Vapor Intrusion Assessment and Mitigation 2012

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Environmental Monitoring and
Data Quality Workshop
La Jolla, CA
26 March 2012

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
26 MAR 2012		**00-00-2012 to 00-00-2012**

4. TITLE AND SUBTITLE
Vapor Intrusion Assessment and Mitigation 2012

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Geosyntec Consultants, Inc,2002 Summit Blvd, NE Suite 885,Atlanta,GA,30319

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
Presented at the 9th Annual DoD Environmental Monitoring and Data Quality (EDMQ) Workshop Held 26-29 March 2012 in La Jolla, CA. U.S. Government or Federal Rights License

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Same as Report (SAR)**	**39**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

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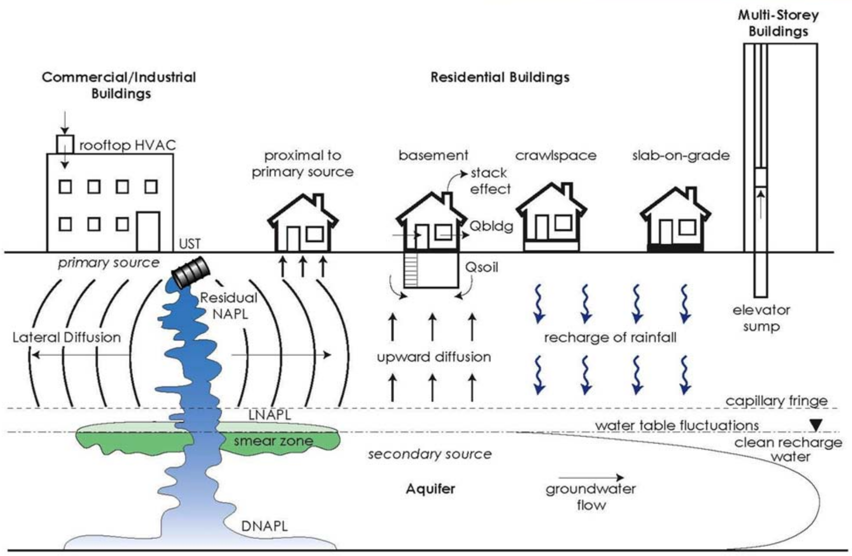
Contents

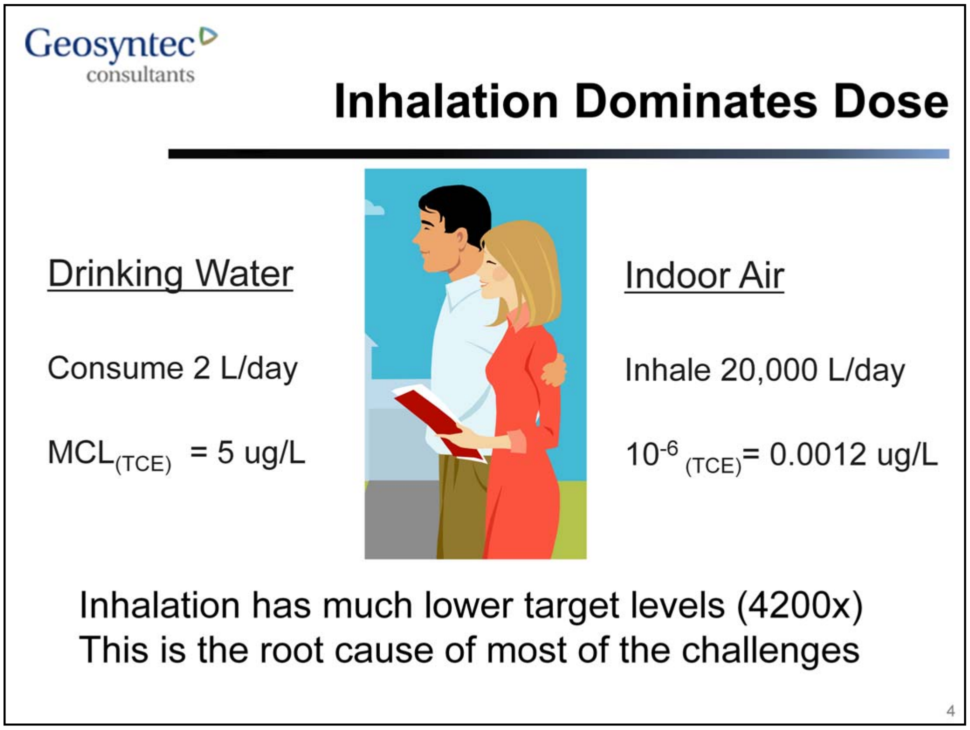
- What is Vapor Intrusion and why do we care? (Ettinger)
  - Historic and Regulatory Perspectives and Updates
  - Typical Assessment Approaches and Common Challenges
- Methods to Distinguish Background Sources (McHugh)
  - Significance
  - Compound-Specific Stable Isotope Analysis
  - Hapsite GC/MS
- Managing Spatial and Temporal Variability (McAlary)
  - Passive Sampling to Manage Temporal Variability
  - High Purge Volume Sampling to Manage Spatial Variability
- Navy Web-Based Tool (Caldwell)

Conceptual Model

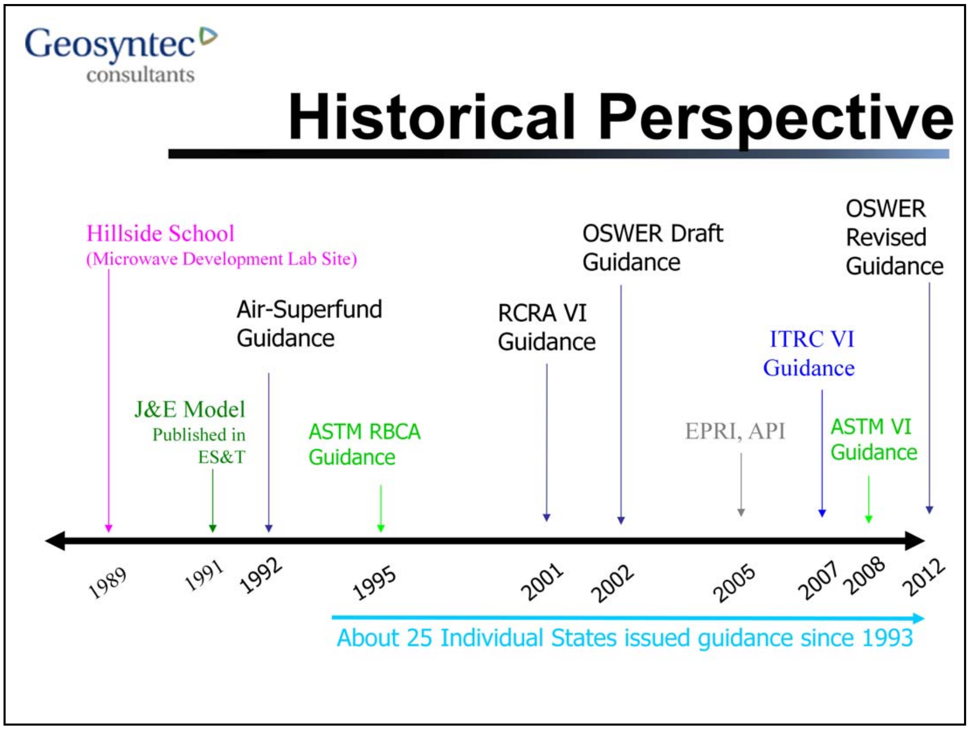


Conditions vary according to the source (NAPL or not, above or below the water table, proximity, mass, compounds), pathway (porous and well-drained, or heterogeneous) and receptor (building design, quality, ventilation, pressure and occupancy)

There are no “one-size fits all” solutions.



If you remember nothing else: we inhale a very large volume of air compared to any other media we are exposed to (water, soil. etc.). So the concentrations must be MUCH lower. This make everything more challenging.



This is nothing new, but there wasn't much real data until the late 1990s and prior assessments were based mostly on modeling

Since around 2000, there's been a lot more sampling and analysis, and mostly we have learned that VI can happen more than previously thought, but we still don't understand the root causes well enough to predict it with much confidence.

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Variability in Screening Levels

Table 3. Residential Screening Levels for Selected VOCs

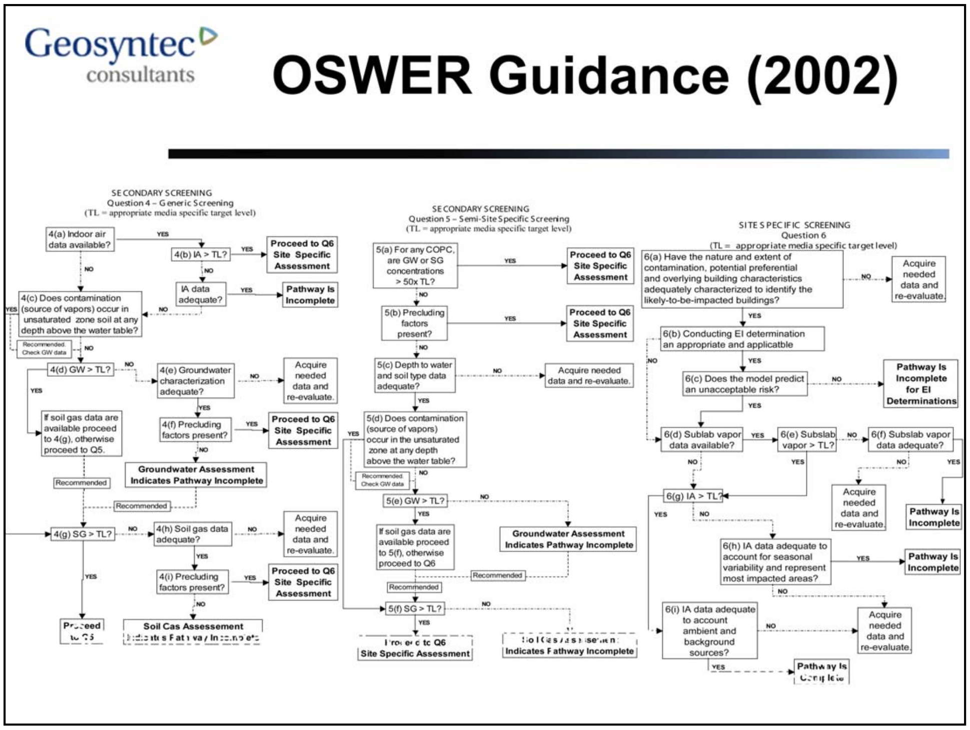
State	Benzene			TCE			PCE		
	Ground Water	Soil Gas	Indoor Air	Ground Water	Soil Gas	Indoor Air	Ground Water	Soil Gas	Indoor Air
Alaska	5	3.1	0.31	5	0.22	0.022	5	8.1	0.81
California	NA	36.2	0.084	NA	528	1.22	NA	180	0.41
Colorado	15	NA	0.23	5	NA	0.016	5	NA	0.31
Connecticut	130	2,490	3.3	27	752	1	340	3,798	5
Indiana	95-850	250 - 1400; 25 - 140[a]	2.5	4.6 - 700	120 - 2000; 2 - 200[a]	1.2 - 4.1	7.4 - 1100	320 - 5200; 32 – 520[a]	3.2 - 10
Louisiana	2,900	NA	12	10,000	NA	59	15,000	NA	110
Maine	NA	NA	10[b]	NA	NA	NA	NA	NA	NA
Massachusetts	2,000	NA	0.3	30	NA	1.37	50	NA	0.04
Michigan	5,600	150	2.9	15,000	700	14	25,000	2,100	42
Minnesota	NA	1.3-4.5	1.3-4.5	NA	NA	NA	NA	NA	20
New Hampshire	2,000	95	1.9	50	54	1.1	80	68	1.4
New Jersey	15	16	2	1	27	3	1	34	3
New York	NA	NA	NA	NA	NA	5	NA	NA	100
Ohio	14	31	3.1	--	122	12.2	11	81	8.1
Oklahoma	5	3.1	0.27	5	0.17	0.017	5	0.33	0.33
Oregon	160	NA	0.27	6.6	NA	0.018	78	NA	0.34
Pennsylvania	3,500	NA	2.7	14,000	NA	12	42,000	NA	36

Notes:
1. Units are µg/L for groundwater and µg/m³ for soil gas and indoor air
2. See individual state guidance documents for additional information, including limitations and exceptions
3. Trigger or action levels for mitigation based on indoor air concentrations may be higher than the screening levels shown.

[a] Second range of values shown is for sub-slab soil gas.
[b] Chronic exposure value.

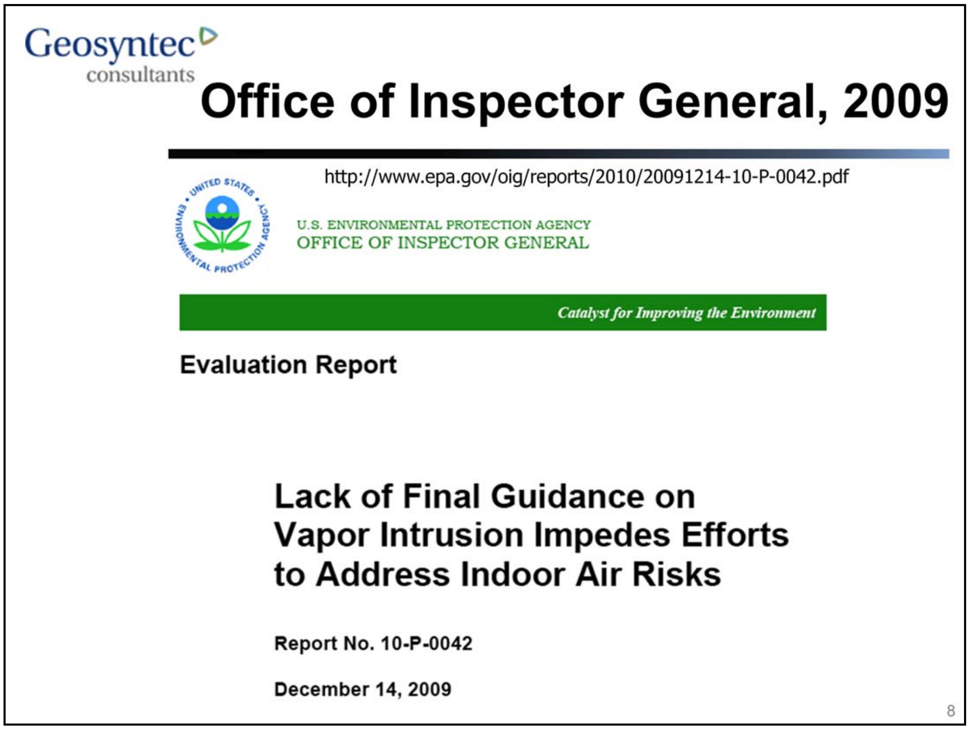
(Eklund, 2007)

Depending on the assumed risk level and attenuation factor, screening levels vary considerably between jurisdictions. This indicates the level of uncertainty among regulators.



CERCLA folks joined RCRA folks (Brownfields too, but not UST program) to provide draft Federal Guidance in 2002. Still has not been finalized almost a decade later, although a revision is promised for November 2012.

Public comments on the draft were over an inch thick.



OIG report has inspired OSWER to commit to a 2012 date for “final” guidance.

Several work products are either recently completed or nearly complete (next slides)

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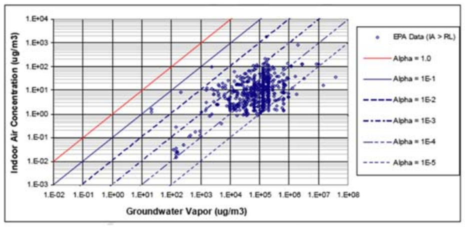
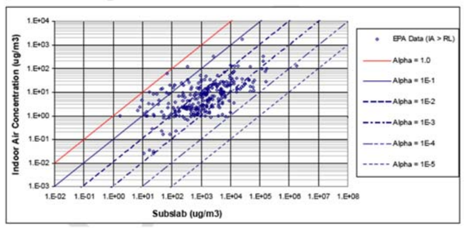
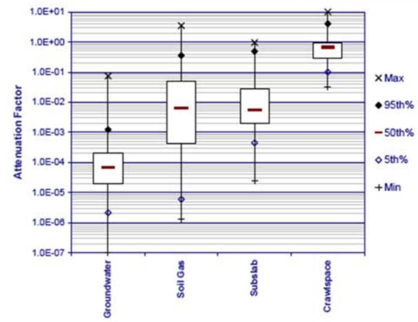
2008 USEPA VI Database







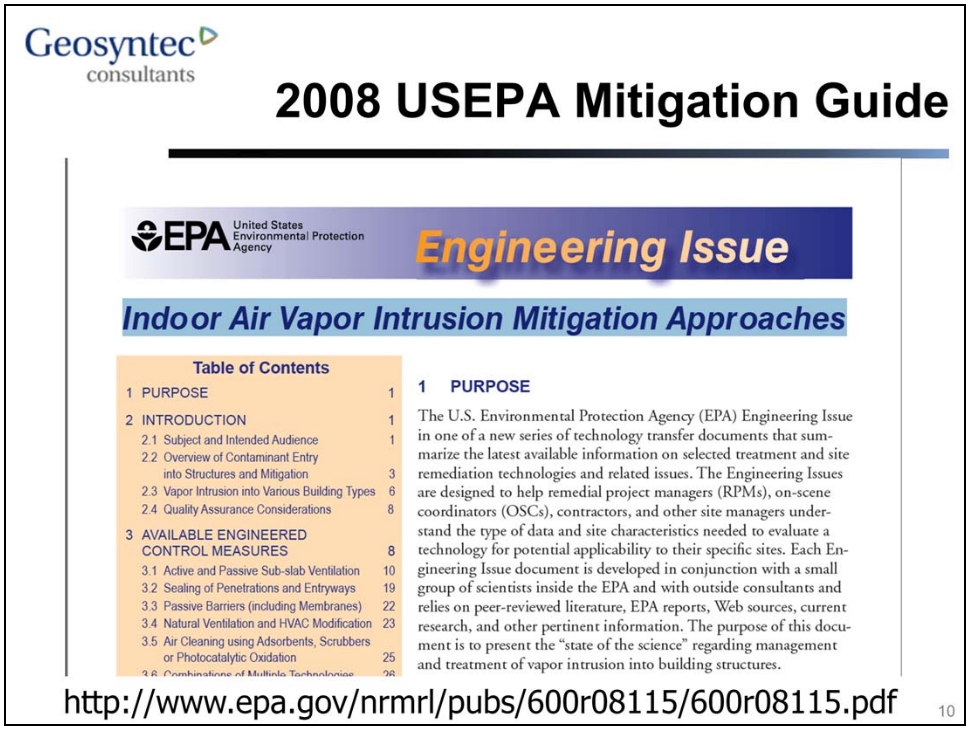
Statistic	Groundwater	Soil Gas	Subslab	Crawlspace
0%	1.0E-07	1.3E-06	2.5E-05	3.2E-02
5%	2.1E-06	5.9E-06	4.5E-04	1.0E-01
25%	1.9E-05	4.2E-04	1.9E-03	2.8E-01
50%	6.7E-05	6.3E-03	5.5E-03	6.5E-01
75%	2.0E-04	4.9E-02	2.8E-02	9.6E-01
95%	1.2E-03	3.5E-01	4.8E-01	4.0E+00
100%	7.4E-02	3.5E+00	9.6E-01	1.0E+01
Count All	910	218	991	110
Count IA > RL	877	169	876	110
Count IA < RL	33	49	115	0
No. of Sites	36	17	15	4

http://www.epa.gov/oswer/vaporintrusion/documents/oswer-vapor-intrusion-background-Report-062411.pdf

9

EPA has compiled a database of subsurface and indoor air data, filtered it to focus on higher concentrations (more clearly resolved signal compared to background) and reported order statistics for attenuation factors.

Most of the data is for chlorinated solvents in residential setting. This is not necessarily representative of Military facilities.



Conventional mitigation methods are summarized in this document. (later in this presentation, improvement/optimization options are discussed)

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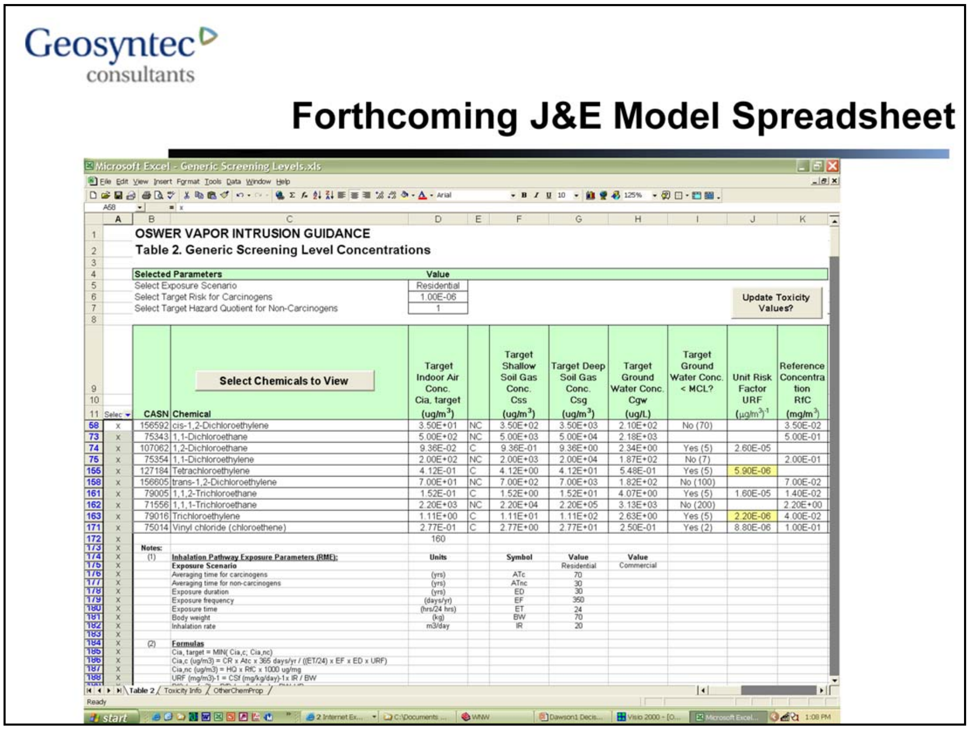
2011 USEPA Background Data

Compound	Number of Studies	Number of Samples	Range % Detect	Total % Detects	RL Range	Range of 50th%	N*	Range of 75th%	N	Range of 90th%	N	Range of 95th%	N
Benzene	14	2,615	31–100	91.1	0.05–1.6	<RL–4.7	14	1.9–7.0	9	5.2–15	11	9.9–29	5
Carbon tetrachloride	6	1248	1–100	53.5	0.15–1.3	<RL–0.68	6	<RL–0.72	3	<RL–0.94	5	<RL–1.1	2
Chloroform	11	2,278	9–100	68.5	0.02–2.4	<RL–2.4	11	<RL–3.4	7	<RL–6.2	9	4.1–7.5	5
Dichloroethane, 1,1-	2	682	1	1	0.08–0.25	<RL	2	<RL	2	<RL	2	<RL	2
Dichloroethane, 1,2-	7	1,432	1-25	13.8	0.08–2.0	<RL	7	<RL–0.08	6	<RL–0.4	7	<RL–0.2	4
Dichloroethylene, 1,1-	2	475	7-45	13	0.01–0.25	<RL	2	<RL-0.37	2	<RL-0.8	2	0.7	1
Dichloroethylene, cis 1,2-	3	875	1–9	4.9	0.25–2.0	<RL	3	<RL	3	<RL	3	<RL–1.2	3
Ethylbenzene	10	1,484	26–100	85.7	0.01–2.2	1–3.7	10	2–5.6	5	4.8–13	7	12–17	3
Methyl tert-butyl ether (MTBE)	4	502	9–70	54.5	0.05–1.8	0.025–3.5	4	0.03–11	4	0.03–41	4	71–72	2
Methylene chloride	8	1,724	29–100	79.1	0.12–3.5	0.68–61	8	1.0–8.2	6	2.0–510	8	2.9–45	4
Tetrachloroethylene	13	2,312	5–100	62.5	0.03–3.4	<RL–2.2	13	<RL–4.1	8	<RL–7	10	4.1–9.5	5
Toluene	12	2,065	86–100	96.4	0.03–1.9	4.8–24	12	12–41	7	25–77	9	79–144	4
Trichloro-1,2,2-trifluoroethane, 1,1,2- (Freon 113)	3	600	1–56	37.5	0.25–3.8	<RL–0.5	3	<RL–1.1	3	<RL–1.8	3	<RL–3.4	2
Trichloroethane, 1,1,1-	9	1,877	4–100	53.4	0.12–2.7	<RL–5.9	9	<RL–7	7	<RL–68	8	3.4–28	5
Trichloroethylene	14	2503	1–100	42.6	0.02–2.7	<RL–1.1	14	<RL–1.2	9	<RL–2.1	11	0.56–3.3	5
Vinyl chloride	4	1484	0–25	9.2	0.01–0.25	<RL	4	<RL	4	<RL–0.04	4	<RL–0.09	4
Xylene, m/p-	10	1,920	52–100	92.9	0.4–2.2	1.5–14	10	4.6–21	7	12–56	9	21–63.5	4
Xylene, o-	12	2,004	31–100	89.0	0.11–2.2	1.1–3.6	12	2.4–6.2	7	5.5–16	9	13–20	4

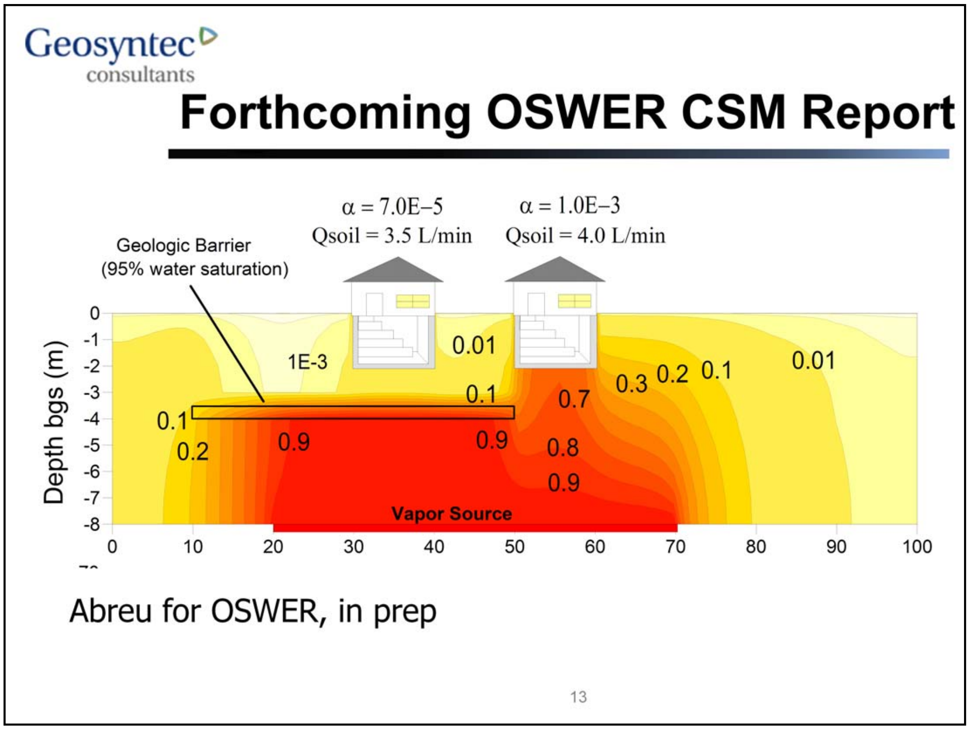
https://iavi.rti.org/OtherDocuments.cfm?PageID=documentDetails&AttachID=369

11

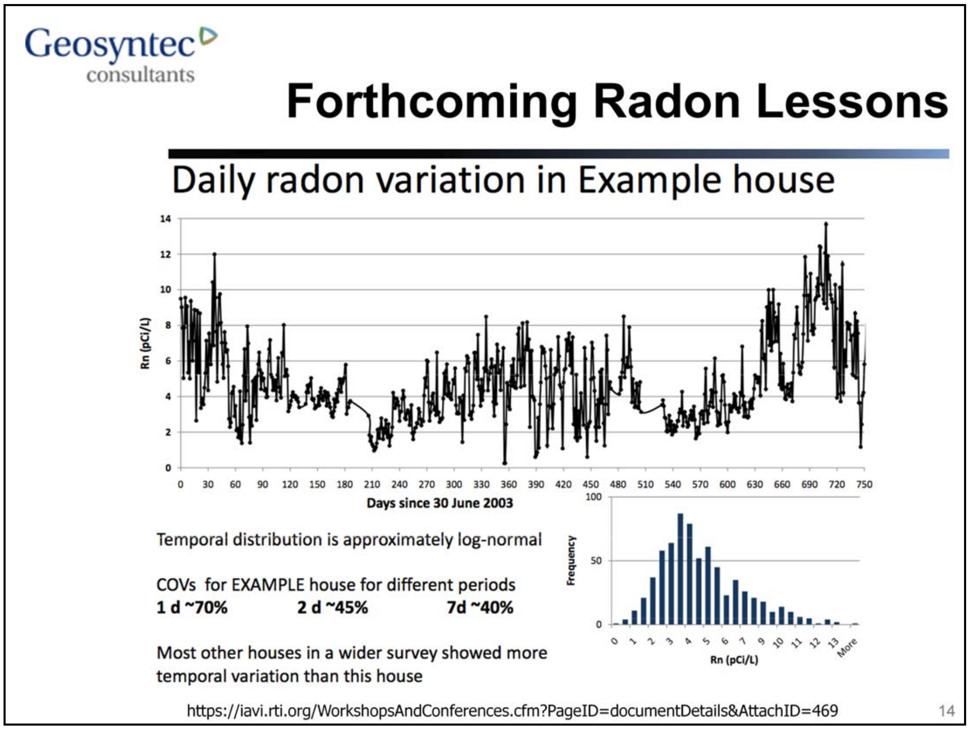
EPA compiled indoor air quality data to help establish expectations for background concentrations. Several compounds have background concentrations that are within or above the typical screening levels (benzene, carbon tetrachloride, chloroform, tetrachloroethene, 1,2-dichloroethane).



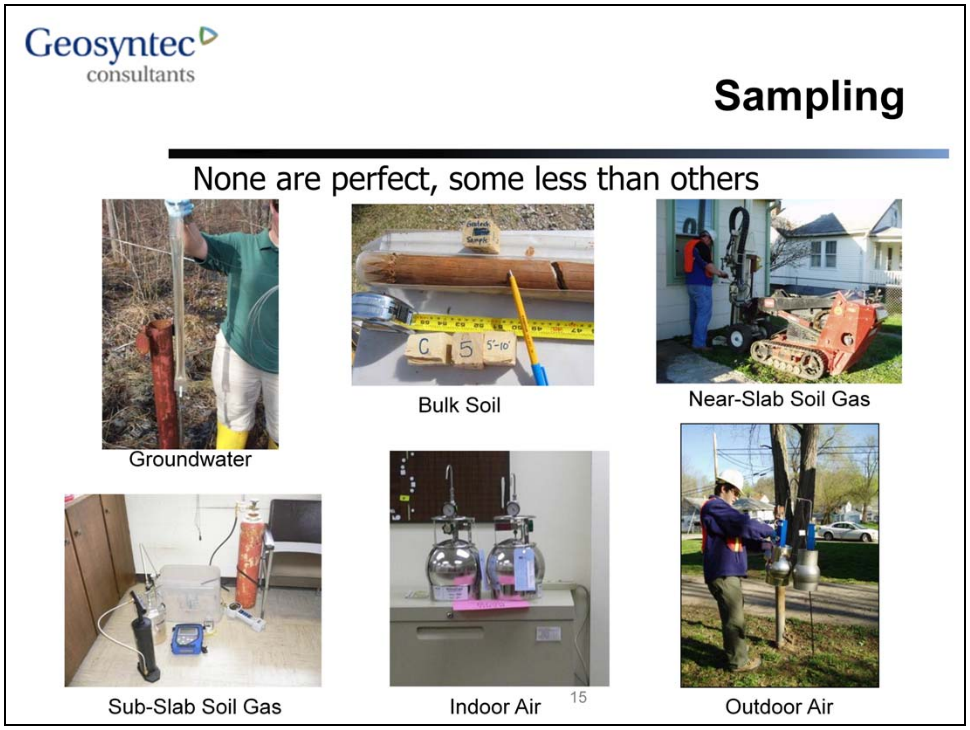
The Johnson and Ettinger (1991) Model was coded into a spreadsheet many years ago, and a recent update was made to incorporate the recommendations in the Johnson (2002) Critical Parameters paper.



Lilian Abreu wrote a 3-D model for her PhD thesis, and EPA commissioned her to develop a range of simulations to help formulate expectations for subsurface vapor distributions and the effect of a range of processes and mechanisms.



EPA commissioned Dan Steck (a Radon expert) to prepare a report on Lessons learned in the radon field that might help us all manage vapor intrusion for VOCs.



Every sample has some potential sources of bias and variability. Some more than others.

Samples specific to VI assessment will be discussed next.

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Summa Canister and TO-15

Complex procedure, requires special training ($)

Must be cleaned and certified ($)

Bulky ($) to ship and handle

Maximum ~24 hour samples

Costly: $150 to $300+/sample, depending on reporting limit, can rental, flow controller rental, certification level, reporting details

Not useful for analytes heavier than naphthalene (poor recovery)

This is the most common method for indoor, outdoor and soil vapor samples for VOCs for VI assessment. The data quality is usually pretty good, but there are several limitations.

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Automatic Thermal Desorption Tubes / TO-17

Typically customized for each application – high level of training required

Allows longer than 24-hour samples, but the pump must run reliably throughout the sampling period

Capable of a larger list of analytes

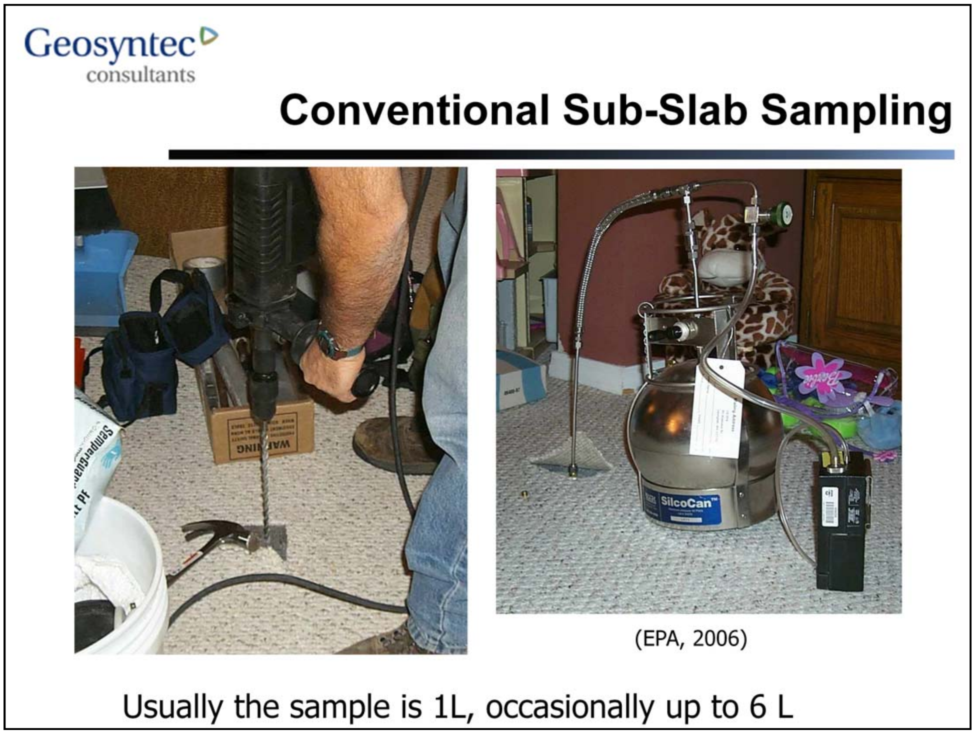
Typically <$200/sample, depending on analyte list

Potential for breakthrough and competition in high concentration zones

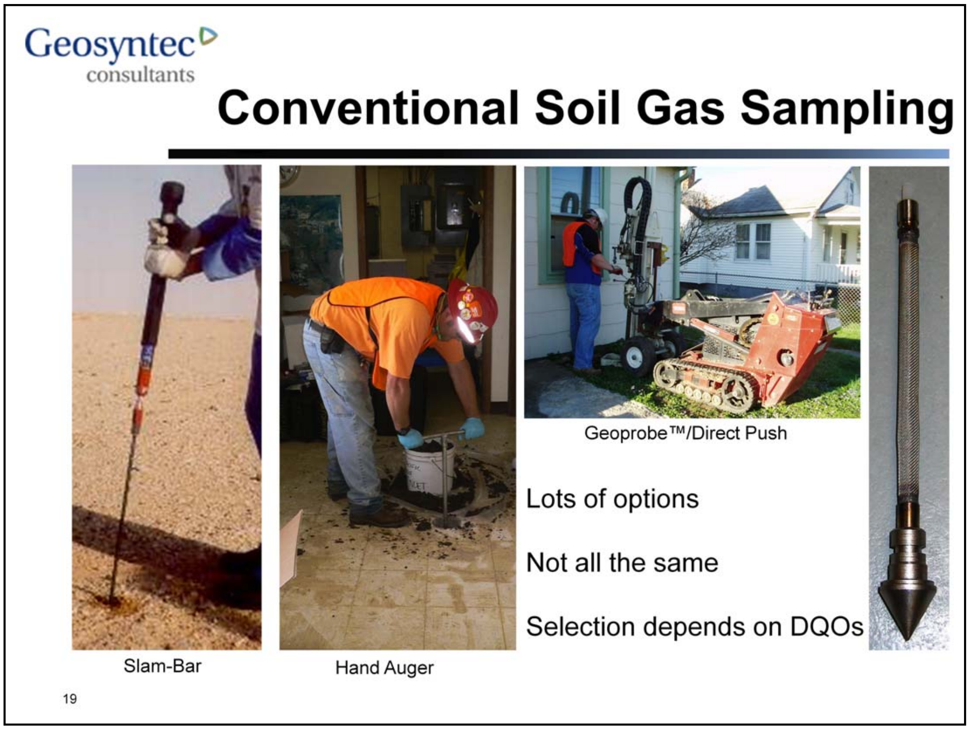
Challenging to get sufficient sample volume in low permeability soils

17

This method is most common for industrial hygiene, sick building assessment and much more commonly used in Europe. Still not without limitations.



Subslab samples are mostly all collected by this method. Really only tells you what the concentration is at that specific location, and if the building breathes both ways 9most do), you may collect a sample with an unknown amount of indoor air. It is also fairly common for the probes to leak.



There are lots of ways to collect soil gas samples. The method needs to be commensurate with the data quality objectives.

Matrix for Guidance on Selection of Soil Gas Sampling Methods with Compatible DQO Results

(GeoProbe Systems, Technical Bulletin No. MK3098, May 2006)

Downhole Sampling System		Sample Collection Method			
		Syringe	Tedlar Bag	Glass Bulbs	Summa Canister
	Increase Quality				
Direct Sampling		Low/Low			Low/High
PRT System					
Implants					
Gas Wells		High/Low			High/High

Geoprobe wrote a good guide to soil gas sampling.

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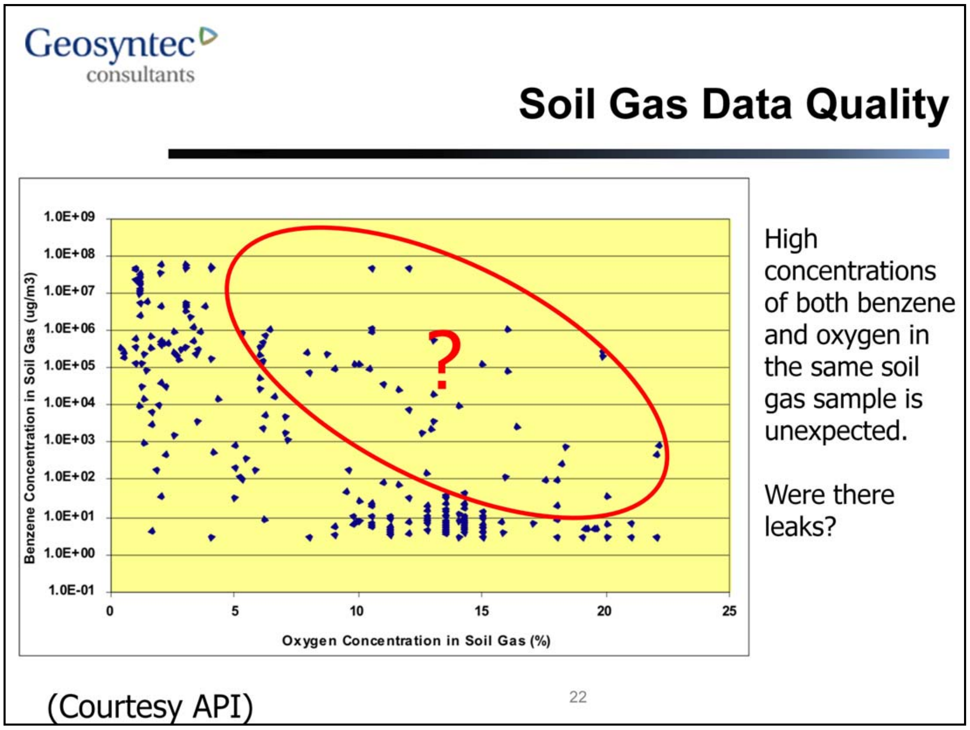
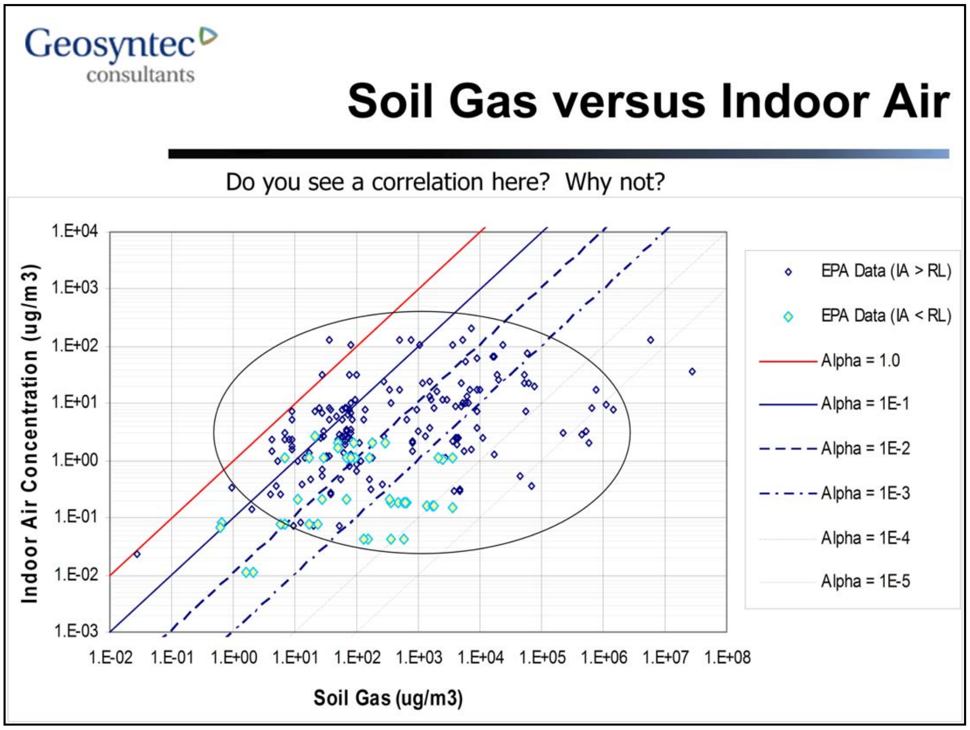
QA/QC Considerations

- Probe Design
- Materials & Seals
- Shut-in Test
- Helium Tracer Test
- Purging rate, volume, vacuum and permeability
- Field Screening
- TO-15, TO-17, TO10A, etc.

Collecting reliable soil gas samples is at least as much work as groundwater sampling. Although there are few guidance documents that spell out all the QA/QC steps in sufficient detail to avoid the common biases (leaks, equipment blank contamination, adsorptiive losses).



This is “typical” soil gas data. Where oxygen concentrations are high, benzene degrades very rapidly, so high concentrations of both is not likely. However, a sample with a leak can have both.



Data variability limits our ability to predict indoor air concentrations from subsurface concentrations. Regulators respond by asking for a lot of data and setting very cautious screening levels, both of which are costly.

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Pros and Cons of Different Media

Media Investigated	Evaluation Method	Principal Issues
Groundwater	Attenuation factor or modeling based on site-specific conditions used to predict indoor air concentration	Imprecision of attenuation factors or modeling requires very conservative assumptions. Henry's law must be corrected for the aquifer temperature.
Soil gas	Attenuation factor or modeling based on site-specific conditions used to predict indoor air concentration	Fewer pathway assumptions required than groundwater, but the accuracy and representativeness of measurements may be an issue
Subslab soil gas	Attenuation factor estimated or measured (e.g., using radon) to predict indoor air concentration	Fewest pathway assumptions required, but intrusive and attenuation factors may still be conservative for many buildings.
Indoor air	Indoor air concentrations directly measured	Intrusive, and background sources may confound data interpretation. Seasonal variations are also an issue.

http://www.itrcweb.org/Documents/VI-1.pdf

24

Each of the sample types has certain benefits, and certain limitations. They are not all the same. This is why it is often best to make decisions using more than one line of evidence, there's less risk of making a bad decision.

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Decision Matrices

Decision Flow Chart for Vapor Intrusion Pathway

Remediation Decision Matrix - Stage 8

New Jersey DEP, 2005

		Indoor Air Concentrations (for COCs)	
		< IASL	>IASL
Sub-Slab Soil Gas Concentrations (for COCs)	<SGSL	No Action	No Action * (if no other subsurface source)
	>SGSL to 10X SGSL	No Action or Monitor	Investigate further or Mitigate
	>10X SGSL	Monitor or Mitigate	Mitigate

New York DOH, 2006

Soil Vapor/Indoor Air Matrix 1
October 2006

	INDOOR AIR CONCENTRATION of COMPOUND (mcg/m³)			
SUB-SLAB VAPOR CONCENTRATION of COMPOUND (mcg/m³)	< 0.25	0.25 to < 1	1 to < 5.0	5.0 and above
< 5	1. No further action	2. Take reasonable and practical actions to identify source(s) and reduce exposures	3. Take reasonable and practical actions to identify source(s) and reduce exposures	4. Take reasonable and practical actions to identify source(s) and reduce exposures
5 to < 50	5. No further action	6. MONITOR	7. MONITOR	8. MITIGATE
50 to < 250	9. MONITOR	10. MONITOR / MITIGATE	11. MITIGATE	12. MITIGATE
250 and above	13. MITIGATE	14. MITIGATE	15. MITIGATE	16. MITIGATE

25

Where concentrations are high inside and below a building, there’s a stronger indication that vapor intrusion is occurring. If concentrations are low in either media, then something else may be going on.

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Background Indoor Air Quality

Risk-based target concentrations below "background" levels

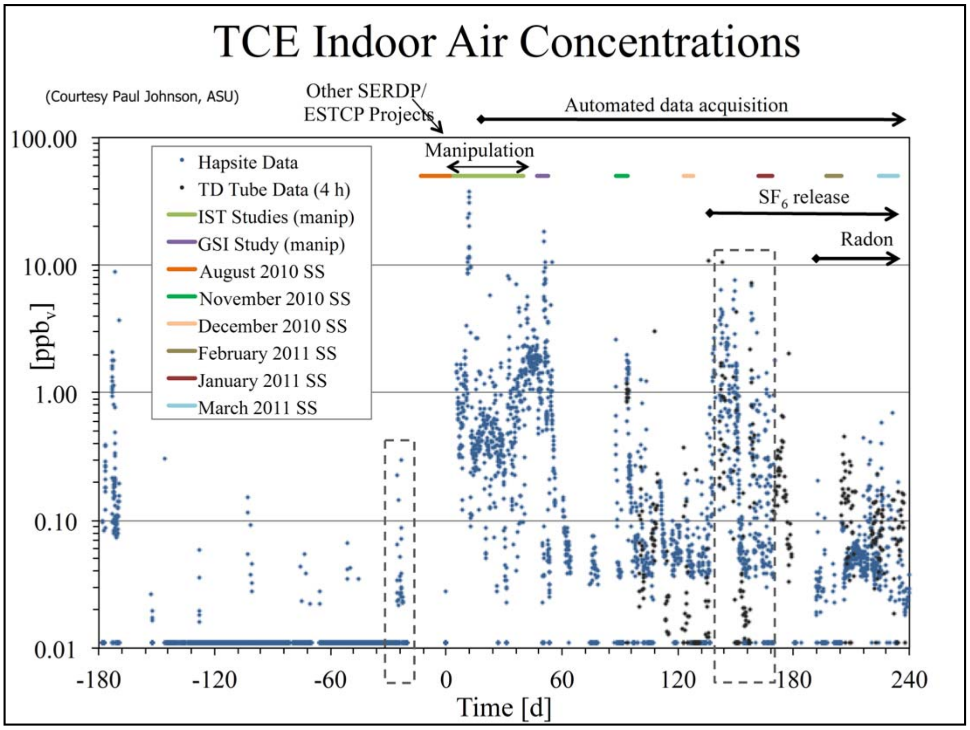
Compound	1E-6 Risk Level for Indoor Air (ug/m^3)	50^{th} %-ile	95^{th} %-ile
PCE	**0.41**	0.9	7.4
CTET	0.41	0.5	1.1
CF	0.11	**1.1**	**6.0**
Benzene	0.31	**2.5**	**17**
12DCA	0.094	**0.1**	**0.8**
Methylene Chloride	**5.2**	1.1	20
TCE	0.25	0.3	1.6

The good news is: 1) it's only a handful of compounds
2) at 1E-5 risk level, its seldom a problem

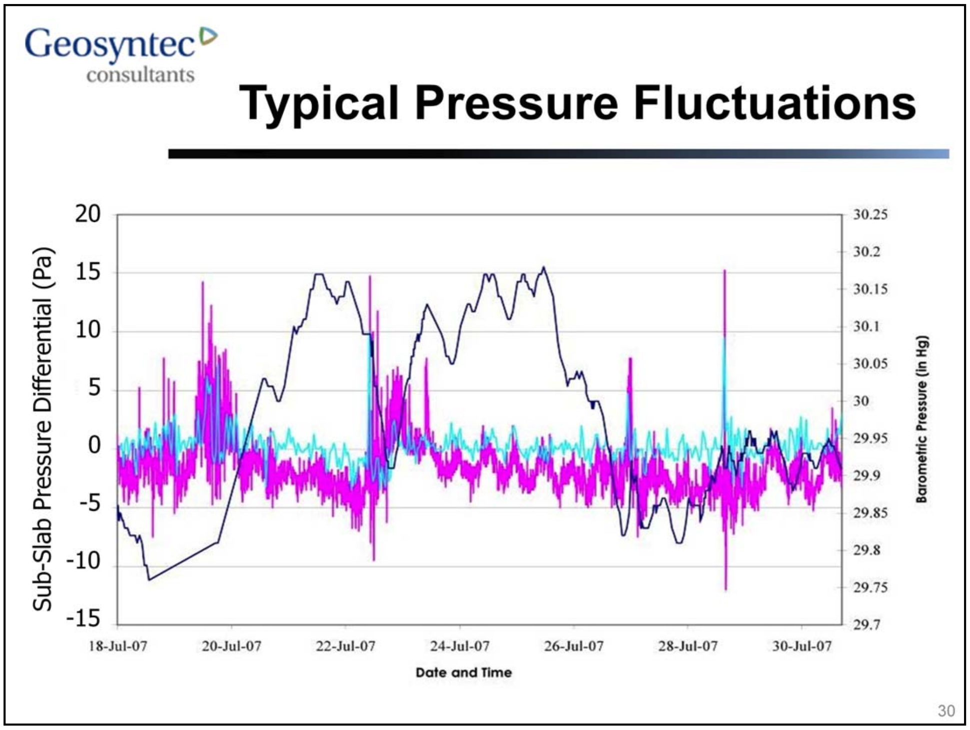
This is one of the most common challenges. But it becomes much less of a challenge if the acceptable risk level is 1E-5 instead of 1E-6.

Building almost always have internal sources of VOCs. If you collect indoor air or sub-slab samples, you will very often detect them.

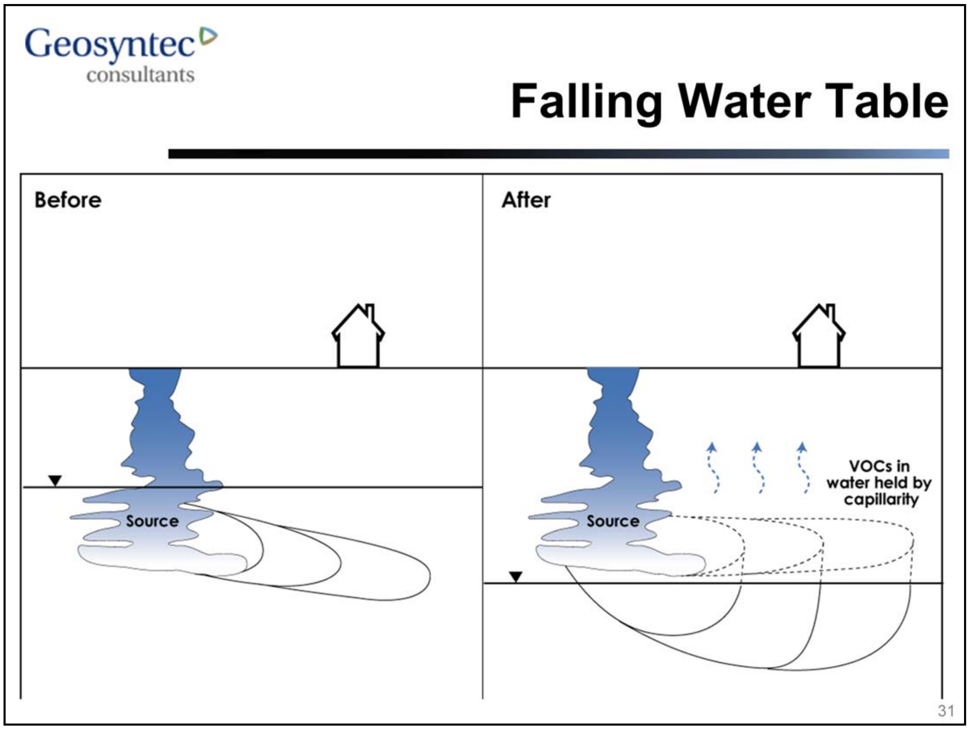
Historic uses can cause contamination of building materials that emit VOCs for a very long time.



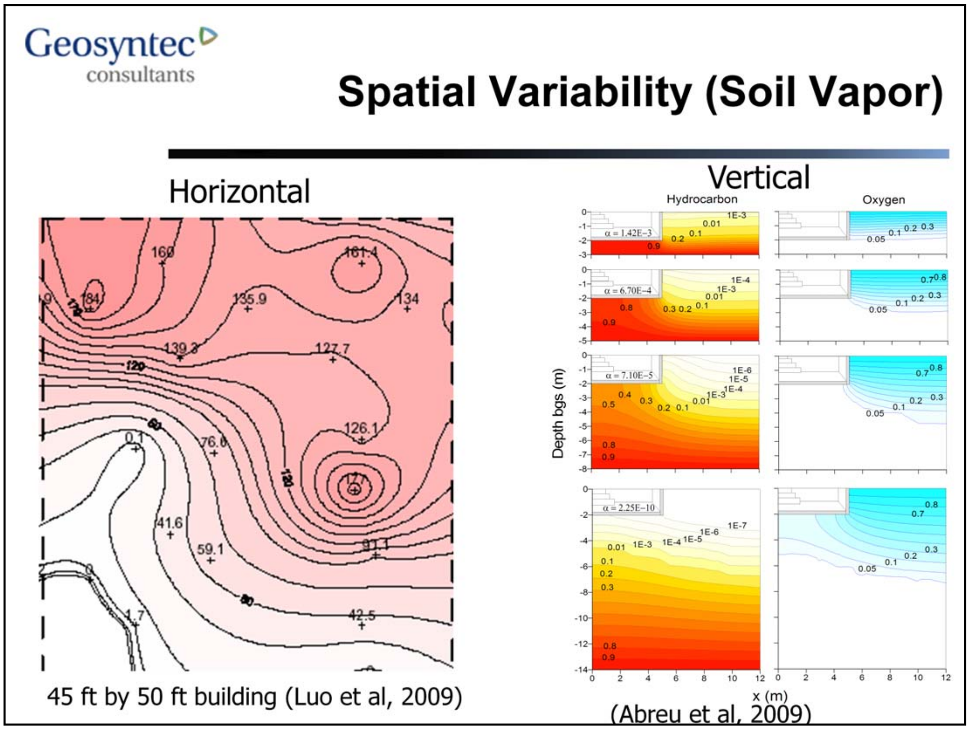
If samples are collected over a shorter time period, the variability is even greater. This plot shows data collected by Arizona State university at the Layton house as part of their SERDP research project. There's seasonal variability in addition to daily variability.



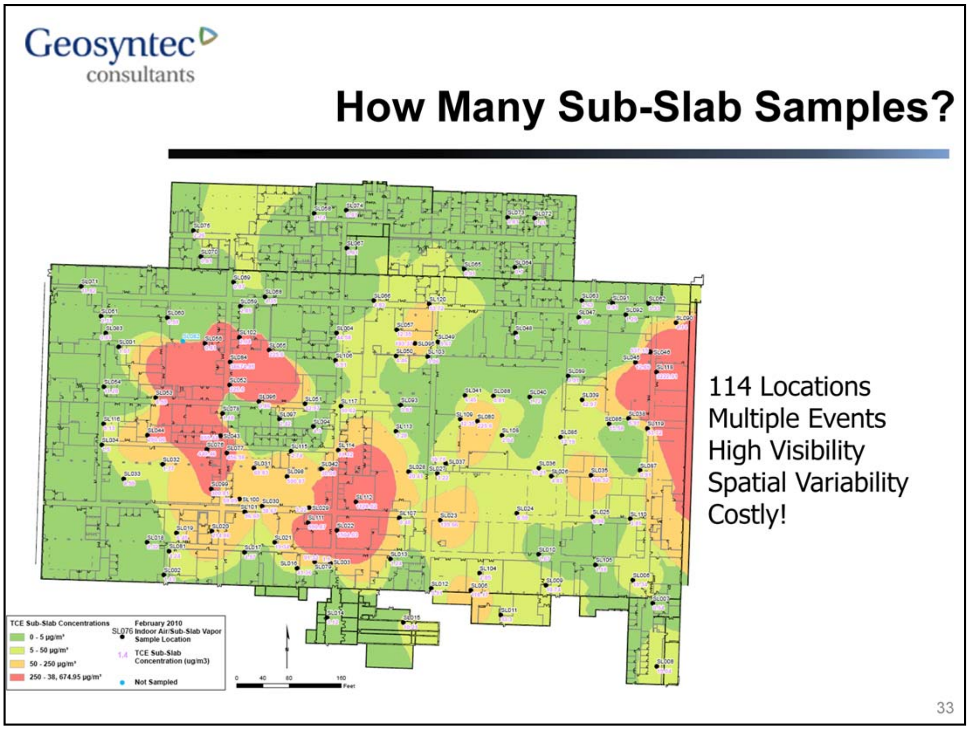
Build pressure fluctuates and varies with wind-speed, barometric pressure and temperature. Sometimes, the pressure can be net-positive or negative, and sometimes it just fluctuates. This contributed to vapor entry, but also indoor air sources can migrate to the subsurface.



Seasonal (or longer-term) changes in the water table can cause changes in the soil vapor concentrations.



Variability is not just temporal, spatial variability can be very significant too. These plots show vertical and horizontal variability.



In large buildings (much of the military building stock), how many samples is enough?

When you get inot a large sampling program, the logistics and costs can really add up.

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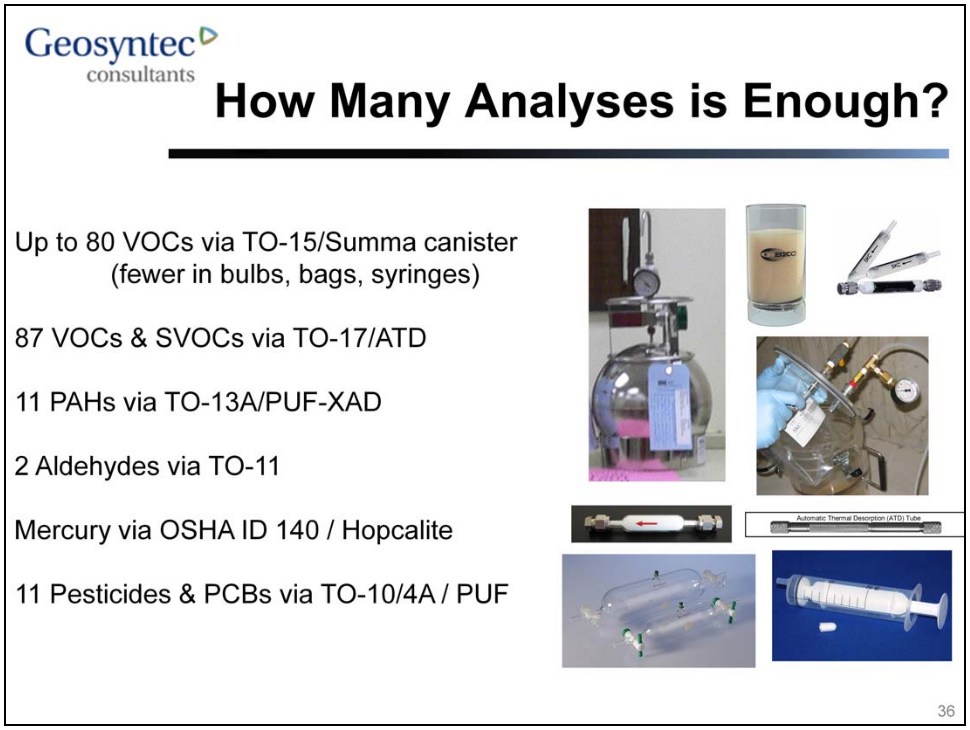
~115 Compounds of Concern

Acenaphthene
Acetaldehyde
Acetone
Acetonitrile
Acetophenone
Acrolein
Acrylonitrile
Aldrin
alpha-HCH (alpha-BCH)
Benzaldehyde
Benzene
Benzo(b)fluoranthene
Benzylchloride
beta-Chloronaphthale
Biphenyl
Bis(2-chloroethyl)ether
Bis(2-chloroisopropyl)ether
Bis(chloromethyl)ether
Bromodichloromethane
Bromoform
1,3-Butadiene
Carbon disulfide
Carbon tetrachloride
Chlordane
2-Chloro-1,3-butadiene (chloroprene)
Chlorobenzene
1-Chlorobutane
Chlorodibromomethane
Chlorodifluoromethane
Chloroethane (ethyl chloride)
Chloroform
2-Chlorophenol
2-Chloropropane
Chrysene
cis-1,2-Dichloroethylene
Crotonaldehyde (2-butenal)
Cumene
DDE
Dibenzofuran
1,2-Dibromo-3-chloropropane
1,2-Dibromoethane (ethylene dibromide)
1,3-Dichlorobenzene
1,2-Dichlorobenzene
1,4-Dichlorobenzene
Dichlorodifluoromethane
1,1-Dichloroethane
1,2-Dichloroethane
1,1-Dichloroethylene
1,2-Dichloropropane
1,3-Dichloropropene
Dieldrin
Endosulfan
Epichlorohydrin
Ethyl ether
Ethylacetate
Ethylbenzene
Ethylene oxide
Ethylmethacrylate
Fluorene
Furan
gamma-HCH (Lindane)
Heptachlor
Hexachloro-1,3-butadiene
Hexachlorobenzene
Hexachlorocyclopentadiene
Hexachloroethane
Hexane
Hydrogen cyanide
Isobutanol
Mercury (elemental)
Methylacrylonitrile
Methoxychlor
Methyl acetate
Methyl acrylate
Methyl bromide
Methyl chloride (chloromethane)
Methylcyclohexane
Methylene bromide
Methylene chloride
Methylethylketone (2-butanone)
Methylisobutylketone
Methylmethacrylate
2-Methylnaphthalene
MTBE
m-Xylene
Naphthalene
n-Butylbenzene
Nitrobenzene
2-Nitropropane
N-Nitroso-di-n-butlyamine
n-Propylbenzene
o-Nitrotoluene
o-Xylene
p-Xylene
Polychlorinated biphenyls (PCBs)
Pyrene
sec-Butlybenzene
Styrene
tert-Butylbenzene
1,1,1,2-Tetrachloroethane
1,1,2,2-Tetrachloroethane
Tetrachloroethylene (perchloroethylene)
Toluene
trans-1,2-Dichloroethylene
1,1,2-Trichloro-1,2,2-trifluoroethane
1,2,4-Trichlorobenzene
1,1,2-Trichloroethane
1,1,1-Trichloroethane
Trichloroethylene
Trichlorofluoromethane
1,2,3-Trichloropropane
1,2,4-Trimethylbenzene
1,3,5-Trimethylbenzene
Vinyl acetate
Vinyl chloride (chloroethene)

35

Most people only look at VOCs (e.g. EPA Method TO-15), but that leaves out more than half the compounds that could potentially be a concern.



If you really want to analyze for all the compounds that could be a concern, you'd have to do several different analysis, and there would still be a dozen or so compounds left out.

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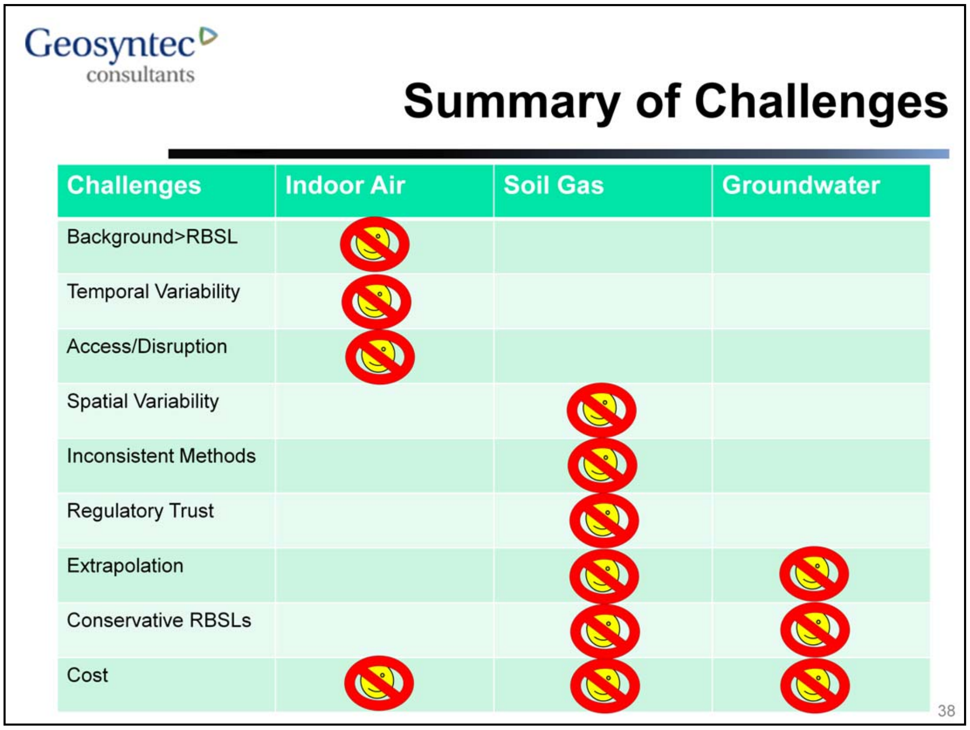
Cost Factors

- **Scope: All** compounds in **all** media at **all** buildings on **multiple** occasions with specified frequency?
- Risks assessed on small data sets (95th UCL or max = mean)
  - Variability is the enemy
- Conservative screening levels and elevated background
  - Lots of false positive outcomes
- Guilty until proven innocent
- Lack of stakeholder confidence
- Media, legal, public interests and other third parties

37

Lots of these common features make assessing vapor intrusion costly.



This should be just a recap. Note that the limitations are not the same for all lines of evidence, which is a key reason to use more than one.

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Questions/Comments?

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