Indoor and Soil Gas Concentration Distributions: The Reality and What That Means for Site Assessment Strategies

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U.S. EPA "State of VI Science" Workshop

Reliable Ongoing Human Exposure Protection to Vapor Intrusion Using Cleanup as the Simplest Approach

Disclaimer: The views expressed in this presentation are those of the author and do not necessarily represent the views or policies of U.S. EPA.

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Presentation archived at https://iavi.rti.org/

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Disclaimer

- This presentation represents the personal opinion of the authors and does not necessarily represent the policy of the organizations with which they are associated.
- New science-based ideas are presented here to stimulate discussion and to move the field forward.

Key Concepts to Be Presented

- Definitions related to acceptable concentrations – reviewing EPA concepts and state implementation
- How effective your sampling will be is dependent on the shape and range of the real, underlying distribution.
- Because of temporal variability most typical current sampling strategies have a high risk of false negatives in indoor air.
- Subslab and deep soil gas are somewhat less variable
- Therefore, concurrence of multiple lines of evidence remains an important concept
- Indicator and tracer (I&T) based sampling; as well as longer duration samples can improve performance of sampling strategies.

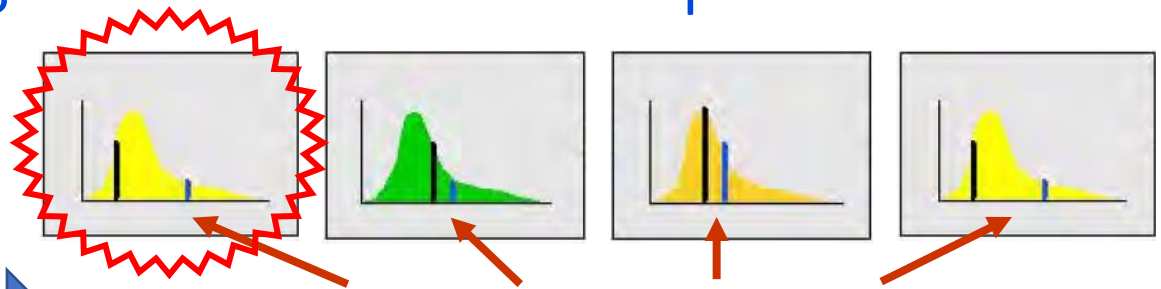
Goals/Definitions from EPA 2015 VI Guide

- Guide requires evaluation of chronic effects for both cancer and noncancer and short duration non-cancer effects where appropriate.
- "*EPA recommends basing the decision about whether to undertake response action for vapor intrusion on a consideration of a reasonable maximum exposure*"
- **reasonable maximum exposure (RME) =**

A semi-quantitative term, referring to the lower portion of the high end of the exposure distribution; conceptually, above the 90th percentile exposure but less than the 98th percentile exposure.

- The **RME** as defined by USEPA (1989) Risk Assessment Guidance for Superfund (RAGS) is a combination of central tendency and high-end values for concentration, exposure time, frequency and duration.

Estimating the Inhalation Exposure Concentration (EC)



USEPA (2009) RAGS Part F, Supplemental Guidance for Inhalation Risk Assessment

$$EC = (CA \times ET \times EF \times ED)/AT$$

EC ($\mu g/m^3$) = exposure concentration;
CA ($\mu g/m^3$) = contaminant concentration in air;
ET (hours/day) = exposure time;
EF (days/year) = exposure frequency;
ED (years) = exposure duration; and
AT (ED in years x 365 days/year x 24 hours/day) = averaging time

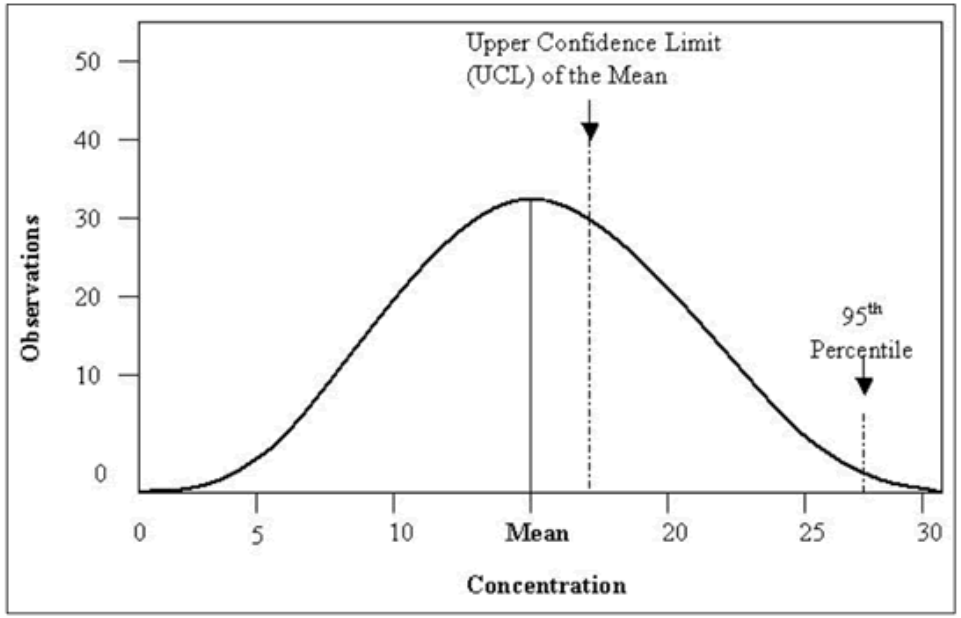
$$\text{Cancer Risk} = EC \times \text{Toxicity Value}$$

$$\text{Noncancer Hazard} = \frac{EC}{\text{Toxicity Value}}$$

Risk Management (USEPA, 1991)
- Cancer: 1E-06 to 1E-04
- Non-cancer hazard: 1

- RME needs to account for:
  - Uncertainty in chemical concentration (CA); and
  - Variability in exposure parameters (ET, EF, and ED)
- Chemical concentration:
  - Use estimate of arithmetic average (e.g., 95UCL)
  - Account for time and space (exposure area)
  - 95UCL can be > max with limited data or extreme variability

USEPA (1992) Supplemental Guidance to RAGS: Calculating the Concentration Term



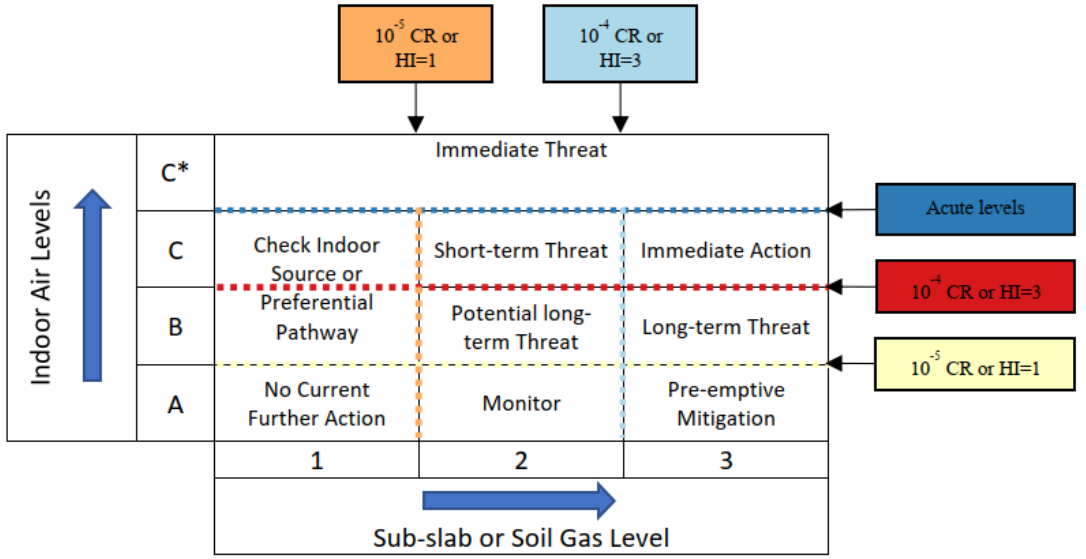
Some States Emphasize Soil Gas in Decisions Over Indoor Air

- **MI:** *"because of the variation and potential for indoor air samples to be influenced by ambient air sources, decisions regarding potential risk and completion of response actions must be weighted toward the sub-slab soil gas sampling results".*
- **WI:** *"Response actions for vapor intrusion are required primarily based on sub-slab vapor concentrations, but the timing for vapor mitigation can take into account other factors,." "If the results from sub-slab vapor samples are at or over vapor risk screening levels, then interruption or mitigation of the vapor exposure pathway is required per Wis. Admin § NR 726.05."*
- **TN**: *"collect soil gas data and use it as the primary line of evidence to assess the VI pathway ". "It is unrealistic to expect a building slab to remain static over time, and it is impractical to control or monitor the integrity of a slab for decades, as is sometimes proposed. Therefore, current favorable indoor air monitoring results cannot be extrapolated into the future with any certainty"*
- **IL:** *"Indoor air samples are highly susceptible to bias from occupant sources…. Sample collection is also invasive, requiring site evaluators to obtain access to indoor space. For these reasons, TACO does not contain a table of indoor air remediation objectives and the use of indoor air data to demonstrate compliance is limited to a Tier 3 evaluation"*

Many States and Regions Use a Soil Gas and Indoor Air Matrix

- Many state use soil gas vs. indoor air matrix-type approaches to evaluate MLE
- A conservative subslab concentration requires mitigation regardless of any VOC indoor air data.
- EPA regions 2, 4, 5 and 7 also use matrix approaches.

Table 8-1. Risk-Based Decision Matrix for VI Sites



Notes:

CR Carcinogenic risk
HI Hazard Index

Figure from US EPA Region 5, Superfund and Emergency Management Division, Vapor Intrusion Handbook, March 2020

Region V Matrix – Applied to TCE

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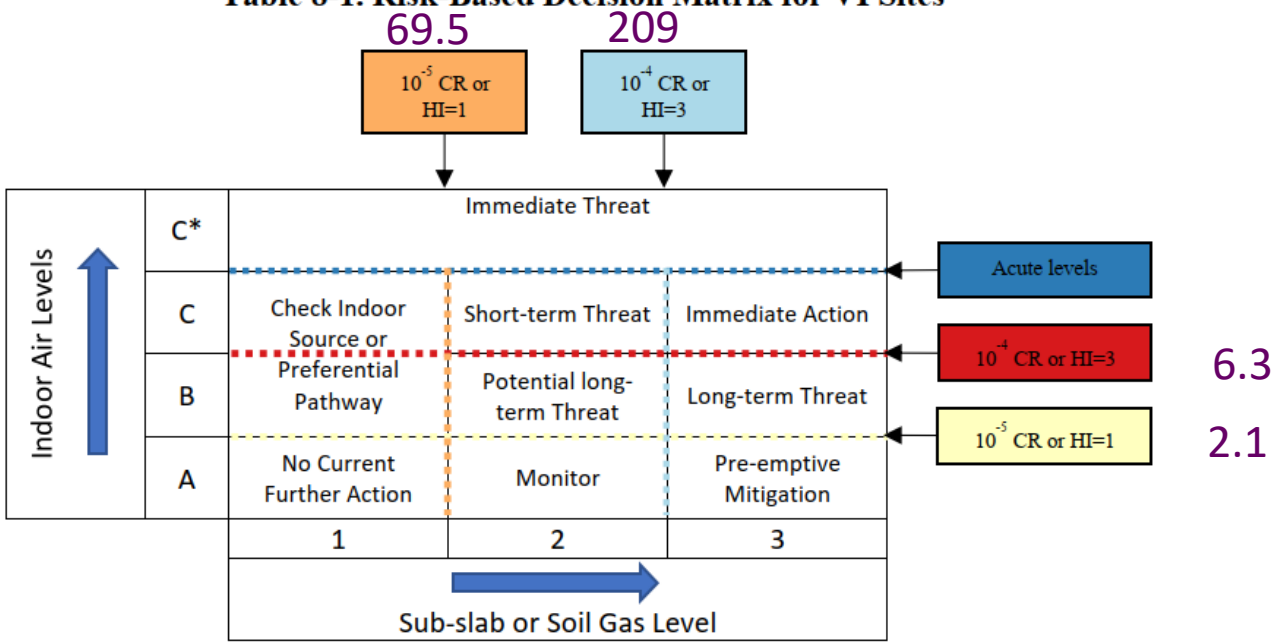

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Figures from US EPA Region 5, Superfund and Emergency Management Division, Vapor Intrusion Handbook, March 2020

TCE Concentrations from VISL Calculator as of 10/3/24 for Residential in µg/m^3

Table 8-2. Decisions Associated with Vapor Intrusion Categories

Air Results			
Category	Indoor	Sub-slab	Decision
C1	>Acute or RML	<RSL	Likely indoor source; warn homeowner of hazard
C2	>Acute or RML	>RSL, <RML	Concern about acute exposure; plan for remediation within weeks
C3	>Acute or RML	>Acute or RML	Concern about acute exposure; plan for remediation ASAP; consider APUs
C3*	>1% LEL	>10% LEL	Immediate action; consider relocation depending on conditions
B1	>RSL, <RML	<RSL	Check potential for indoor source; notify homeowner of potential concern
B2	>RSL, <RML	>RSL, <RML	Concern about long term-exposure; develop strategy for inclusion in site
B3	>RSL, <RML	>Acute or RML	Concern about long-term exposure; more rapid remediation plan
A1	<RSL	<RSL	No further action at this time, pending new data
A2	<RSL	>RSL, <RML	Continue monitoring subsurface conditions
A3	<RSL	>Acute or RML	Consider pre-emptive mitigation to prevent future indoor air impact

Region V Matrix – Applied to PCE

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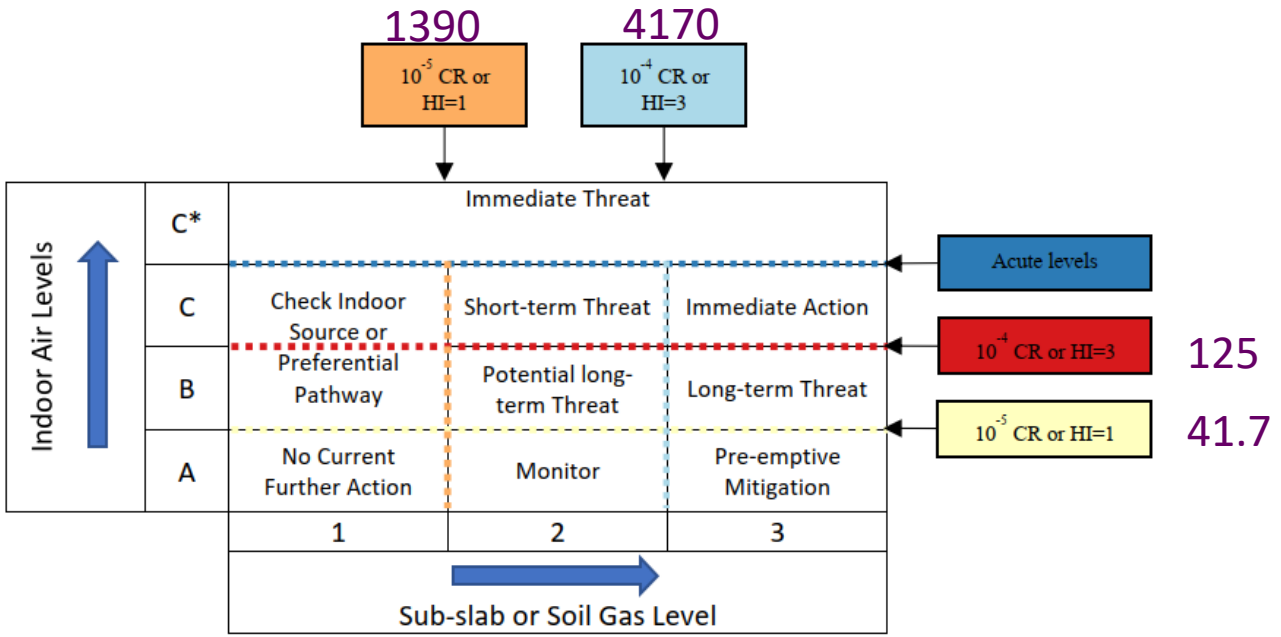

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PCE Concentrations from VISL Calculator as of 10/3/24 in µg/m^3

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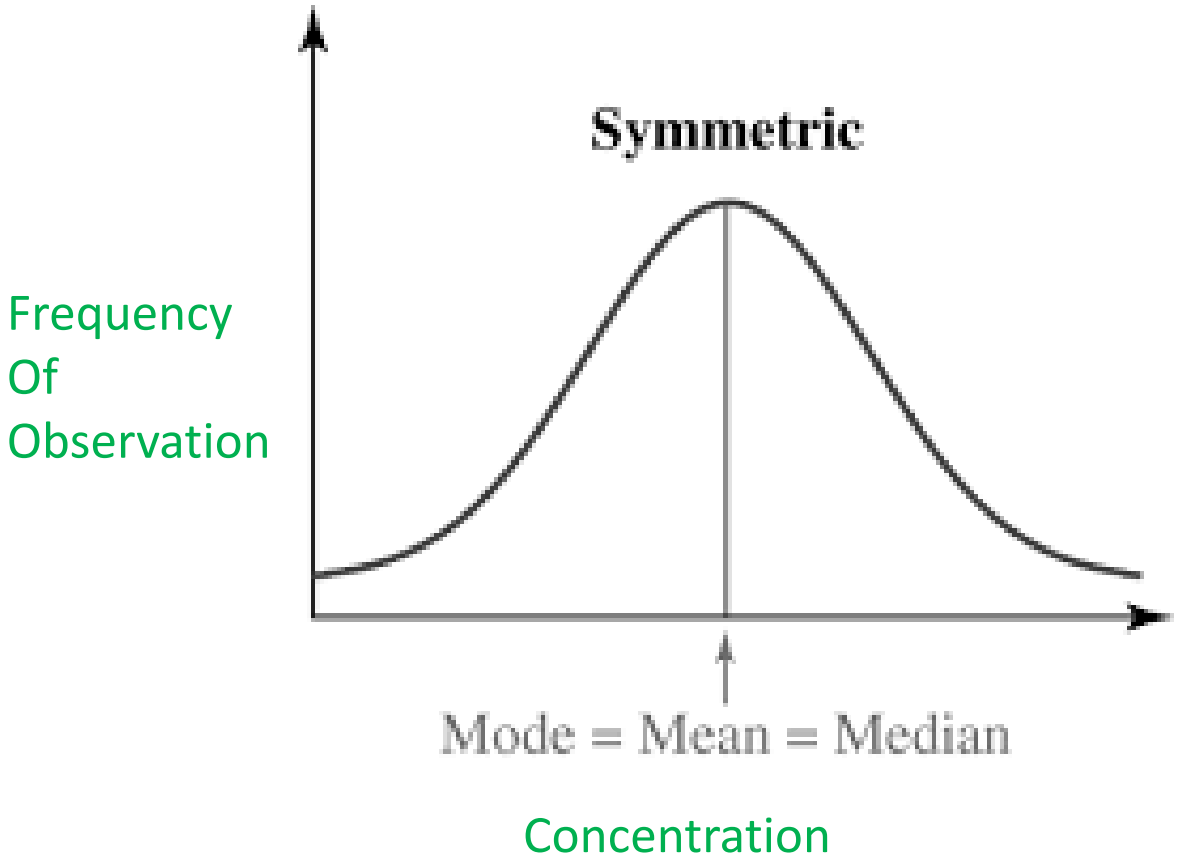
EPA (2015) Manages the Risk of False Negatives/Positives with These Key Concepts

1. Seeking "concordance" or "agreement" from Multiple Lines of Evidence (MLE)
2. Requiring decisions to be made based on "reasonable maximum exposure (RME)... "above the 90th percentile exposure but less than the 98th percentile exposure."
3. Calling for the use of differential pressure measurements to determine if conditions are likely to provide RME
4. Suggesting the use of long-term time integrated indoor air samples
5. "Background" vapor sources are managed by limiting analysis target list, building survey; subslab to indoor air comparisons = "multiple paired samples"

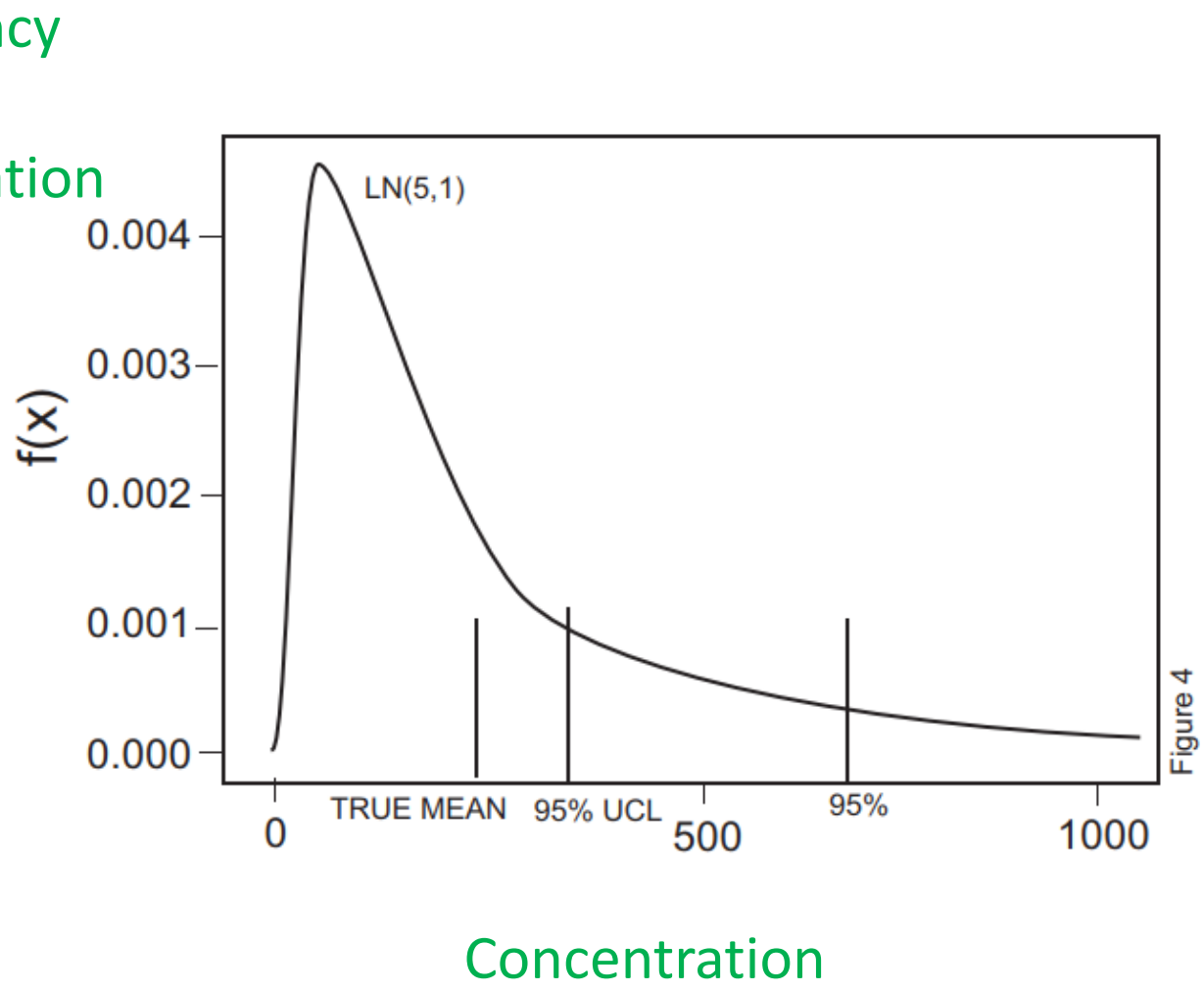
The first two concepts are much less prevalent/explicit in state guidance documents, which suggests that states may be managing the risk of false negatives with other strategies, such as decision making with a strong emphasis on subslab soil gas data. States that do use MLE as EPA suggests do so using decision matrices of SS/IA.

If The Distribution is Symmetrical (or Normal) It is Easier to See the Mean With a Few Samples



With a symmetrical distribution you have a 50% chance to be above the mean with at least one sample and a 75% chance to be above the mean with at least one of two samples. The median is the most common sample (highest frequency).

But: It is Harder to Observe the True Mean With a Small Number of Samples When the Distribution is Skewed - as it Often Is in Environmental Samples



Skewness is a measure of the asymmetry of the distribution.

Figure Reprinted from EPA/600/R-97/006

The Performance of Purely Random Sampling Can Be Determined Mathematically if the Metric is the 90th Percentile of the Distribution (a noncancer criteria assumption)

- You have a 10% chance with one random sample of observing the >90th percentile of any distribution.
- You have a 19% chance with two random samples of observing the >90th percentile of any distribution.
- You have a 34**%** chance with **four** random samples of observing the >90th percentile
- You have a **90%** chance with **22** random samples of observing the 90th percentile at least once

Image from https://wi101.wisc.edu/2020/09/09/object-history-a-twenty-sided-die/

Explaining the Concept of 50% Cumulative Exposure With an Invented, Simplified Ten Sample Example

(Note: **cumulative inhalation exposure** is only a simple sum to show what daily samples represented the most **inhalation exposure** and does not account for processes in the human body)

duration (days)	Concentration (µg/m^3)	Percentile of the underlying distribution	Inhalation rate (m^3/day)	Exposure (µg/day)	Cumulative Exposure (µg)	Percent of cumulative exposure from individual sample	Percent of cumulative exposure
1	1	0	16	16	16	1.1%	1.1%
1	1	0	16	16	32	1.1%	2.3%
1	2	22.2	16	32	64	2.3%	4.6%
1	2	22.2	16	32	96	2.3%	6.9%
1	2	22.2	16	32	128	2.3%	9.2%
1	3	55.5	16	48	176	3.4%	12.6%
1	5	66.6	16	80	256	5.7%	18.4%
1	11	77.7	16	176	432	12.6%	31.0%
1	20	88.8	16	320	752	23.0%	54.0%
1	40	100	16	640	1392	46.0%	100.0%
			Sum Total Exposure	**1392**	µg		
			50th percentile of cumulative	696	µg		

Median Concentration 2.5 µg/m^3

Mean Concentration 8.7 µg/m^3 (95th UCL is 8.96)
Mean Exposure 139.2 µg/day.

50th Percent of the cumulative exposure = 696 µg; 8 of 10 days contribute less then 50%!

90th and 95th percentiles of underlying distribution

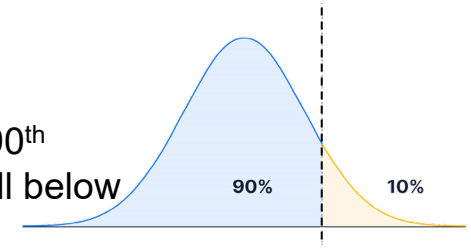
Key Point: The few samples at the top of a skewed distribution dominate the total long term exposure.

Format of Box and Whisker Diagrams

95th percentile

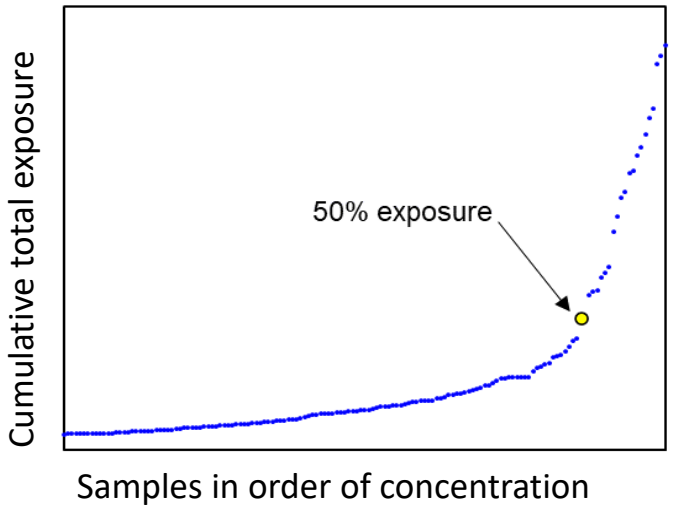
90th percentile

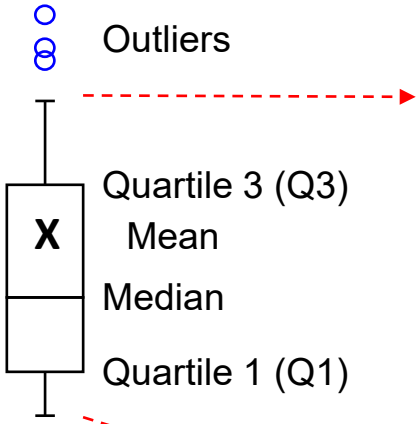
k-th percentile is a value below which a given percentage of *k* scores fall. For example, the 90th percentile is the value at which 90% of data fall below and 10% are above.



50% exposure

The value at which the sum of all data that fall above equals 50% of the total exposure. Total exposure is calculated at the sum of all data.





Outliers

Whisker extends from the top of Q3 to the largest data element that is less than or equal to 2.2 times the interquartile range (IQR). Values greater than 2.2 times the IQR are shown individually as outliers.

Quartile 3 (Q3)

Mean

Median

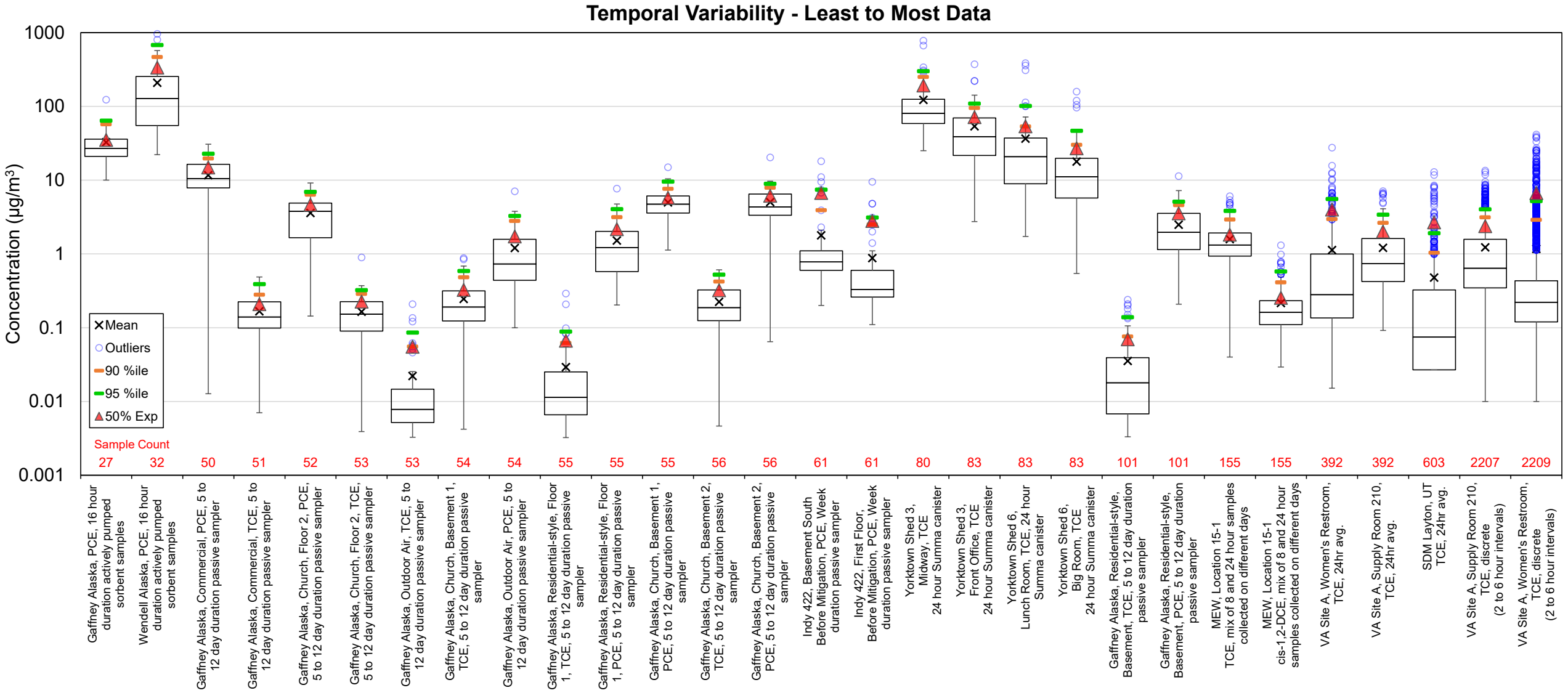
Quartile 1 (Q1)

Q3 and Q1 are the 75th and 25th percentiles.

Whisker extends from the bottom of Q1 to the smallest data element that is greater than or equal to 2.2 times the interquartile range (IQR). Values less than 2.2 times the IQR are outliers.

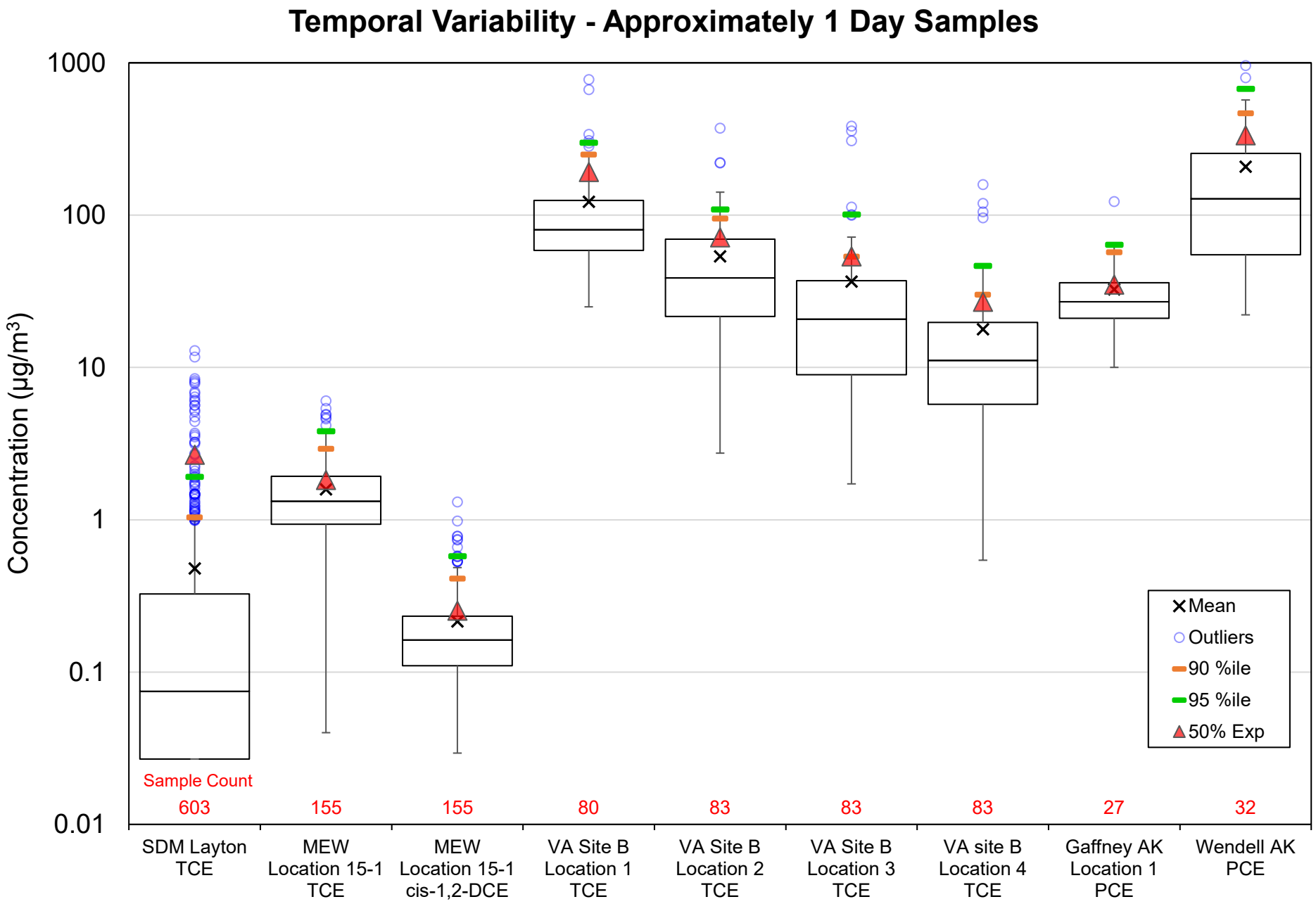
Median = value or quantity lying at the midpoint of a frequency distribution of observed values or quantities, such that there is an **equal probability** of one sample falling above or below it.

Temporal Variability of Indoor Air Concentrations Across 7 Sites



Key points:

1. The long-term mean is always above the median and sometimes above the 75th percentile.
2. Half the exposure often comes from only a small percentage of the days.
3. The more samples you take the more “outliers” you see. Note log axis – those outliers are really high!



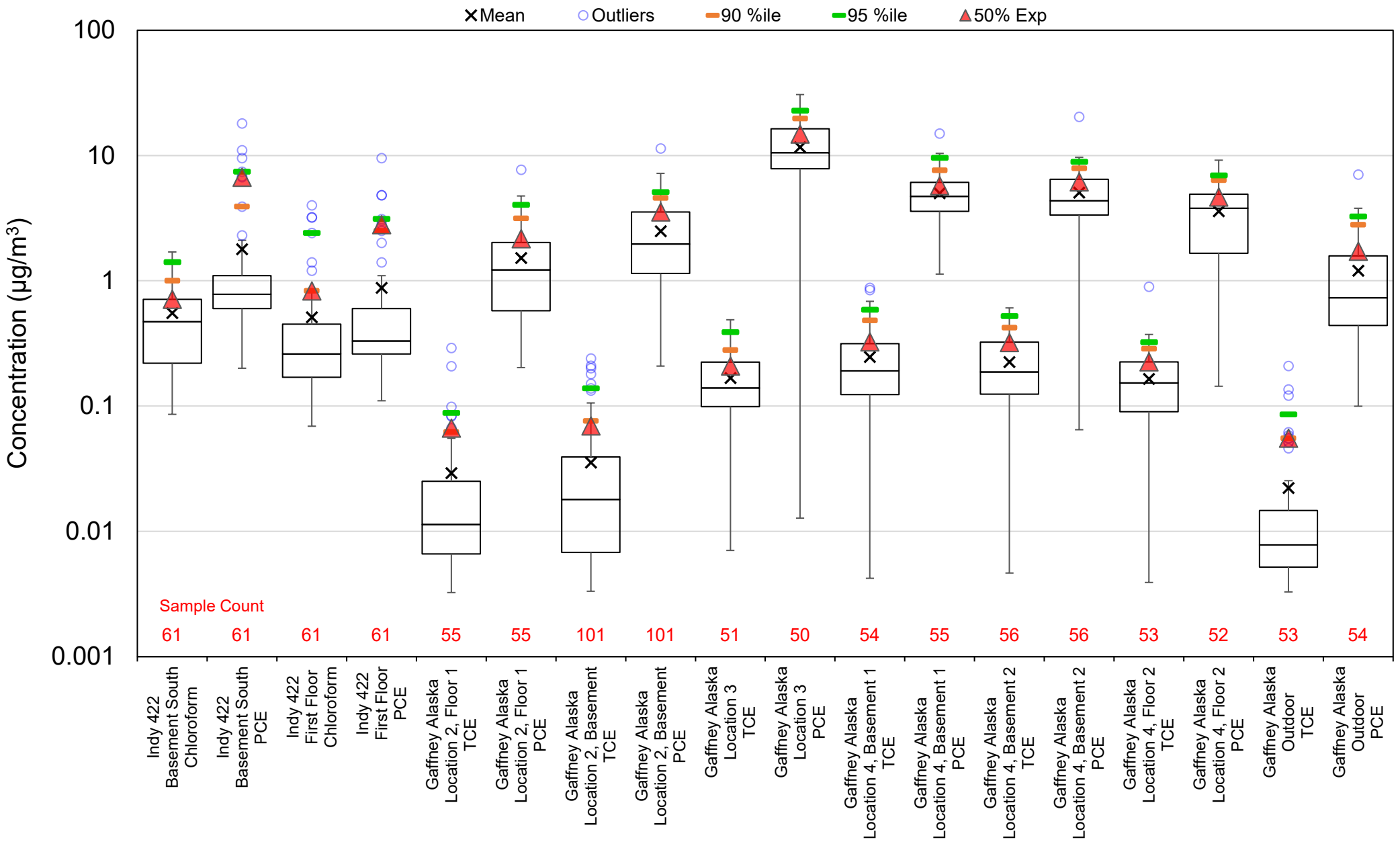
Key Points:

The **X** = true mean is almost always well above the median. So most of the samples will be below the mean.

The 50th percentile of total ▲ exposure is often above the 75th percentile.

Only at SDM is the 50th percentile total exposure above the 95th percentile.

Temporal Variability - Approximately 1 Week Samples



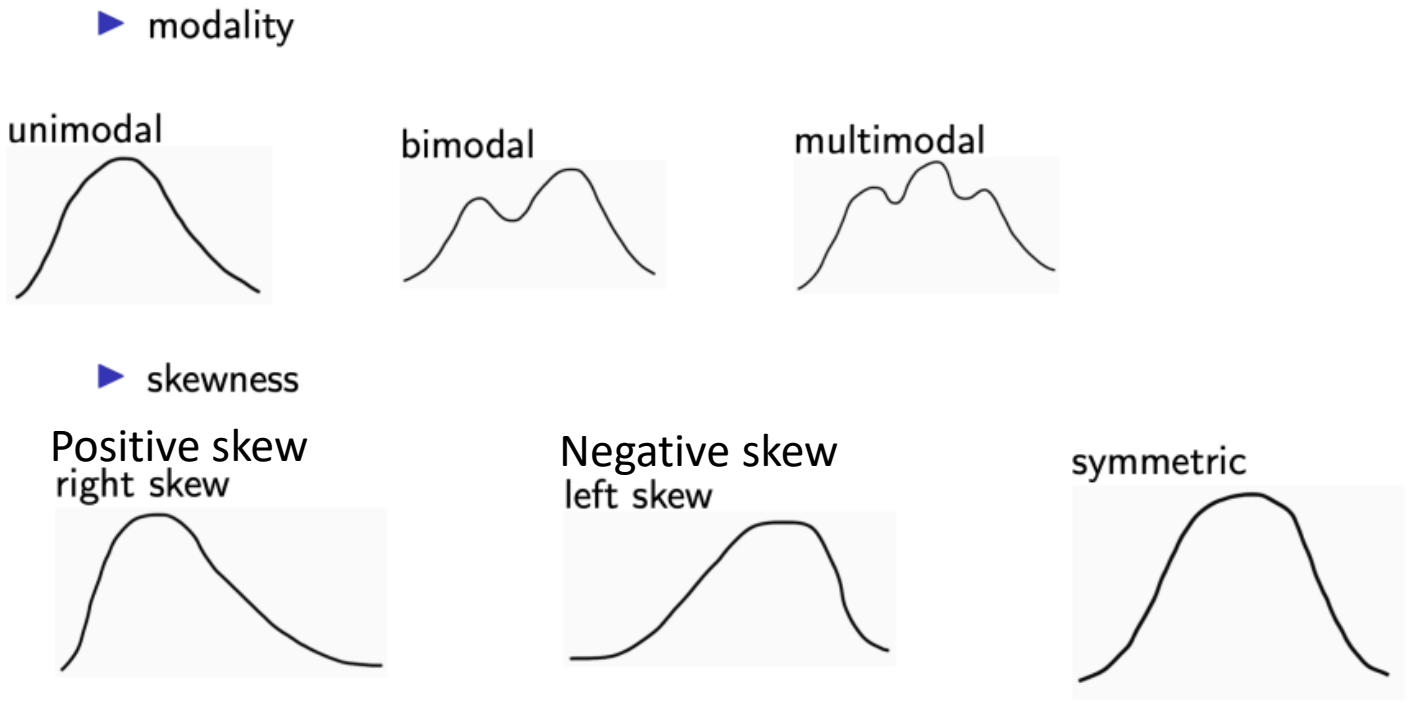
Key Points:

The **X** = true mean is almost always well above the median. So most of the samples will be below the mean.

The 50th percentile of total exposure is often above the 75th percentile.

Results of Statistical Tests of Distribution Types/Characteristics

- Of all the distributions tested, only a few are multimodal = Sun Devil Manor, VA Site A Women's restroom and TCE in Fairbanks Church Basement. The Sun Devil Manor and Women's restroom cases are known to involve preferential pathways/fluctuating water levels.
- Skewness is a measure of the asymmetry of the distribution. Skewness for normal distribution is near zero. Skewness >1 interpreted as "significantly positively skewed". Of 31 skewness tests on VI indoor data sets all were positive. 28 of 31 were skewness >1.
- SDM = 5.4 skewness. VA site A bathroom = 5.5 skewness.



Graphic adapted from Y. Tian "Lecture 3 Probability Basics", Columbia University, 2022. https://www.columbia.edu/~yt2661/S1201/slides/lecture-3.pdf

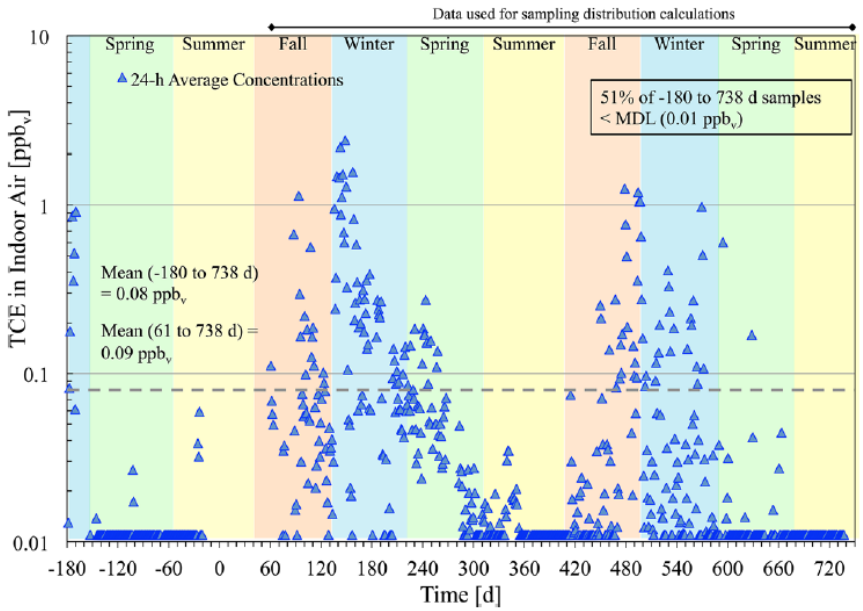
Goals for a Sampling Strategy

- Is a >90% confidence in making the assessment decision about an individual structure required? (<10% false negative?) or 95% confidence (<5% false negative?)
- Sampling strategies should be applicable to a wide variety of buildings, using a minimum of easily available preexisting information; such as point of contaminant release and climate zone.
- Sampling strategies should be significantly better than random sampling, while still allowing a reasonable number of potential sampling days per year.
- Sampling strategies should be robust = perform well across a variety of situations (building types, climates, climate change)

Sample Scheduling Approaches Tested in this Study

- One sample per calendar season (Winter = Dec 1 to Feb 28, Spring March 1 to May 31…..) – either winter/summer or four quarterly samples
- Half the samples in heating season (November 1 to March 31st), half not in heating season
- All samples in heating season.
- All samples in winter; all samples in summer etc.
- OR sampling event begun based on:
  - decrease in temperature day over day of 5 F
  - indoor/outdoor differential temperature of 15 F
  - negative differential pressure of 0.01 inches of water or 2.49 Pa or more
  - day over day increase in radon concentration of 0.5 pCi/l
  - threshold Level of > 2 pCi/l in radon
  - exceeding the 90th percentile of radon levels expected for the structure either based on heating season or the full data set.
- 24 hr duration samples or week duration samples compared
- Full details at https://iavi.rti.org/assets/docs/05_Lutes-Sampling_Strategies.pdf; journal paper in draft.

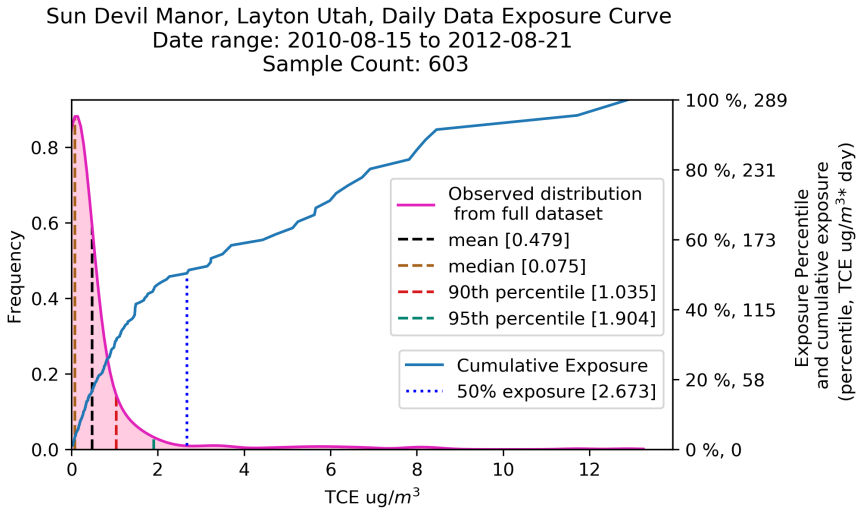
Sampling Performance With a Highly Skewed Distribution? (Sun Devil Manor 603 days)

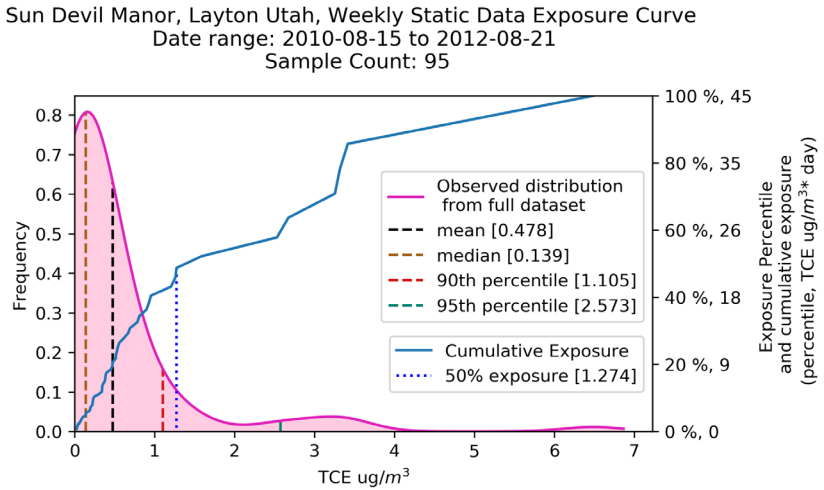


Above figure in ppb (1 ppbv= 5.5 µg/m^3)

Your chances of once

- Seeing TCE sample over the 90th percentile with four daily samples (vs four weekly):
  - Random = 35% (36%)
  - Only in heating season = 62% (68%), In winter only = 74% (80%)
  - When radon >90th of full radon dataset = 95% (100%)
- Seeing TCE over the 50th percentile of cumulative VOCs with four daily samples (vs four weekly):
  - Random = 16% (30%)
  - Only in heating season =31% (59%), in winter only = 40% (68%)
  - When radon >90th of full radon dataset = 60% (100%)





Key Points:

1) Weeklong sampling gives better odds than day long sampling

2) The 90th percentiles are almost identical for the daily and weekly distributions, but the 50th percentile of cumulative is quite different.

3) Preferential pathway case.

What Does Temporal Variability Look Like in Subslab at Sun Devil Manor?

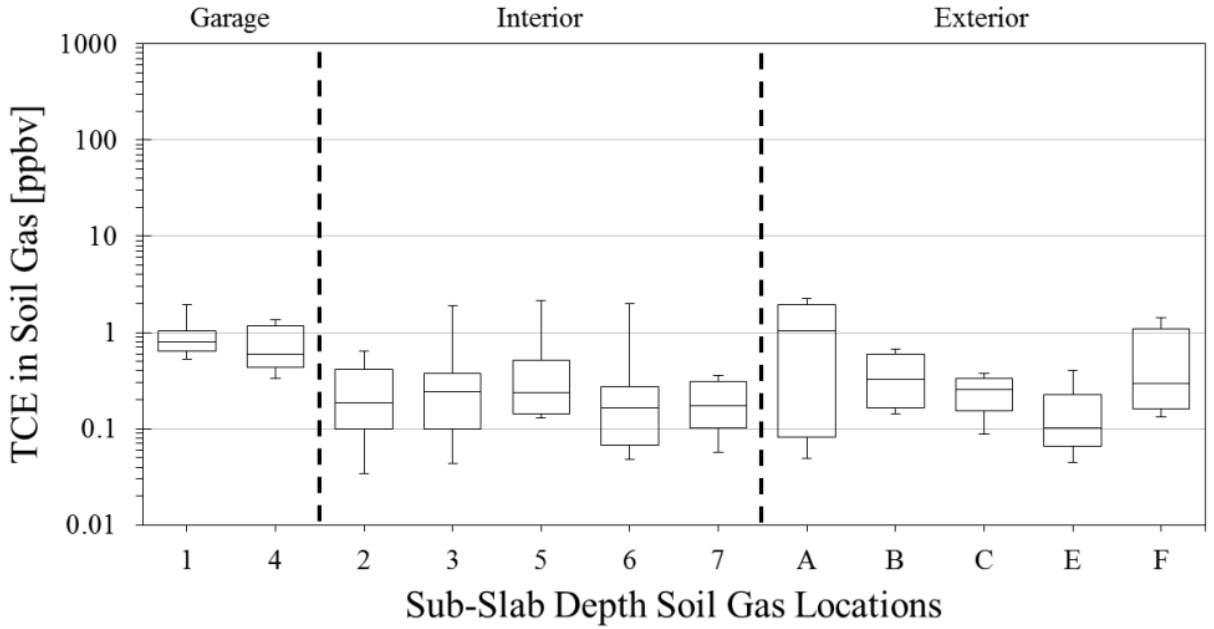


Figure 3.19. Box and whisker plot of TCE concentrations in soil gas at the sub-slab depth sampling points from August 2010 to August 2012.

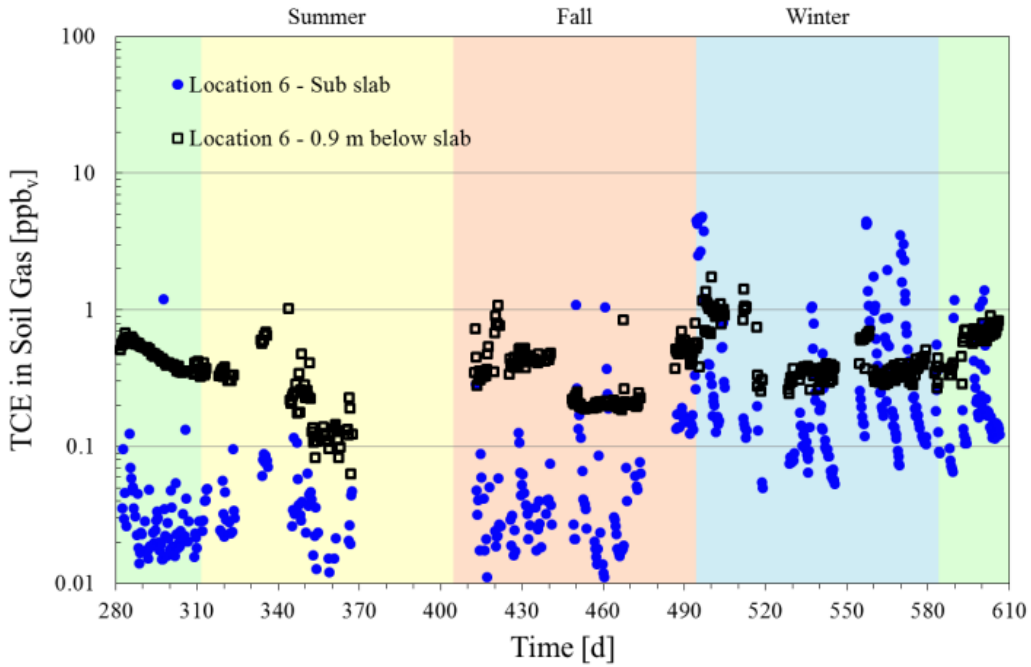


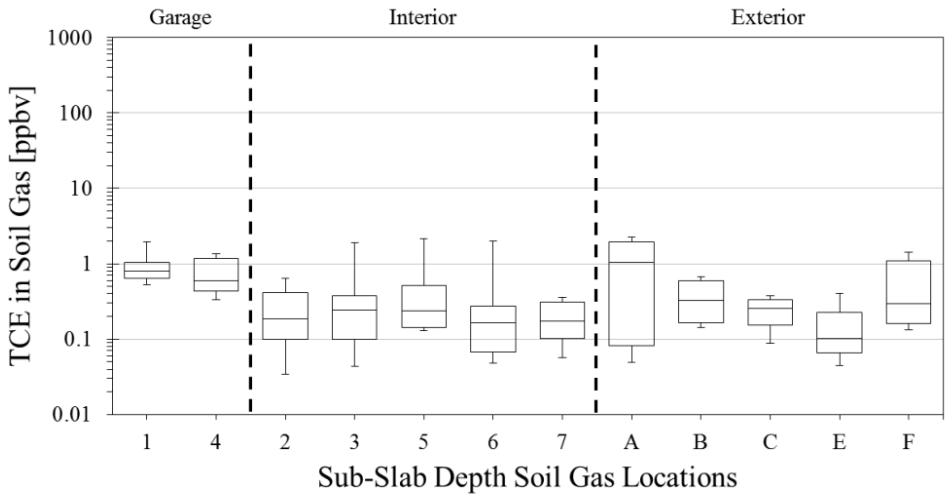
Figure III.21. TCE concentration in sub-slab and 0.9 m below-slab soil gas at location 6 from May 2011 to April 2012.

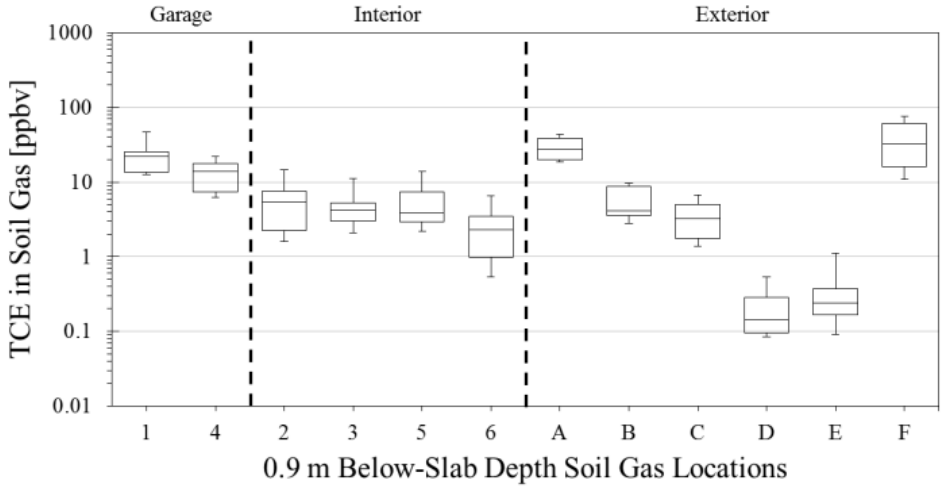
Key Points:

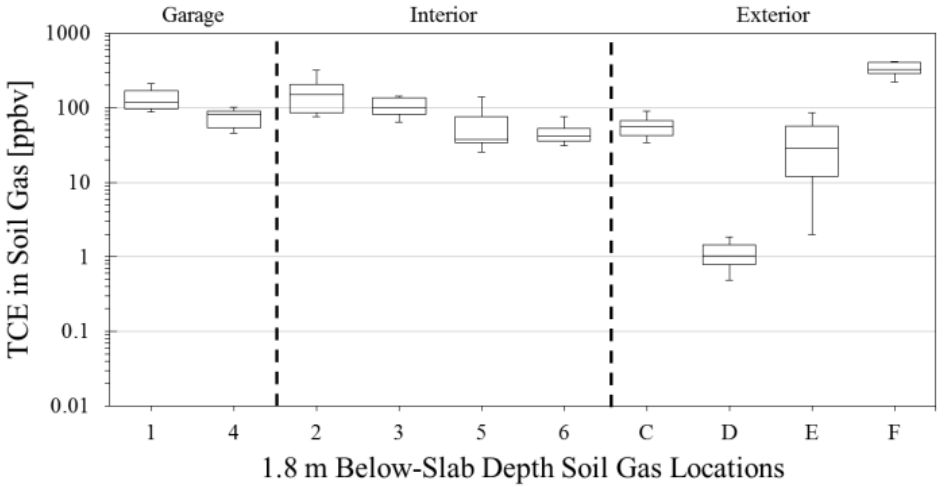
1) Subslab concentration spatially uniform
2) Subslab concentration less temporally variable then indoor air.
3) Subslab concentrations in the lowest risk tier in Region V matrix.
4) Subslab higher during periods when indoor air higher.

Figures reprinted from Evaluation of Vapor Intrusion Pathway Assessment Through Long-Term Monitoring Studies by Chase Weston Holton, Dissertation, Arizona State University 2015

Comparing Subslab and Deep Soil Gas Variability at SDM







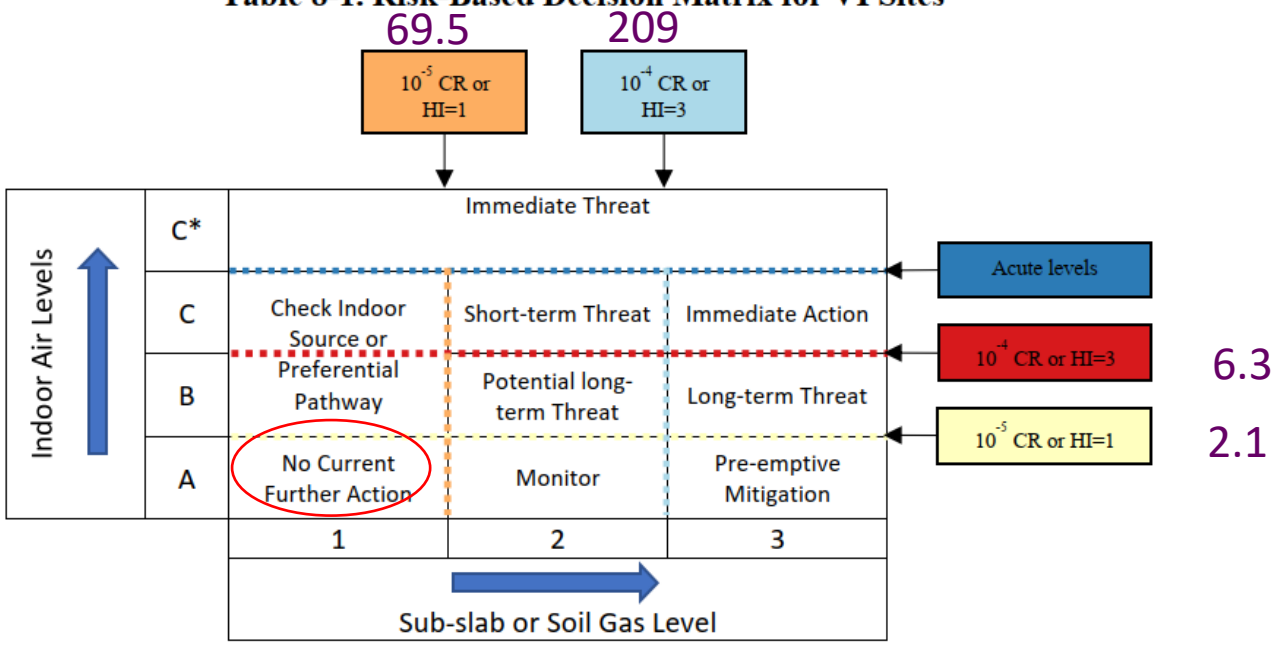
Key Points:

1. Temporal variability: indoor air >> subslab > deep soil gas
2. Spatial variability: deep soil gas > subslab
3. Groundwater concentration was 10 to 50 µg/l
4. The deep soil gas comparison to subslab soil gas suggested that VI was reduced substantially by vadose zone attenuation.
5. The indoor concentrations were ultimately discovered to be due to land drain to subslab preferential pathway – even though none of the subslab ports installed were high.

Figures reprinted from Evaluation of Vapor Intrusion Pathway Assessment Through Long-Term Monitoring Studies by Chase Weston Holton, Dissertation, Arizona State University 2015

How Would Sun Devil Manor be Interpreted Under Region V Matrix?

Table 8-1. Risk-Based Decision Matrix for VI Sites



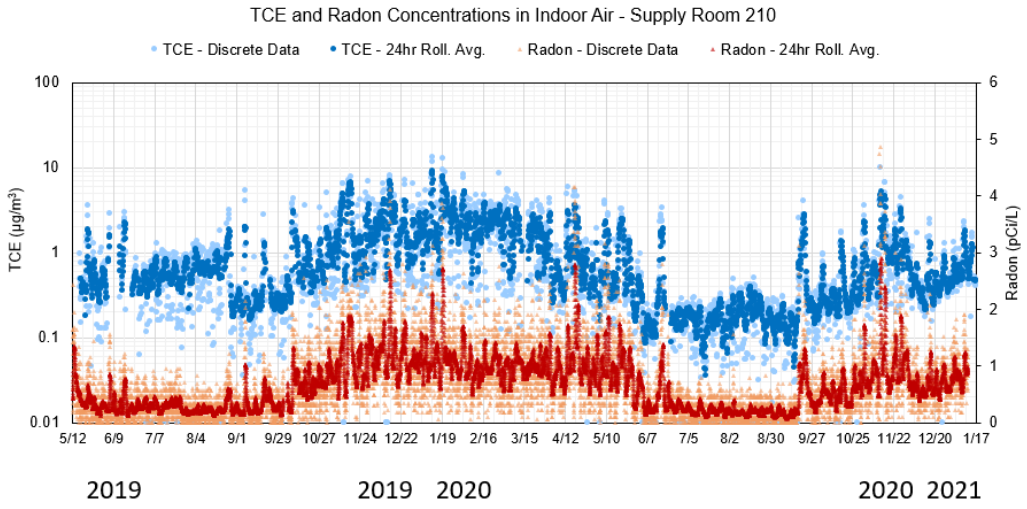
Figures from US EPA Region 5, Superfund and Emergency Management Division, Vapor Intrusion Handbook, March 2020

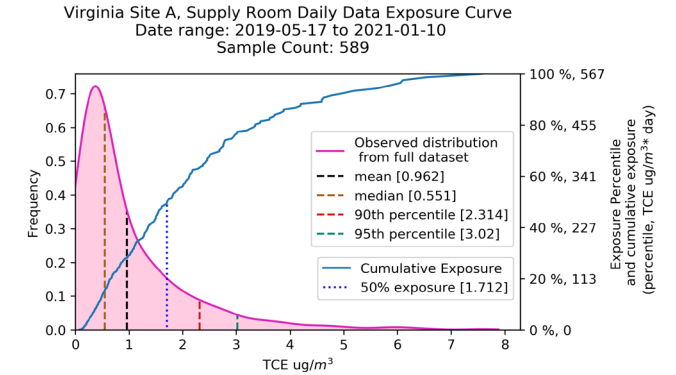
TCE Concentrations from VISL Calculator as of 10/3/24 for Residential in µg/m^3

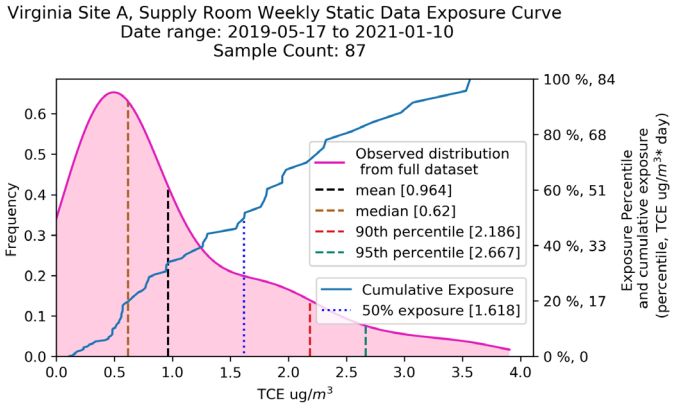
Key Points

1. Mean indoor concentration of 0.48 µg/m^3 is around 10^{-6} and
2. 95th percentile of daily 1.9 µg/m^3 is below HQ=1, so indoor air is in the lowest risk category A.
3. Subslab concentrations are also in the lowest category 1 (<10^{-5}). So A1 = No current further action.
4. Indoor air was not a big risk. But data illustrates how skewed VI distributions can be and how the vast majority of the samples contribute very little the cumulative total exposure and are far below the mean.
5. Sparse sampling might have led to the right answer by chance despite inaccurate exposure estimates.

Sampling Performance, Moderate Skew: VA Site A: Supply Room (589 days)







Your chances of

- Seeing a TCE sample over the 90th percentile once with four daily (four weekly) samples:
  - Random: 34% (36%)
  - Only in heating season: 67% (74%), only winter: 71% (87%)
  - Radon >90th full radon dataset: 77% (95%)
  - Radon >2 pCi/l: 100% (100%)

- Seeing TCE over the 50th percentile of cumulative VOCs once with one of four daily (four weekly) samples
  - Random: 49% (63%)
  - Only in heating season: 86% (97%); Only winter: 90% (99%)
  - Radon >90% of full radon dataset: 93% (100%)
  - Radon >2 pCi/l: 100% (100%)

Key Points:

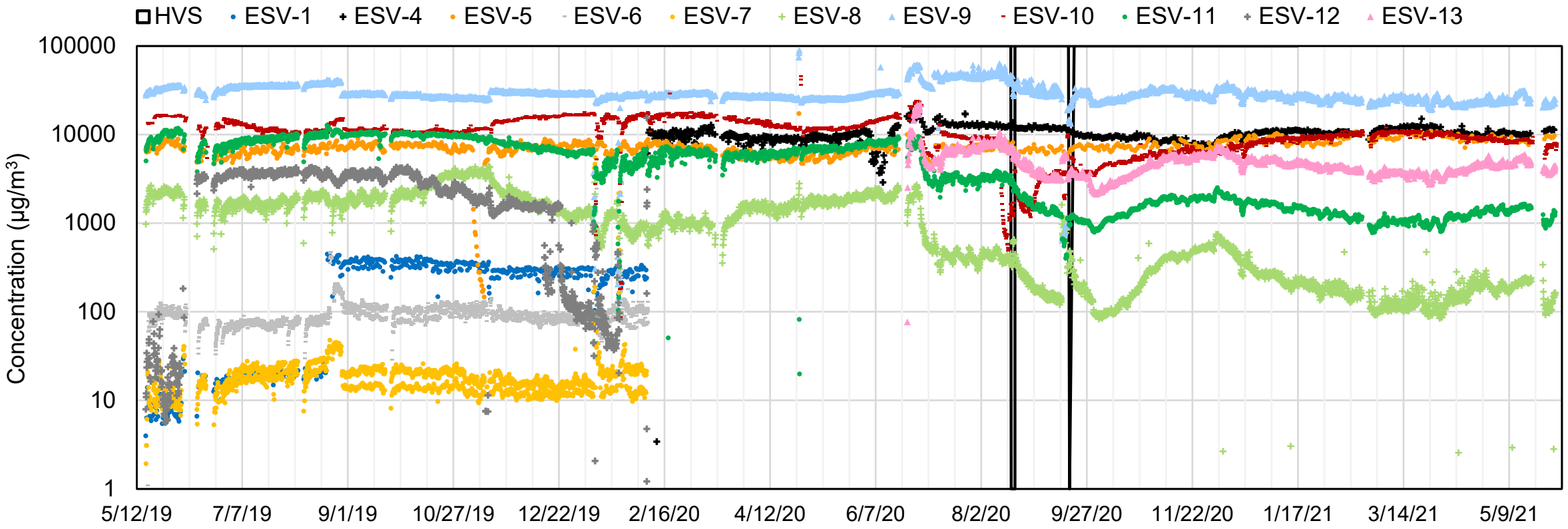
1) Weeklong sampling performed better than day long sampling

2) In this case the characteristics of the weekly and daily distributions were quite similar for both the 90th percentile and 50th percentile cumulative exposure.

3) Zone has "classic" stack effect behavior from a source directly under building.

What Does Temporal Variability in Subslab Look Like at VA Site A? Supply Room Zone is ESV-11 (Dark Green); Very Close ia ESV-10 (Dark Red)

Figure 1a: TCE Concentrations in Subslab - Discrete Data



Key Point: Subslab concentrations stable for months. Occasional changes wouldn't normally be observed with extended sampling time.

Paper in Review: "Influence of Sampling Collection Time and Volume on Observed Subslab Soil Gas Volatile Organic Compound Concentrations"
Published *The Representativeness of Subslab Soil Gas Collection as Effected by Probe Construction and Sampling Methods.* Groundwater Monitoring & Remediation, June 2024.
https://doi.org/10.1111/gwmr.12663

What Does Temporal Variability in Subslab Look Like at this VA Site A? Concentrations in $\mu g/m^3$

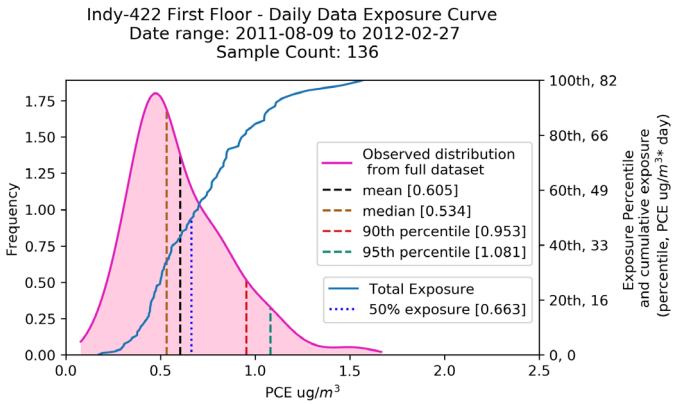
Key Point:
1) Spatial and Temporal Variability is limited despite thousands of measurements over 2 years.

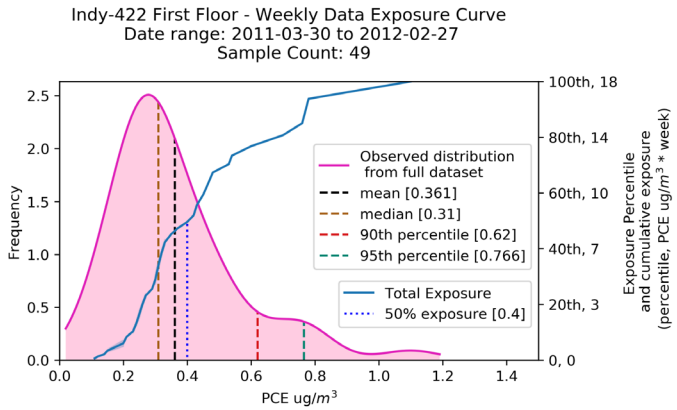
Sampling Zone	Nearby Office	Supply Room
Sample ID	ESV-10	ESV-11
Start Date	5/16/2019	5/16/2019
End Date	1/9/2021	1/9/2021
5 %ile	3,471	1,192
10 %ile	4,792	1,533
25 %ile	8,729	2,983
Median	11,425	6,437
75 %ile	14,708	8,630
90 %ile	16,328	10,039
95 %ile	16,789	10,347
Maximum	45,404	12,817
75/25th	1.7	2.9
90/10th	3.4	6.5
95/5th	4.8	8.7
Average	11,200	5,974
StDev	4,384	3,142
% Detected	100.0%	99.9%
Count	4,826	4835

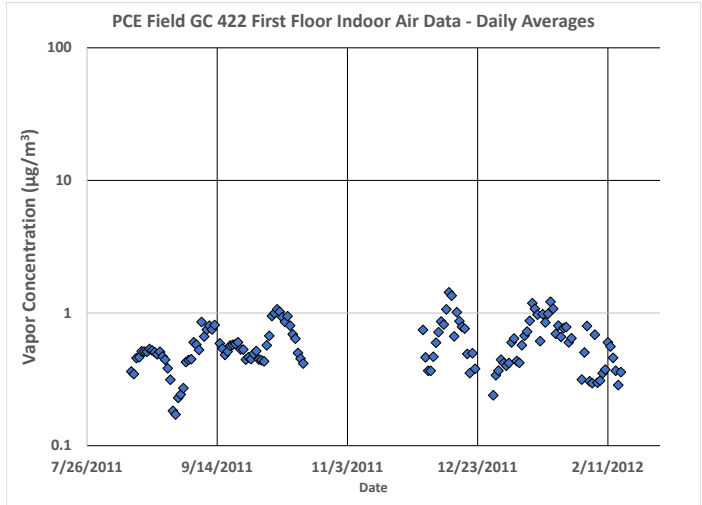
Sampling Performance With Slight Skew – Indianapolis First Floor: Daily (8/9/11 – 2/27/12) Weekly (3/30/11 -2/27/12)

Your chances of once

- Seeing PCE sample over the 90th percentile with four daily (four weekly) samples:
  - Random = 37% (36%)
  - Only in heating season= 51% (39%) or in winter only = 51% (31%)
  - When radon >90th of full radon dataset = 58 % (80%)
  - When radon >90th of heating season Rn, in heat season= 85% (80%)
- Seeing PCE over the 50th percentile of cumulative VOCs with four daily (four weekly) samples:
  - Random = 81% (81%)
  - In winter only = 91% (95%)
  - When radon >90th of full radon dataset = 99% (100%)
  - When radon >90th of heating season Rn, in heat season=100% (93%)







Key Points:

1) Weeklong sampling sometimes better than daylong sample compared to daily distribution.

2) Daily and Weekly distributions from different time periods here.

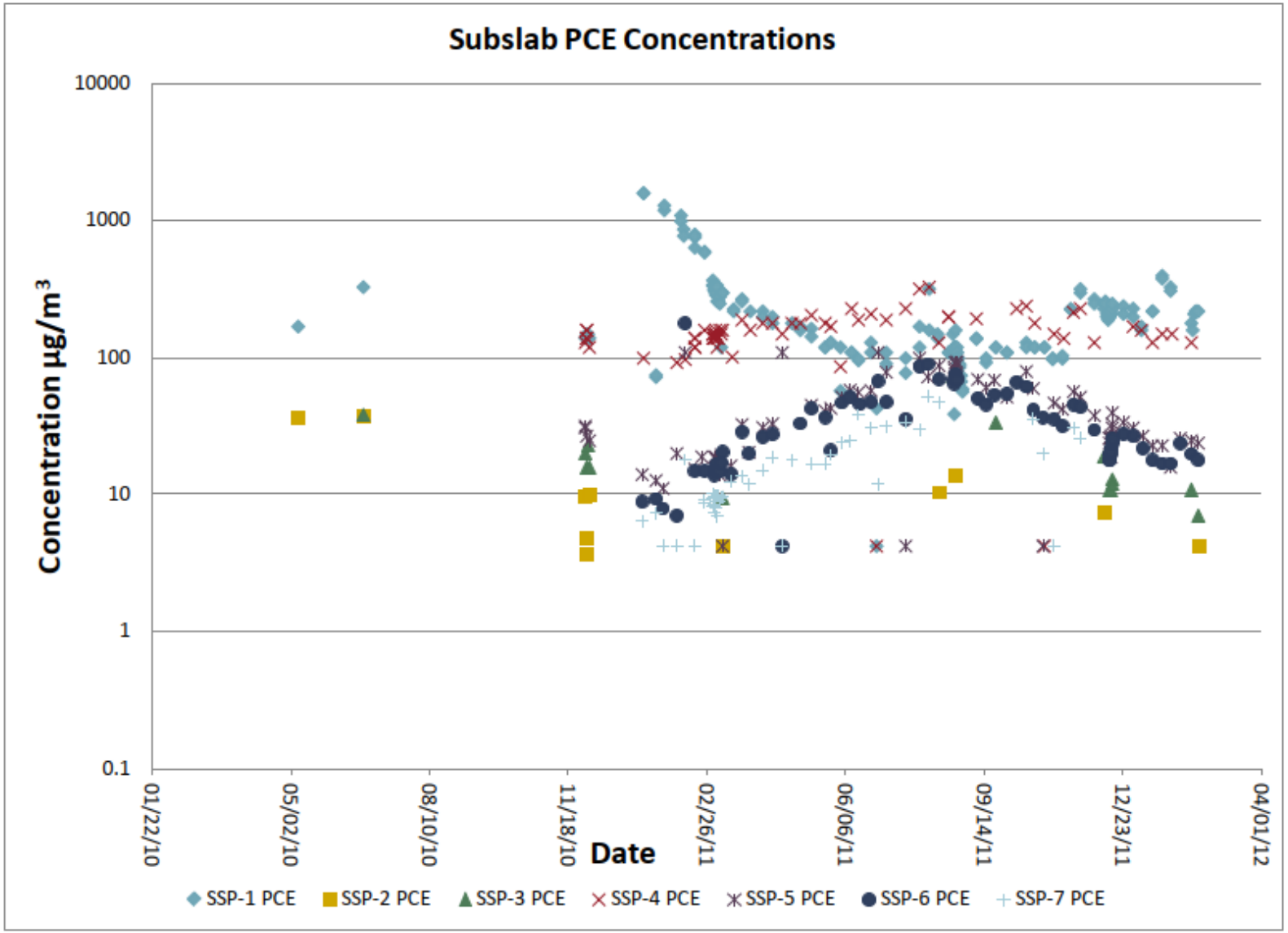
3) This case is at a distance from source, preferential pathway influenced on neighborhood scale.

What Does Temporal and Spatial Variability In Subslab Look Like Under Indianapolis Duplex Basement?

Approximately 13 months of weekly grab samples.

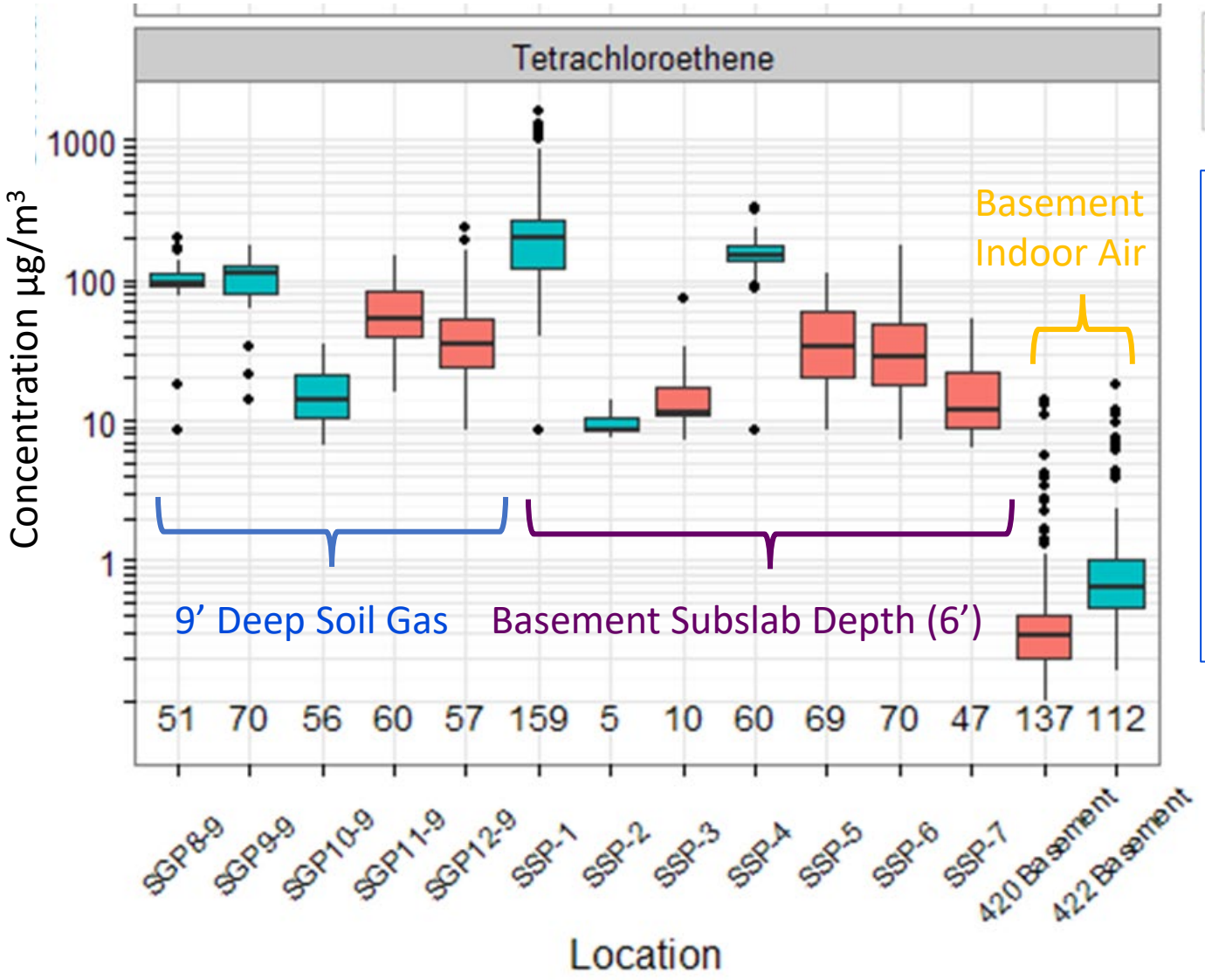
SSP-1, SSP-2, SSP-4 are under the Heated Portion of the Duplex.
SSP-3, SSP-5, SSP-6 and SSP-7 are under the Unheated Portion of the Duplex

Key Point:
Gradual temporal change, distinct spatial variability in winter.



"Fluctuation of Indoor Radon and VOC Concentrations Due to Seasonal Variations" EPA/600/R-12/673, September 2012.

What Does Temporal and Spatial Variability In Soil Gas Look Like in Indianapolis Duplex?



Key Points:

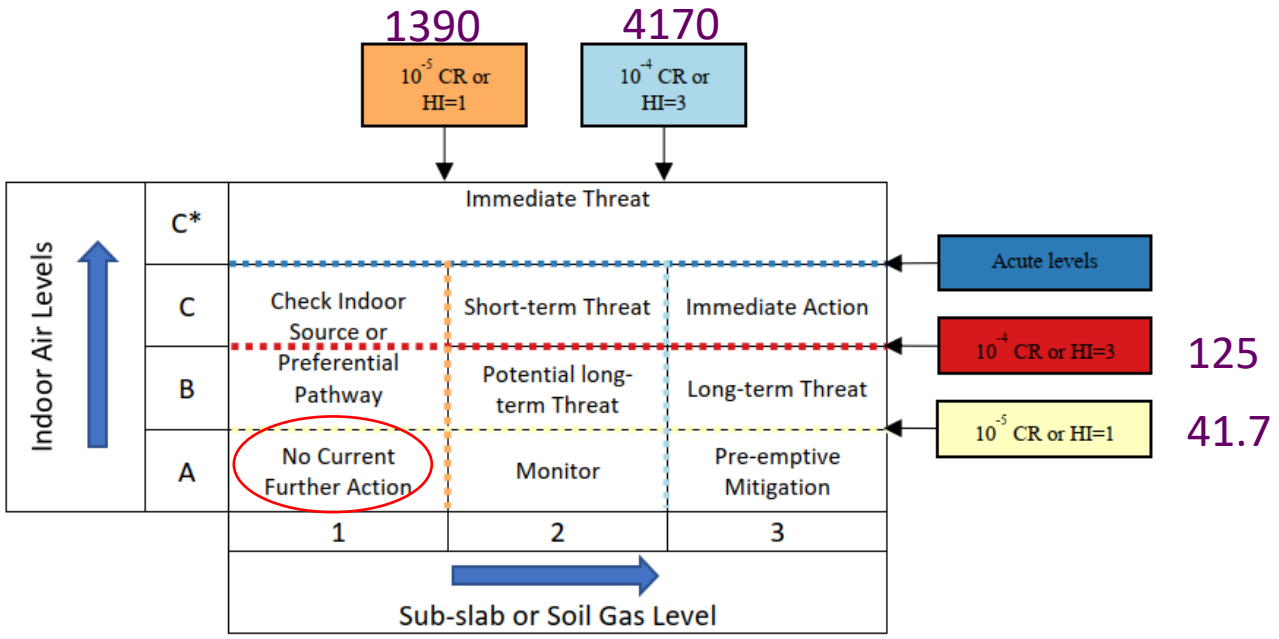
1) Temporal variability indoor> soil gas

2) Spatial variability soil gas > indoor

Adapted from figure 7-3 of "Fluctuation of Indoor Radon and VOC Concentrations Due to Seasonal Variations" EPA/600/R-12/673, September 2012.

How Would Indianapolis Basement Be Interpreted with the Region V Matrix – Applied to PCE – If Occupied

Table 8-1. Risk-Based Decision Matrix for VI Sites



Figures from US EPA Region 5, Superfund and Emergency Management Division, Vapor Intrusion Handbook, March 2020

PCE Concentrations from VISL Calculator as of 10/3/24 in µg/m^3

Key Points:

1) Indoor Air Mean <10^{-5}, 95th Percentile <HQ = 1 so Row A
2) Subslab almost always <1390 µg/m^3 so column 1.
3) Lines of evidence are in agreement.
4) A1 = "No further Action at this time, pending new data"

Note that this structure would be recommended for radon remediation under EPA guidelines.

Comparing Daylong and Weeklong Sample Durations

- One week or longer duration samples can be collected with passive sampling (Schumacher 2012), capillary controller Summa canisters (Rossner, 2020, 2023); or other advanced canister flow controllers (Entech, 2023)
- The sampling and analysis costs for daylong and weeklong are similar, so longer, more representative observation periods may be preferred (EPA, 2015).
- One week duration samples are expected to exhibit less temporal variability than 24-hour (daily) samples and thus yield estimates closer to the mean of the long-term exposure distribution.
- Fewer weeklong samples will be needed to confidently observe goals around the mean.
- But will it then be more difficult to directly observe the concentrations towards the upper end of the distribution of daily average concentrations (i.e. 90^{th} or 95^{th} percentile) using weekly samples?

Alan Rossner , David P Wick, Christopher Lutes, Benjamin Stone, Michelle Crimi; "Evaluation of Long-Term Flow Controller for Monitoring Gases and Vapors in Buildings Impacted by Vapor Intrusion" International Journal of Environmental Research and Public Health, March 2023 Int. J. Environ. Res. Public Health 2023, 20, 4811. https://doi.org/10.3390/ijerph20064811.
Schumacher, B.; J. Zimmerman, J; R. Truesdale, C. Lutes, B. Cosky, B. Munoz and R. Norberg "Fluctuation of Indoor Radon and VOC Concentrations Due to Seasonal Variations" EPA/600/R-12/673, September 2012.
Entech Instruments "CS1200E Passive Canister Sampler"
United States Environmental Protection Agency (USEPA). 2015. "OSWER Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor Sources to Indoor Air."

Summary Across Multiple Sites – Sampling Analysis

- In each individual case analyzed, an I&T based sampling rule and/or a seasonal based sampling rule can be identified that substantially outperforms random indoor sampling.
- However, the top performing I&T based rule is not the same across all sampling zones, so additional mechanistic insight is needed to select *a priori* the optimum sampling rule for a given sampling zone.
- An *a priori* selection of sampling rule would need to be based on the information generally available before initiating sampling at a given building: climate zone, building type, and a conceptual site model describing the primary source of contamination (groundwater vs. soil).
- Making decisions based on four randomly or convenience based short term samples will not likely characterize the 90th or higher percentile of the concentration distribution.
- At some sites with highly skewed concentration distributions, making decisions based on four randomly or convenience based short term samples will underestimate the mean long-term concentration, because a small percentage of the dates contribute >50% of the total exposure.
- However, because many structures are either far above or far below screening levels you may make the right decision even with imperfect information.
- Soil gas samples are less temporally variable so using multiple lines of evidence is important.

U.S. EPA "State of VI Science" Workshop
Reliable Ongoing Human Exposure Protection to Vapor Intrusion Using Cleanup as the Simplest Approach

Break – Return at 3:20 ET

Presentation archived at https://iavi.rti.org/

40th Annual East Coast Conference on Soils, Sediments, Water, and Energy October 22nd, 2024

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