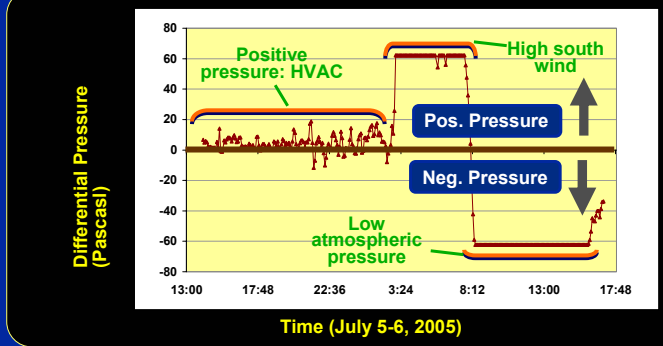
Temperature: 74 - 91 ˚F

HVAC System Operation: Normal

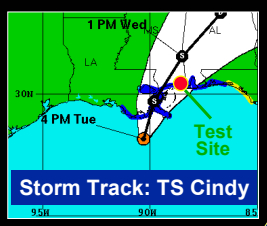
DATA INTERPERATION:

- Measured pressure gradient likely reflects typical conditions (i.e., no extreme weather observed).
- Bi-directions flow expected across building foundation.

Pressure Gradient Measurements: *Tropical Storm Cindy*



Pressure Transducer

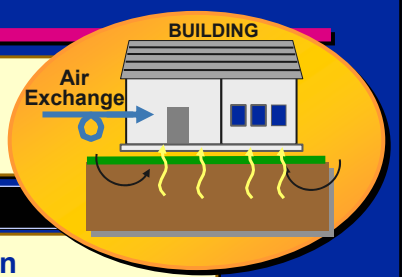


KEY POINT: **Pressure gradients potentially influenced by wide variety of factors. Measurements document non-representative sampling conditions.**

Air Exchange: *What 'n How*

What

Rate at which indoor air is replaced by ambient (fresh) air.



ESTIMATION METHODS

Ventilation Standards

Recommended ventilation rates for commercial building.

HVAC System

- **Fresh air intake rate**
- **Economizer function**

Tracer Gas

Measure dilution of tracer gas to determine air exchange rate

KEY POINT: **Multiple methods available to estimate or measure site-specific air exchange rate.**

Recommended Building Ventilation Rates

ANSI / ASHRAE Standard 62.1 – 2004
Ventilation for Acceptable Indoor Air Quality

Building Type	Air Exchange Rate (# / day)
USEPA Default (Residential)	6
Office Space	12
Supermarket	17
Classroom	68
Restaurant	102

High Building Ventilation

KEY POINT: **Buildings designed for high density use will have high air exchange rates.**

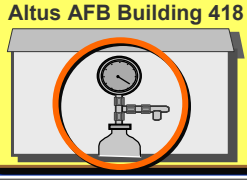
Air Exchange: *Measured Values*

Altus Results: Building Air Exchange

What:

Release SF6 Tracer gas into building to measure from air exchange.

Altus AFB Building 418



Results:

Sample Time	Tracer Gas Study		Expected Fresh Air Entry Rate from HVAC system
	Building Air Exchange	Fresh Air Entry Rate	
Morning	19/day	1200 CFM	> 1140 CFM
Evening	16/day	1000 CFM	1140 CFM

KEY POINT: **Results of tracer gas study matched expected effect of HVAC system.**

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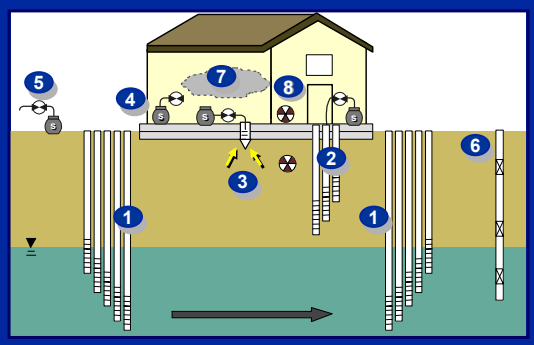
➡ ***Case Study: DoD Research Site***

DoD Study: *Overview*

Study Approach:

1) Collect high density of data around individual buildings
2) Use data to understand VI processes and validate investigation methods.



Distribution of VOCs

1. Vertical GW profile
2. Vertical soil gas profile
3. Sub-slab data
4. Indoor air data
5. Ambient air data

Other Site Data

6. Physical soil properties
7. Indoor air exchange
8. Radon analysis
9. Cross-foundation pressure gradient

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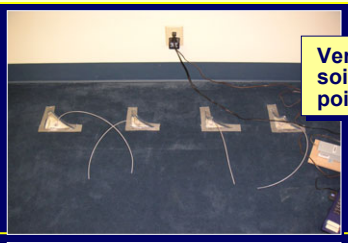
DoD Study: *Data Collection*

Altus AFB Demonstration: ***Field Program***

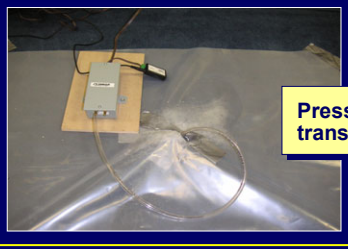
Sample point cluster

Vertical soil gas points



Sub-slab point

Pressure transducer



DoD Study: *Data Collection*

Altus AFB Demonstration: ***On-Site Lab***

H&P Mobile Lab

On-Site Lab Nerd

GC

MS

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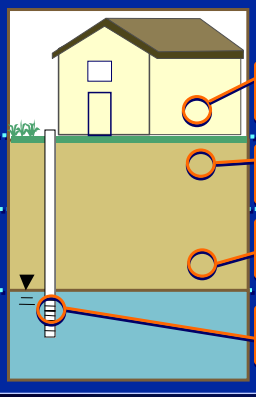
Comparison of VOC Data to EPA Screening Limits

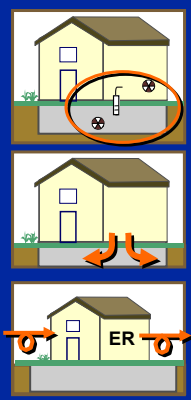


	Measured Conc.	USEPA Screening Limit	Potential VI Impact	Exceedance Factor
PCE	< 5	0.81	?	?
TCE	< 5	0.022	?	?
PCE	59	8.1	YES	7 – 91 X
TCE	20	0.22		
PCE	178	81	YES	2 – 160 X
TCE	353	2.2		
PCE	0.039	0.005	YES	8-12 X
TCE	0.060	0.005		

KEY POINT: ***All*** **Subsurface VOC concentrations exceed USEPA screening values for VI. Indoor data inconclusive.**

Evaluation of Other Site Measurements

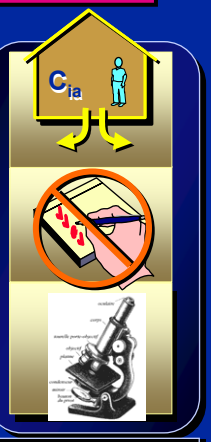
Radon	Paired indoor and sub-slab radon measurements show 2000 x attenuation (USEPA default = 10).
Building Pressure	Measurements show positive building pressure (USEPA default = negative building pressure).
Air Exchange	Tracer gas study shows 2.5 x more fresh air in building than USEPA default.



KEY POINT: **Other (non-VOC) site measurements show no vapor intrusion impact at site.**

Vapor Intrusion: Lessons Learned

Background	■ VOCs detected in or below building foundation may come from indoor sources.
Screening Levels	■ Screening concentrations often exceeded at sites without actual vapor intrusion impacts.
Non-VOC Measurements	■ Multiple lines of evidence may be needed to determine whether a vapor intrusion impact has occurred.



KEY POINT: **Good data and careful analysis needed to identify REAL vapor intrusion impacts.**

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