# EVALUATING THE EFFECTIVENESS OF INDICATOR-BASED SAMPLING STRATEGIES FOR VAPOR INTRUSION INVESTIGATIONS

Indoor Environments Association Symposium – 16 September 2024

Orlando, Florida

*Presented by:*
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# Agenda

- Vapor Intrusion Pathway Assessment Challenges
- Lessons from Radon Literature
- Indicators of Vapor Intrusion
- Evaluation of Indicator-Based Sampling Strategies
- Summary

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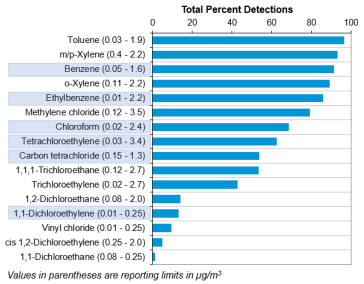
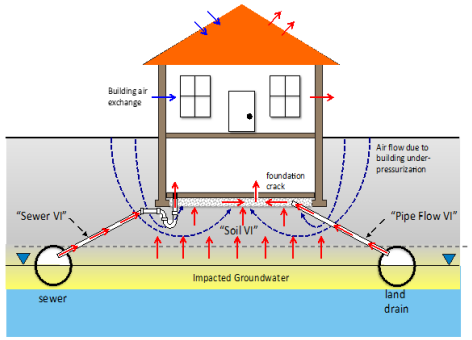
# Vapor Intrusion Pathway Assessment Challenges

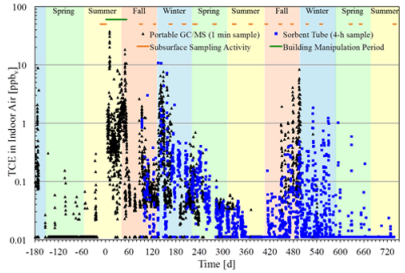
Indoor VOC Sources




Conduit Pathways




Temporal Variability



# Indoor VOC Sources

- **Indoor (background) sources** of some chemicals can result in indoor air concentrations above risk-based screening levels.
- Difficult to find without detailed surveys or advanced screening approaches

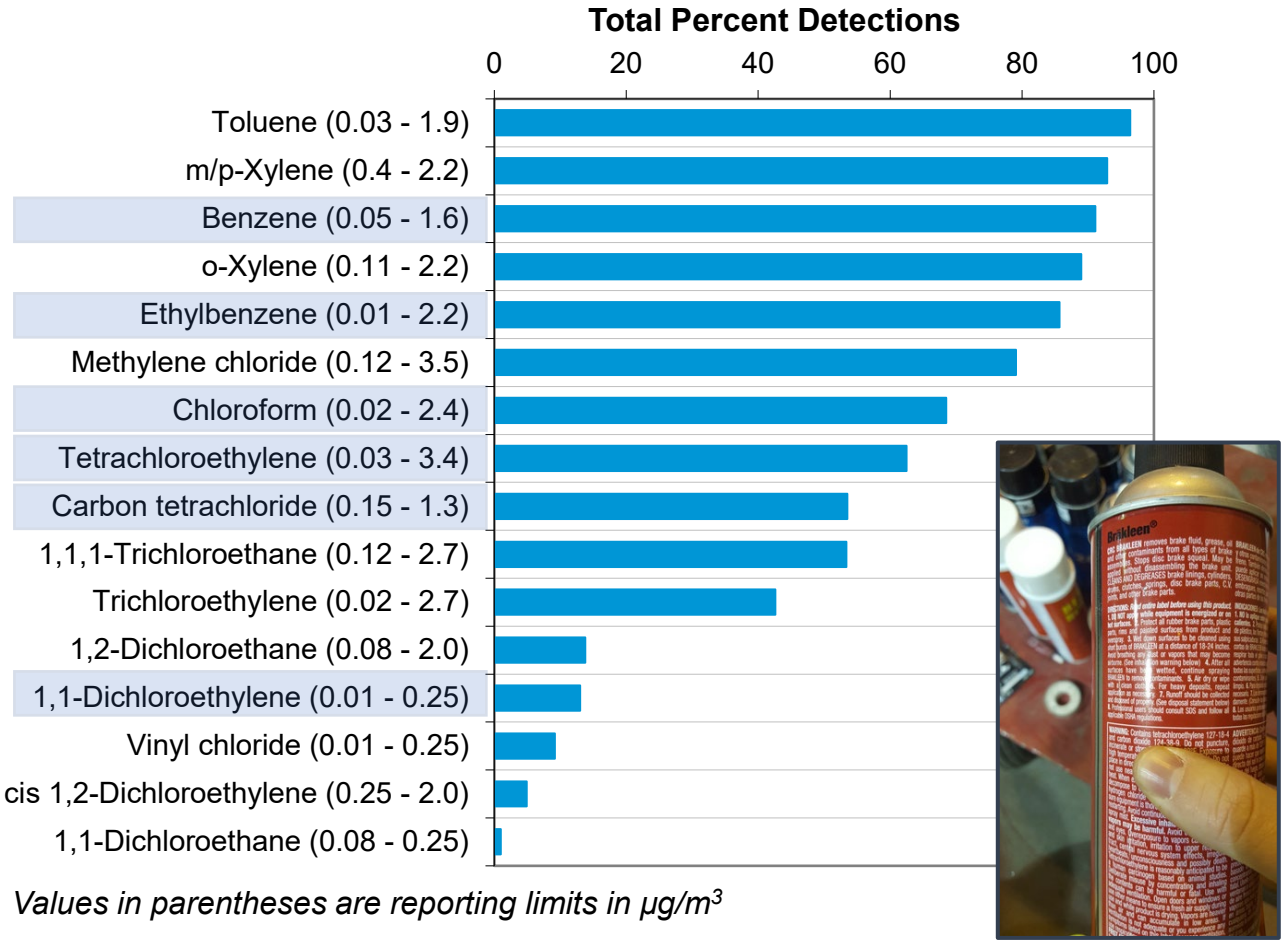
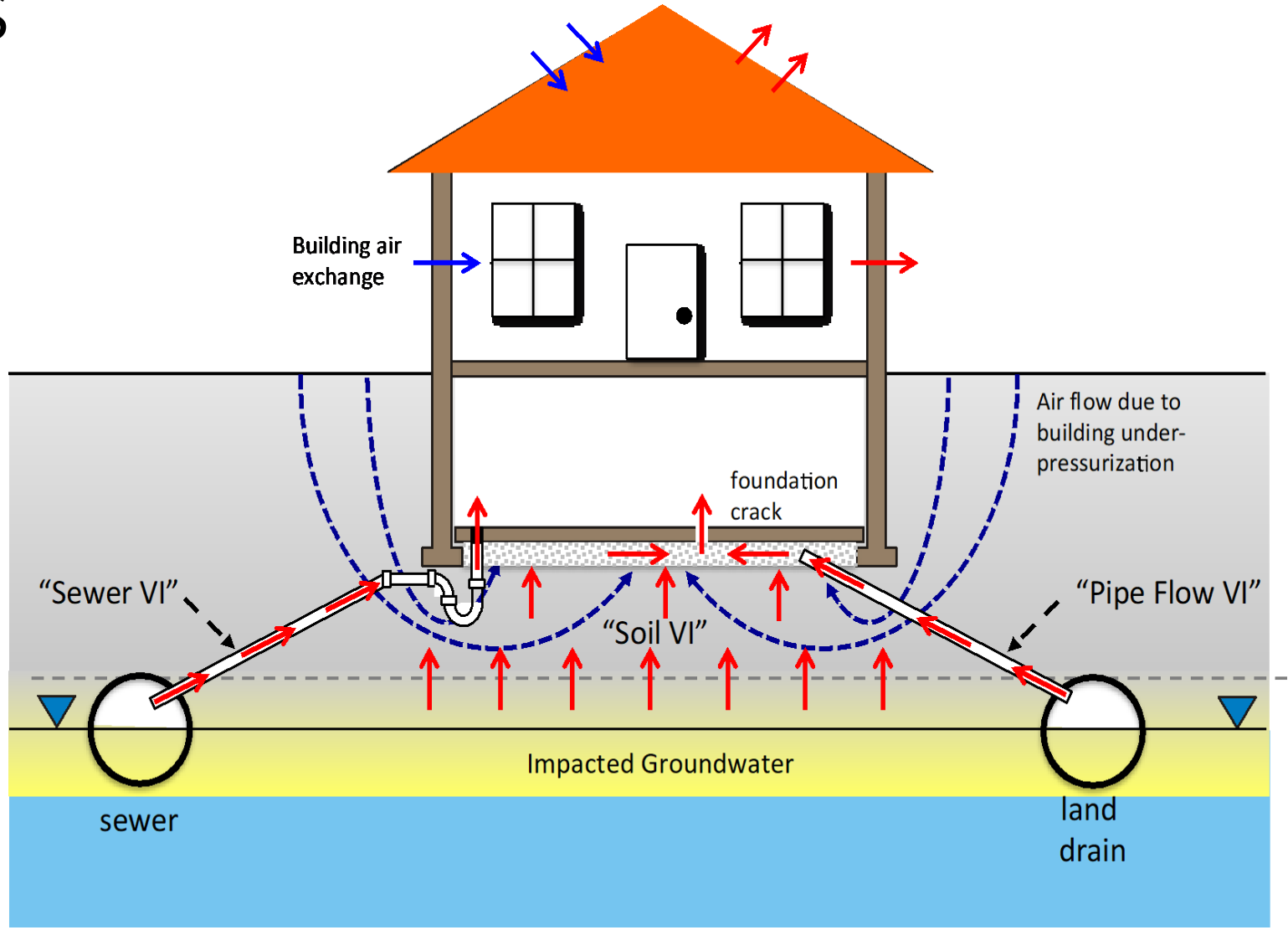



Figure reference: Adapted from Dawson and McAlary, 2009

# Conduit Pathways

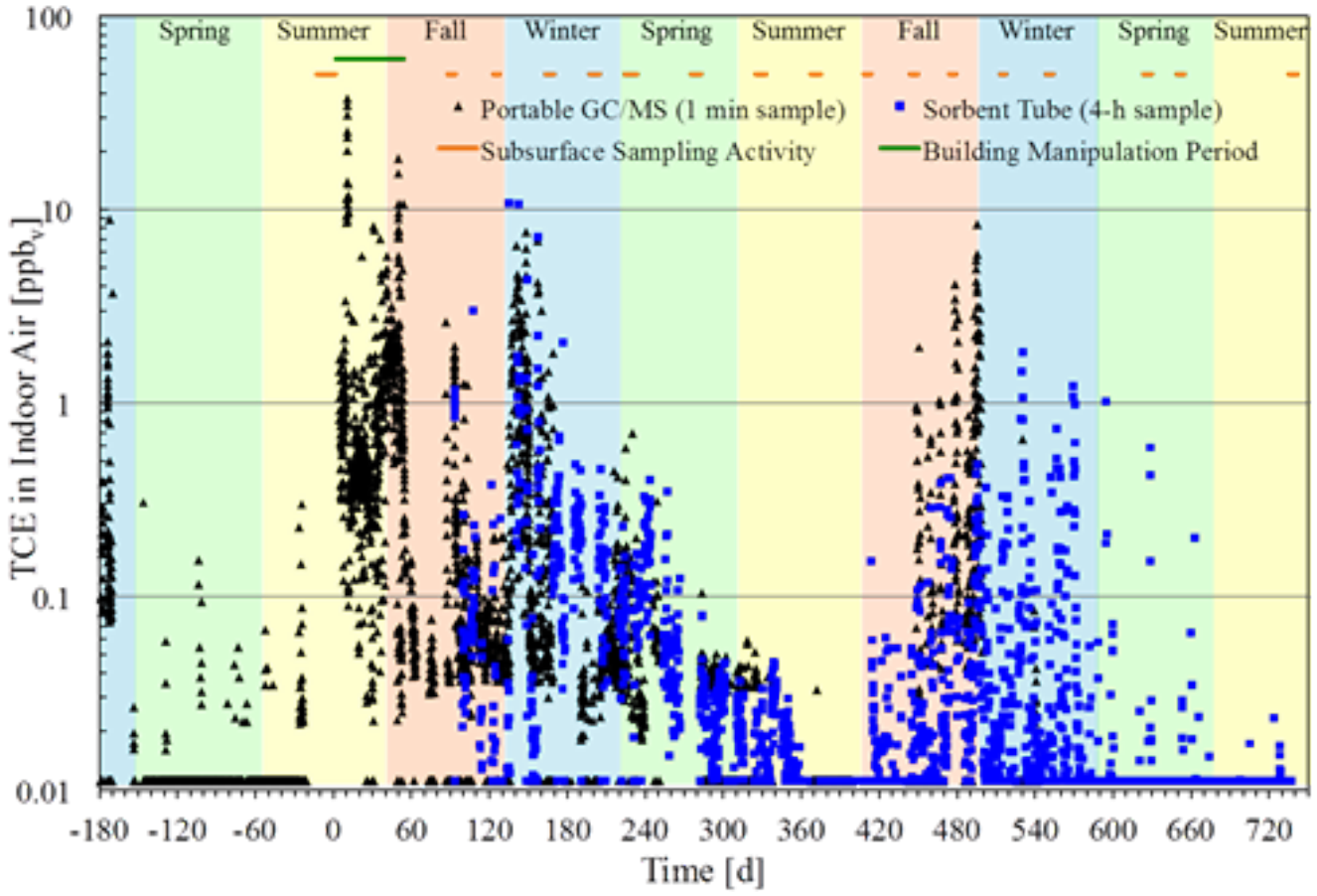
- **Preferential or conduit pathways**, such as sanitary sewers, can serve as significant vapor migration pathway and can be difficult to identify using conventional investigation tools.




Reference: Guo et al., 2015

# Temporal Variability

- **Temporal variability** of indoor air VOC concentrations of 1-3 orders of magnitude reported at several highly studied residences.
- High temporal variability is difficult to characterize using conventional sampling strategies

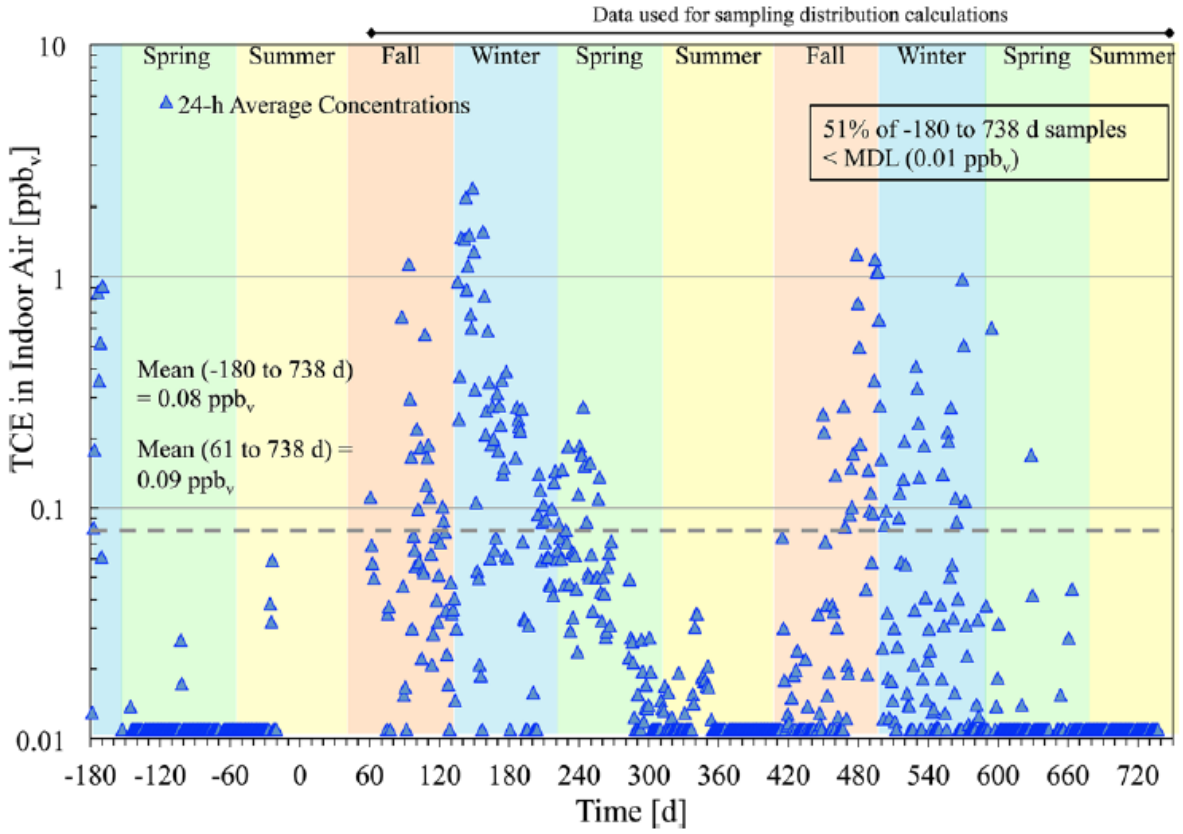



Reference: Holton et al., 2013, *Environmental Science & Technology*

# Temporal Variability: Sampling Strategies

***Data Evaluation Approach:***

- Converted real-time indoor air TCE concentration data sets to 24-hour data set
- Separated 24-hour data set by season
- Simulated sampling schemes
  - Seasonal/Quarterly (4 samples)
  - Winter-Summer (2 samples)
  - Winter-Winter (2 samples)

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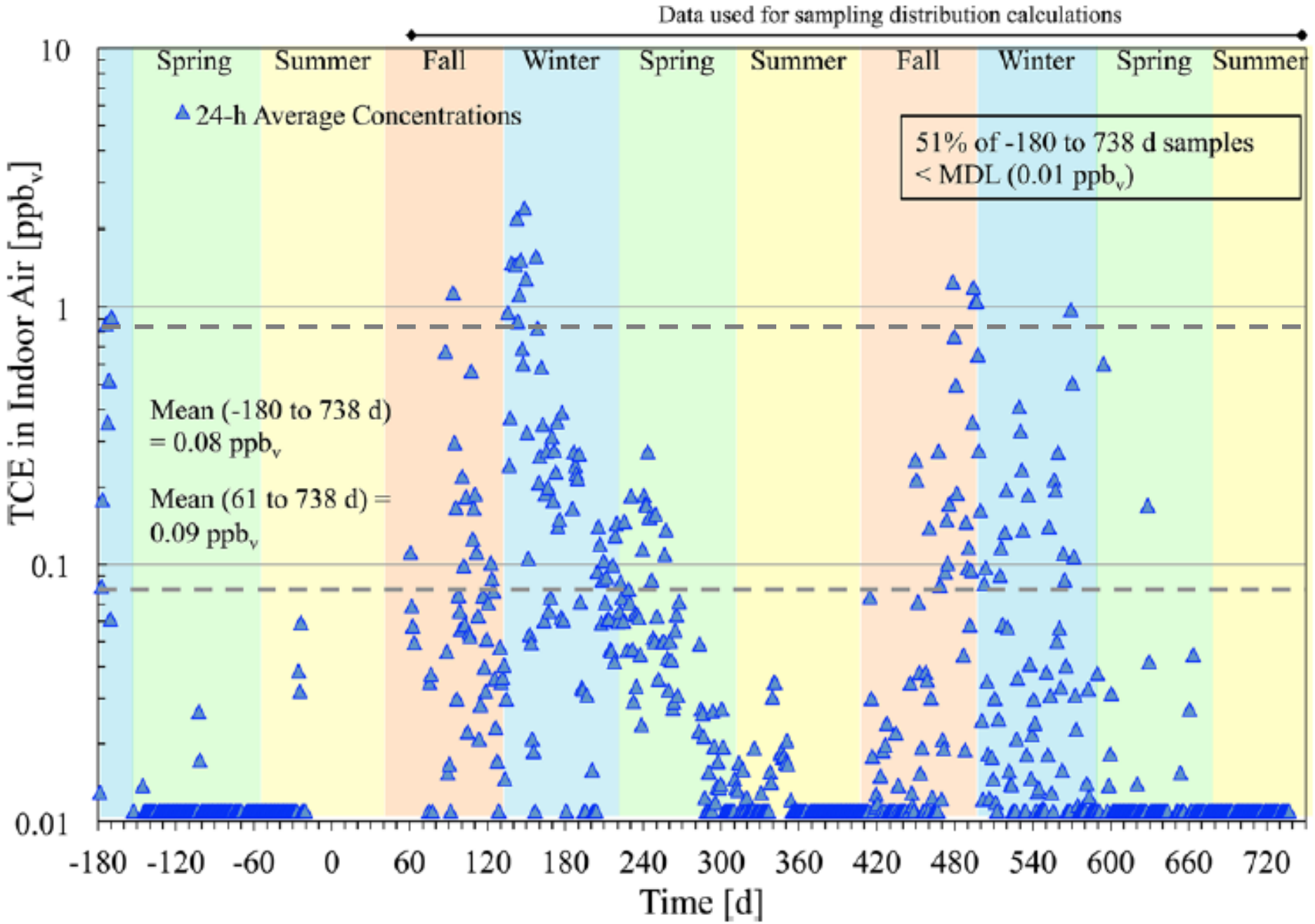


**10x** "True Mean" (0.9 $ppb_v$)

"True Mean" (0.09 $ppb_v$)

# Temporal Variability: Sampling Strategies

**Table 1. Probability of One or More Indoor Air Samples Exceeding the Target Concentration for a Range of (Target Concentration/True Mean Concentration) Ratios and Three Different Sampling Strategies[a]**

| | sampling strategies | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | fall, winter, spring, and summer sampling (four samples total) | | | | winter and summer sampling (two samples total) | | two winter samples (two samples total) | |
| | number of samples exceeding the target concentration | | | | | | | |
| (target/mean) concentration | 1 | 2 | 3 | 4 | 1 | 2 | 1 | 2 |
| 0.2 | 94% | 64% | 20% | 1% | 72% | 4% | 91% | 51% |
| 0.5 | 80% | 34% | 5% | 0% | 54% | 0% | 80% | 28% |
| 1 | 60% | 14% | 1% | 0% | 41% | 0% | 66% | 15% |
| 2 | 38% | 4% | 0% | 0% | 28% | 0% | 49% | 9% |
| 5 | 17% | 1% | 0% | 0% | 12% | 0% | 22% | 1% |
| 10 | 10% | 1% | 0% | 0% | 8% | 0% | 16% | 1% |

[a]True Mean = 0.09 $ppb_v$ for the synthetic data set. MDL = 0.01 $ppb_v$ for the synthetic data set.

Reference: Holton et al., 2013, *Environmental Science & Technology*

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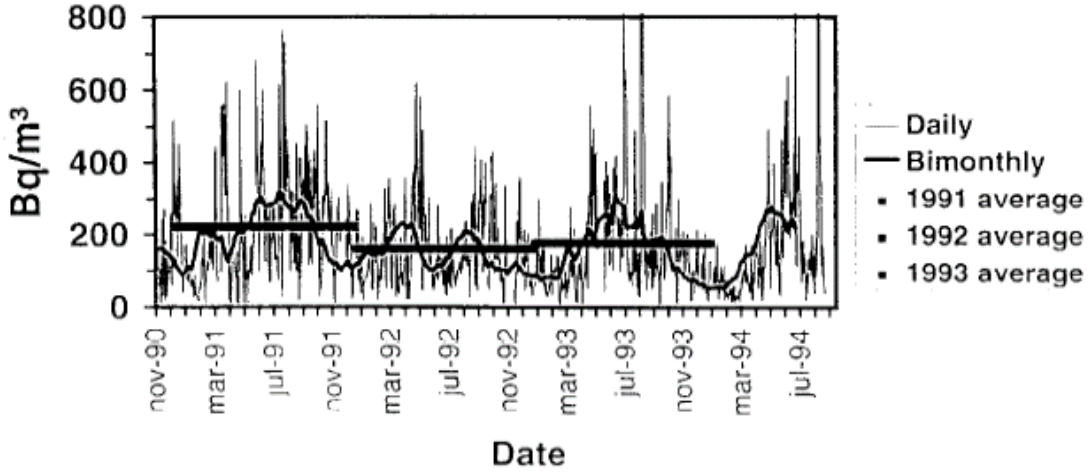
# Lesson from Radon Literature

**STUDIES ON TEMPORAL VARIATIONS OF RADON IN SWEDISH SINGLE-FAMILY HOUSES**

Lynn Marie Hubbard, Hans Mellander, and Gun Astri Swedjemark
Swedish Radiation Protection Institute, S-171 16 Stockholm, Sweden

Environment International, Vol. 22, Suppl. 1, pp. S715–S722, 1996



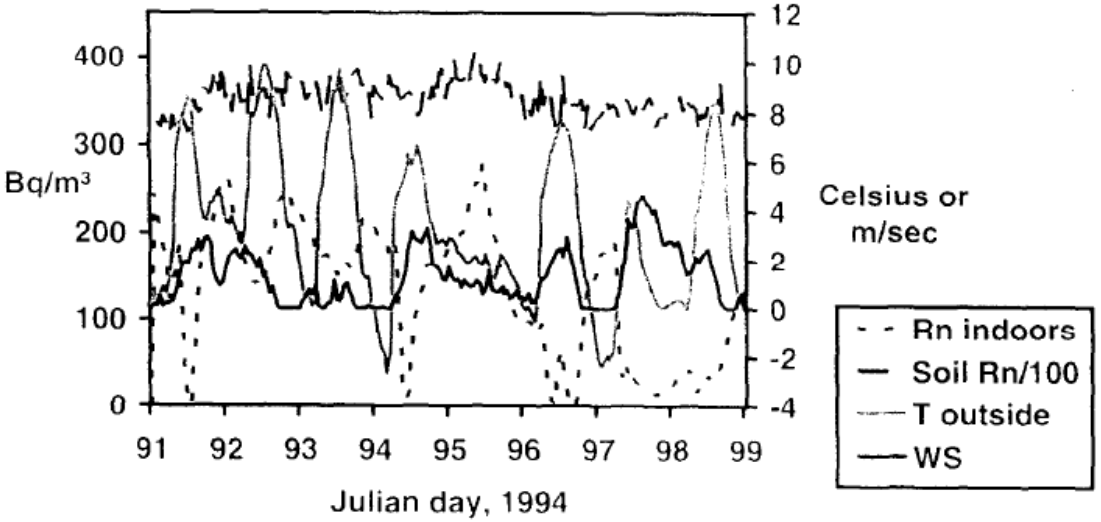




Figure reference: Adapted from Hubbard et al. (1996) (L) and Hubbard and Hagberg, 1996 (R)

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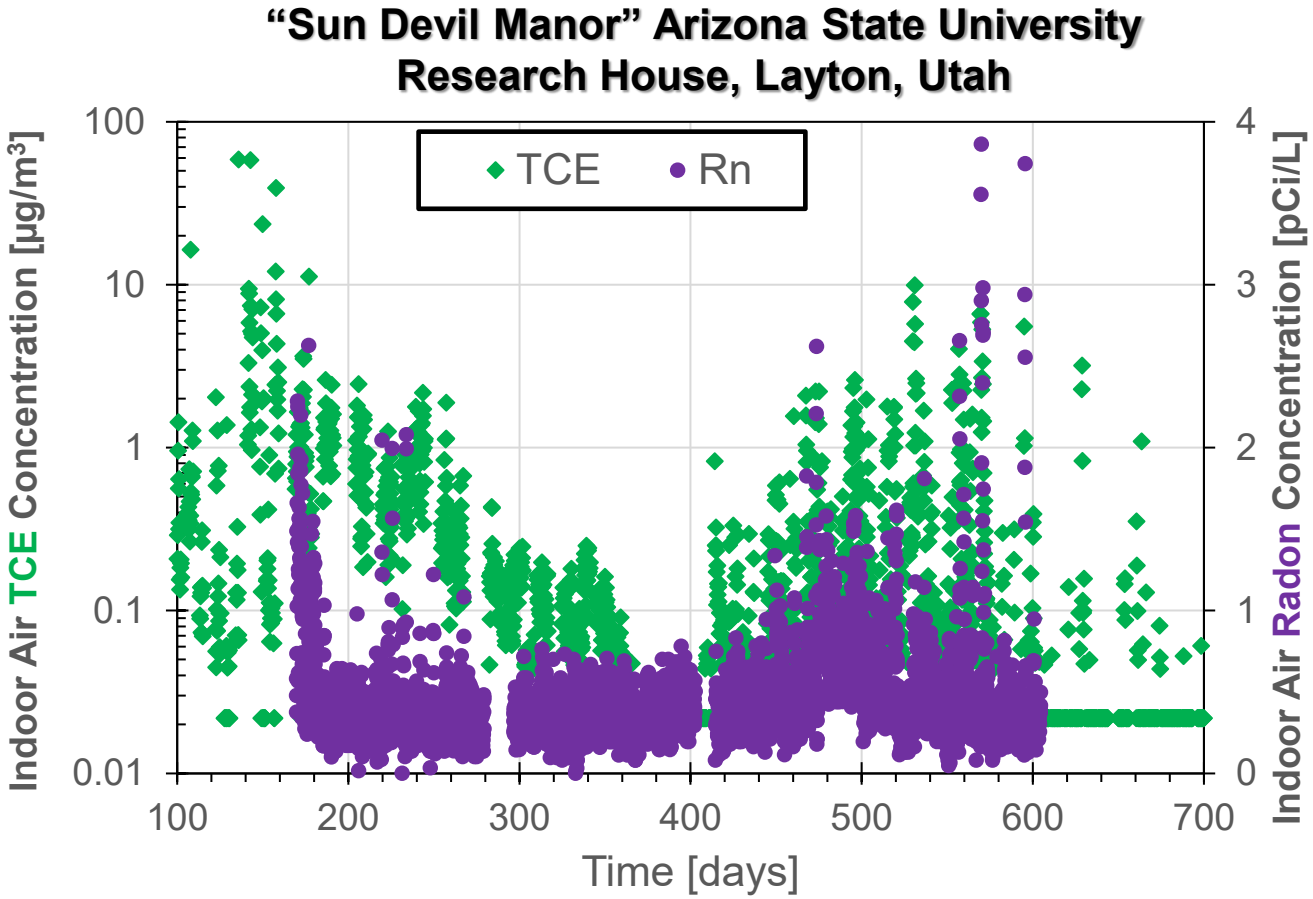
# Indicators of Vapor Intrusion

- Potential indicators of vapor intrusion
  - Indoor air radon concentration
  - Temperature
  - Differential Pressure
- Is there evidence that indicator-based sampling approaches improve indoor air characterization?



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# Evaluation of Indicator-Based Sampling Strategies

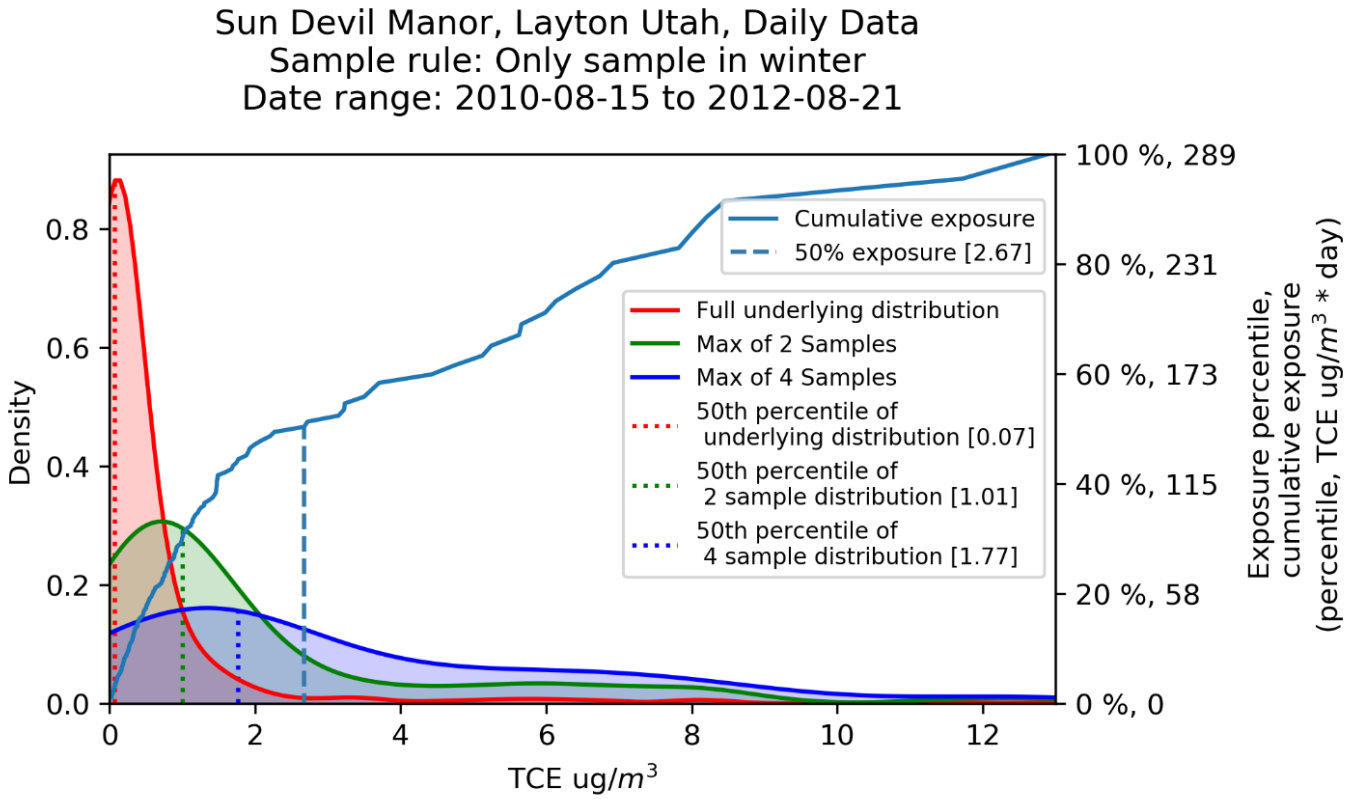
Start with Long-Term Indoor Air and Meteorological Data from Multiple Sites and Sampling Zones

Apply Sampling Rules to Generate Data Subsets

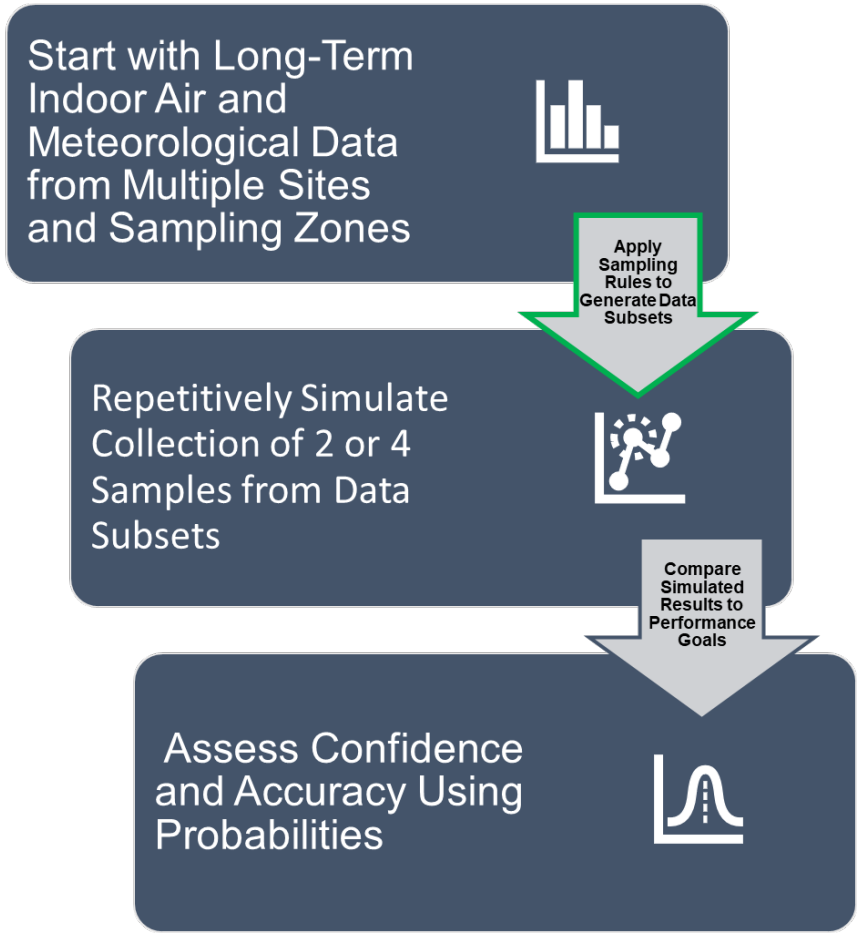
Repetitively Simulate Collection of 2 or 4 Samples from Data Subsets

Compare Simulated Results to Performance Goals

Assess Confidence and Accuracy Using Probabilities



# Evaluation of Indicator-Based Sampling Strategies




**Twenty-five** sample collection "rules" were evaluated:

(a) Calendar or seasonal-based (n=8),

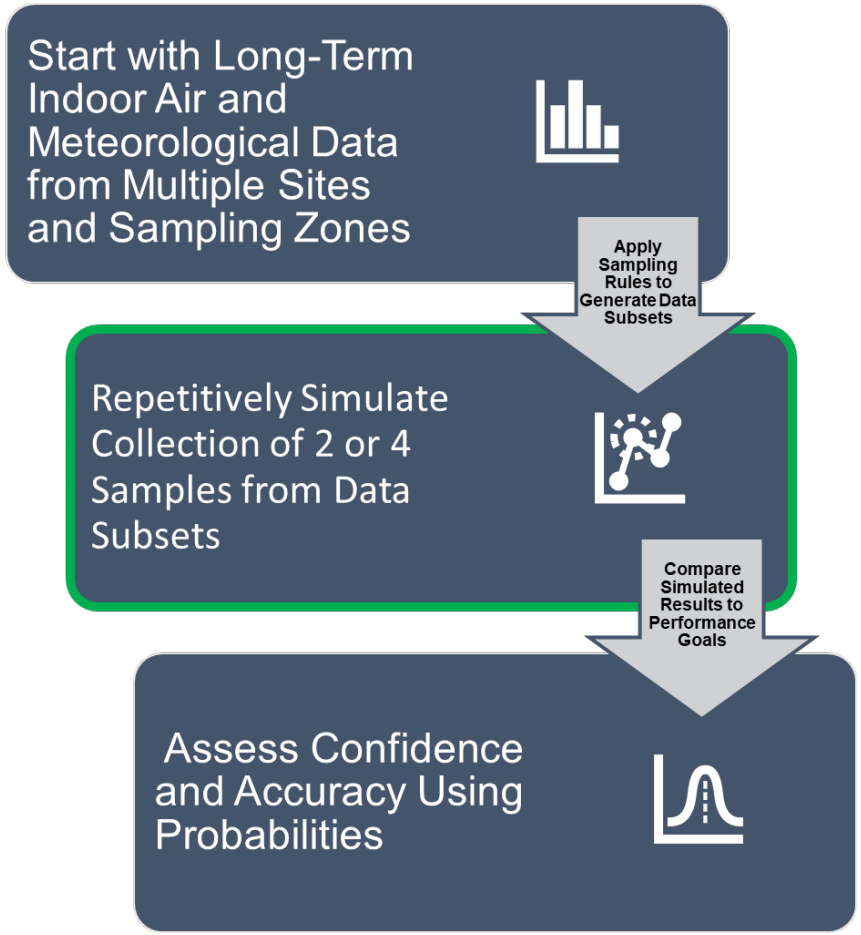
(b) Meteorologically-based (n=5),

(c) Indoor air radon concentration-based (n=5), and

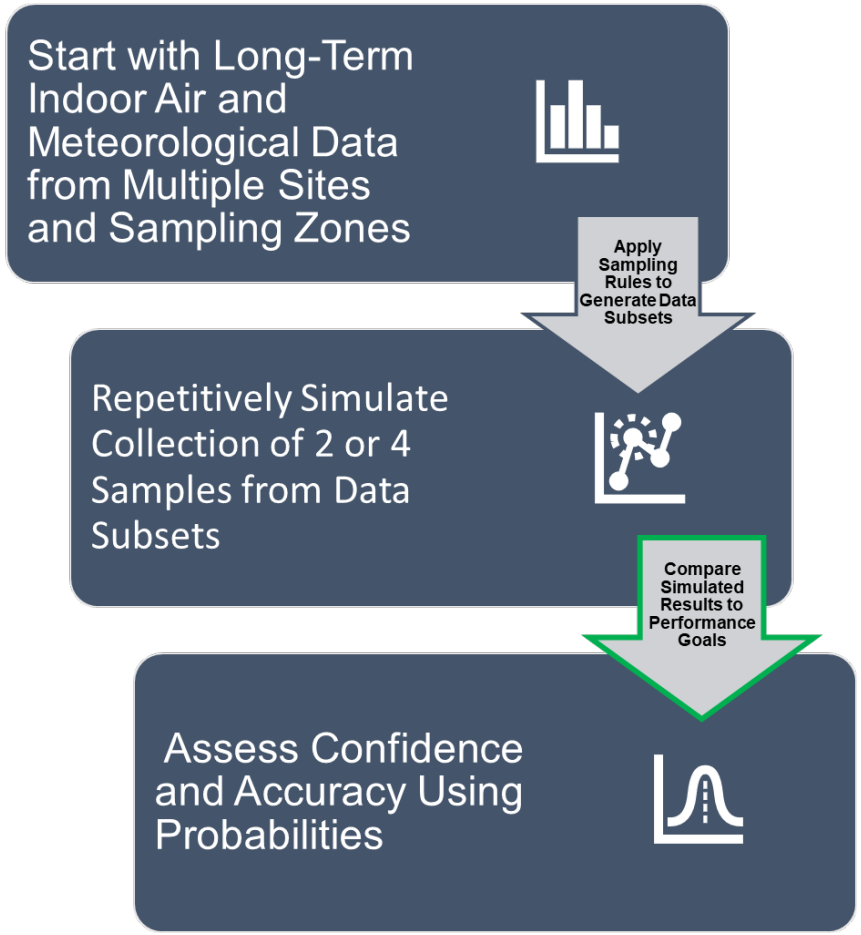
(d) Combination of rules (a) through (c) (n=6).

(e) Convenience-based "random" sample collection (n=1)

# Evaluation of Indicator-Based Sampling Strategies




# Evaluation of Indicator-Based Sampling Strategies




**Performance goals** were set based on summary statistics of the full dataset and included determining if at least one sample in the subsets equaled or exceeded:

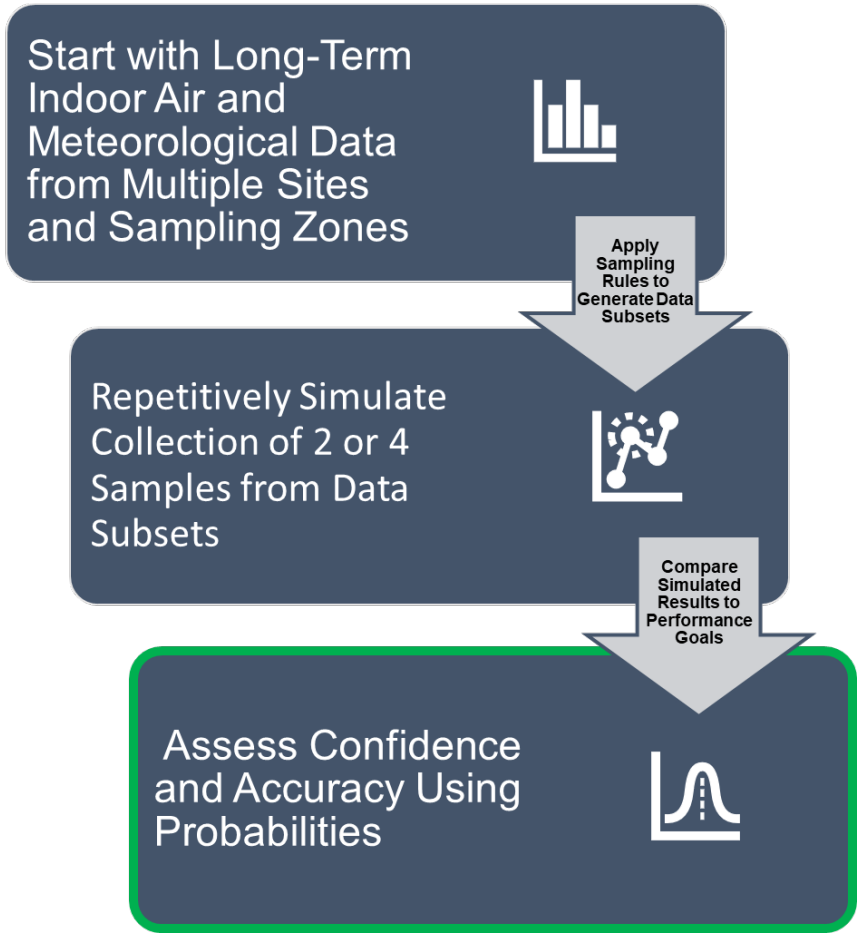
(a) Mean

(b) 90$^{th}$ percentile

(c) 95$^{th}$ percentile

(d) 50$^{th}$ percentile of the cumulative exposure curve

# Evaluation of Indicator-Based Sampling Strategies

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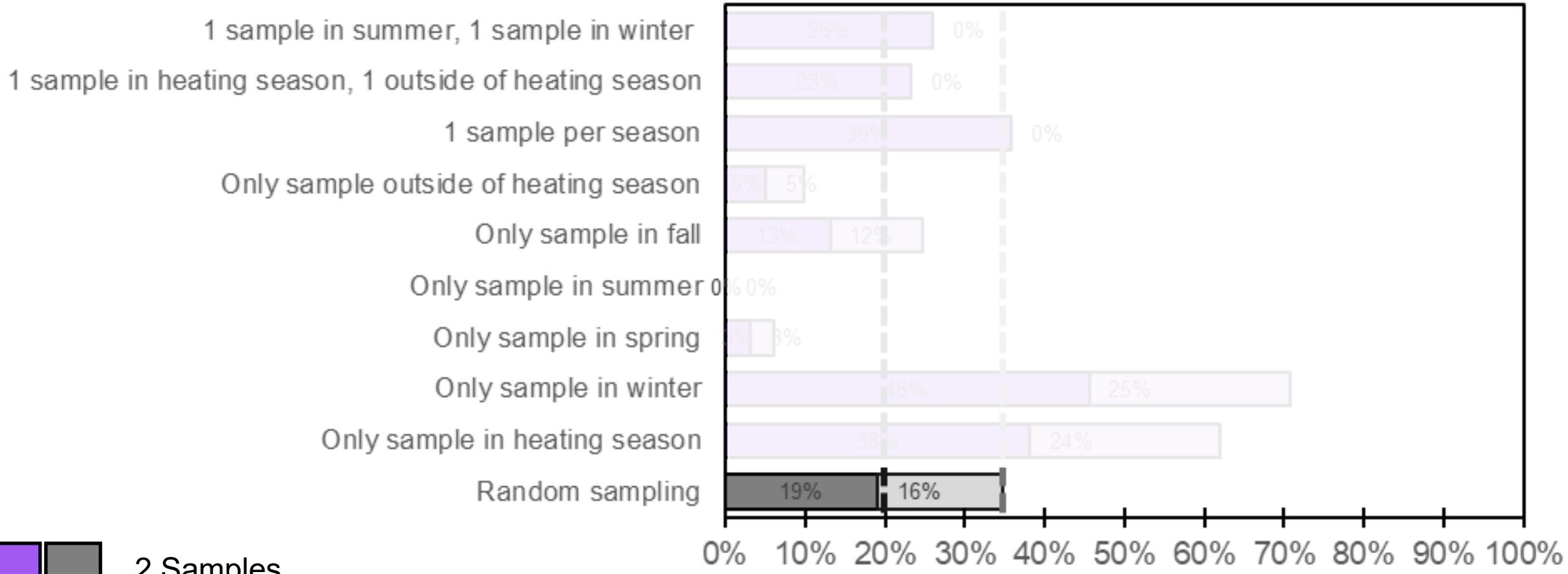
# Median Performance Across All Sites: Seasonal Sampling

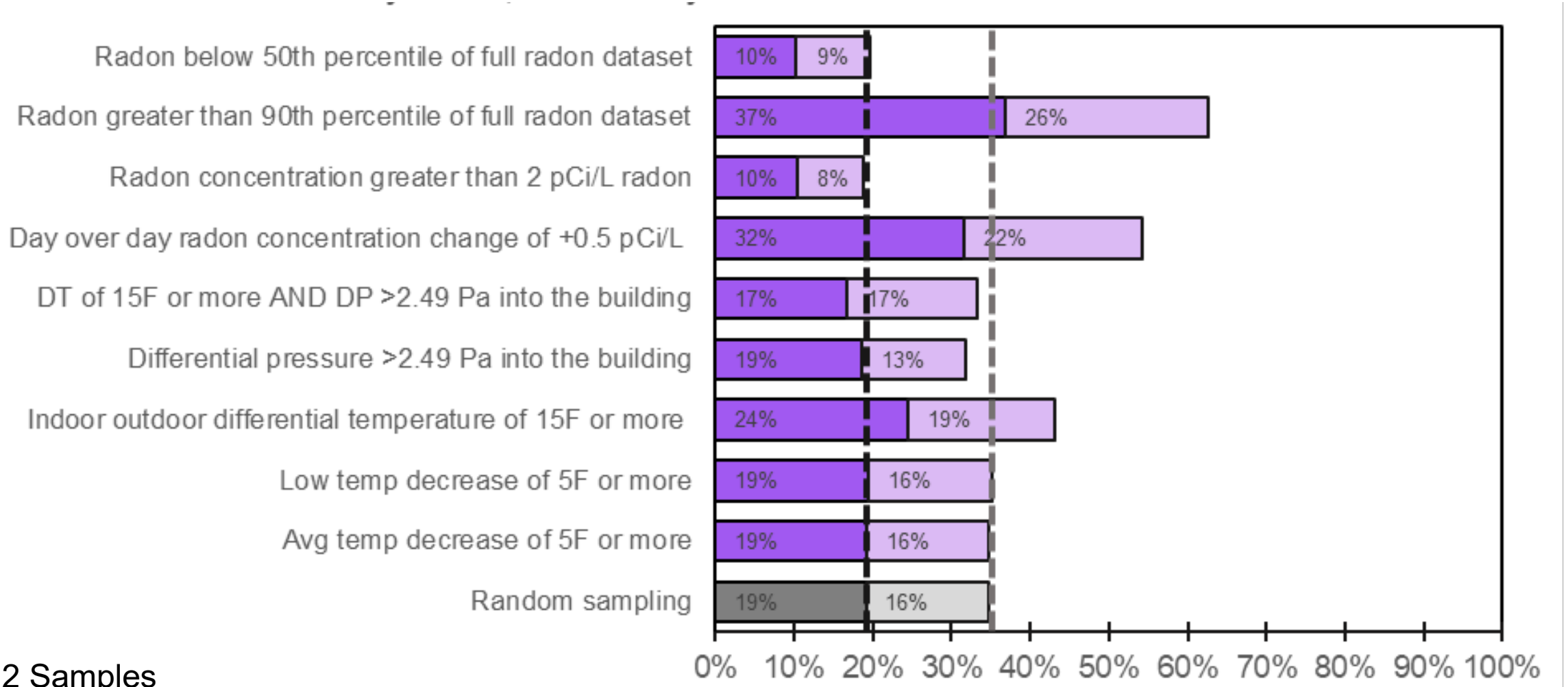



**Probability of collecting 1 sample exceeding the 90th percentile of the underlying distribution**

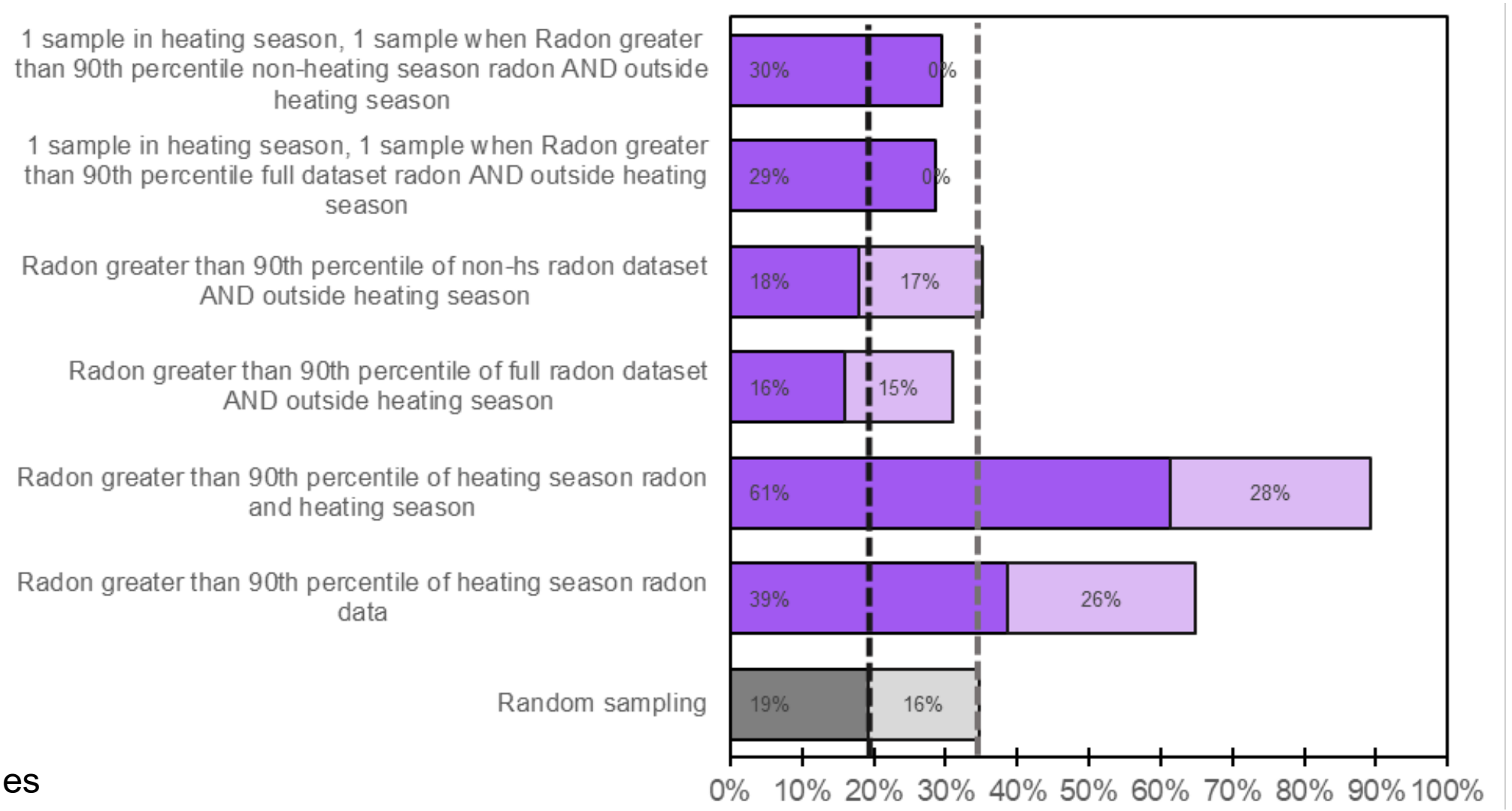
2 Samples

4 Samples

# Median Performance Across All Sites: Indicator-Based Sampling



# Median Performance Across All Sites: Seasonal and Indicator-Based Sampling




2 Samples

4 Samples

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# Summary

- Vapor intrusion assessment challenges are difficult to overcome using conventional sampling methods.
- Indicator-based sampling strategies generally outperform random indoor air sampling, but the optimal strategy varies across sites.
- New sampling strategies are needed to evaluate short- and long-term risks.

# Questions?


*Contact:*
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