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Mostly 'pipe' VI

Some 'pipe' VI

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RTI INTERNATIONAL

Introduction to
Measurement-Based Methods for Protective & Defensible Chlorinated VI Exposure Determinations

Workshop to Incorporate Regulatory Perspectives

Henry Schuver*, Chris Lutes, Chase Holton, Jeff Kurtz, Brian Schumacher, John Zimmerman & Robert Truesdale

AEHS East Coast Conference

Amherst, MA; Oct. 22, 2019

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* *Personal Perspective & Presentation – Does not represent Agency policy*

See: https://iavi.rti.org/workshopsandconferences.cfm and http://epa.gov/oswer/vaporintrusion

Regulatory Context for Workshop
>20 years ago (1999) EPA cautioned … Re: VI*

[2] This [VI] is ***a rapidly developing field*** *and reviewers are encouraged to* ***look to the latest guidance*** *for the* ***appropriate methods*** and **scale of demonstration** necessary to be ***reasonably certain*** that indoor air (in structures located above (and adjacent to) groundwater with volatile contaminants) does **not** present **unacceptable** risks.

2019 – Find **Unacceptable *VI* exposures** have been **on-going …**

- At ***previously-assessed*** sites
- One community w/ > child disease rates; Mothers sampled own indoor air to find on-going VI exposures …

- EPA's **Inspector General** – recommends **verifying the accuracy** of ***all*** **EI (incl. VI) determinations**
  - **Epa.gov/office-inspector-general/report-management-alert-certain-risk-communication-information**
  - **Strong interest** in making sure we **don't have any more surprises** like that
  - **&**
- **RCRA** has **a major EI measurement # Goal deadline by Dec. 2020 –** those *need to* be **accurate**
  - It may be time to update Footnote 2 and make more specific …

*RCRA Human Exposure EI (Environmental Indicator) -Interim Final, Feb. 1999, **Question 2**

Ques. 2 - Media "reasonably suspected to be "contaminated"" – Air (indoors) **[2]**

- https://www.epa.gov/sites/production/files/2016-04/documents/ei_guida.pdf = EI forms/guidance
- https://clu-in.org/eiforum2000/ - EI guidance Training slides

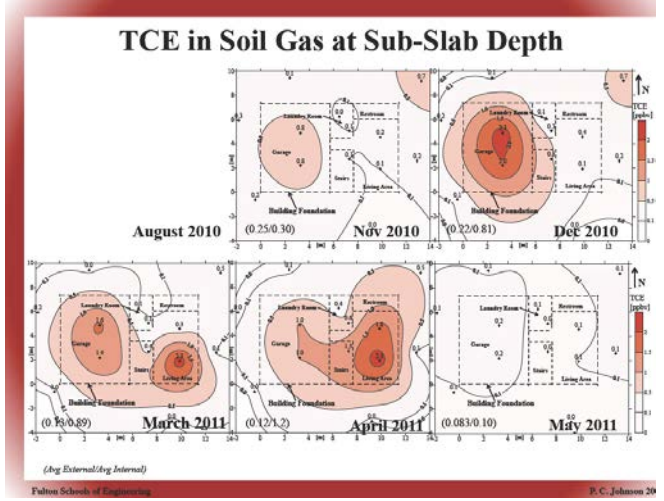
If you were asked to characterize Confidence

for sub-chronic/developmental exposures

- Indoor air Samples representing the Exposures of concern
  - Building
  - Site
  - e.g., ___% Confidence
  - How would you do that? What evidence would you use?
  - That has been our challenge for > 20 years - & led to today's workshop

Technical Background:

Why supplemental measurements (MLE)?



- ***Only* <u>indoor</u> air *<u>conc</u>*. –** reflects all variables*
  - Rich-data-sets show **Highly variable** across **Time** (& Space)

- Chemical measurements – **expensive**** & **disruptive** to occupants: **1-4**?
  - Confidence in exposures is typically **low** – so need Multiple Lines of 'Evidence'
  - Hypothesis today – The MORE **<u>MEASURABLE</u>** VI-*associated* evidence the Better

***Model predictions** of VI have **not** been **validated**
(e.g., one attempt since 1992 – only works if silt is considered sand …)
Soil gas conc. weakly correlated with indoor conc. (**Atten. Fact. vary over S & T**)
**access, clearing 'background' sources, collection & analysis

Quantifiable Confidence – Still *missing* for VI

- Quantifiable Objectives for Confidence – e.g. **guidance** criteria:
  - **95th UCL*** on Mean (chronic effects)
  - **95th %ile**** RME (sub-chronic effects)
  - These Goals **are** achievable for various environmental media/exposure pathways:
    - **Groundwater** ingestion
    - **Ambient Air** inhalation
    - **Soil Ingestion/Dermal** contact
  - And ***should be*** demonstrably achievable for **Vapor Intrusion** exposures
    - **IF** we want to provide the same level of protection from VI as from other pathways

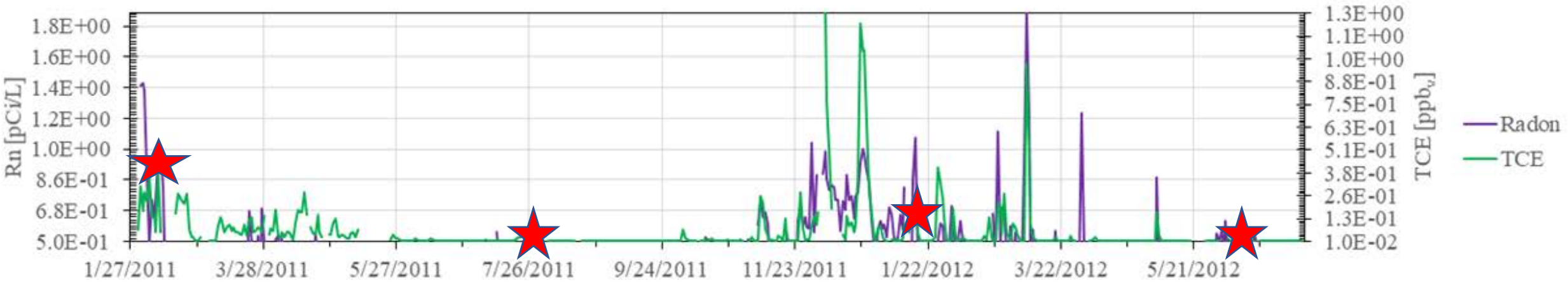
* UCL = Upper Confidence Limit

** a central estimate of RME range of 92nd to 98th%tile of exposure distribution

How confident are we of VI exposure est.?

What level of confidence is appropriate?

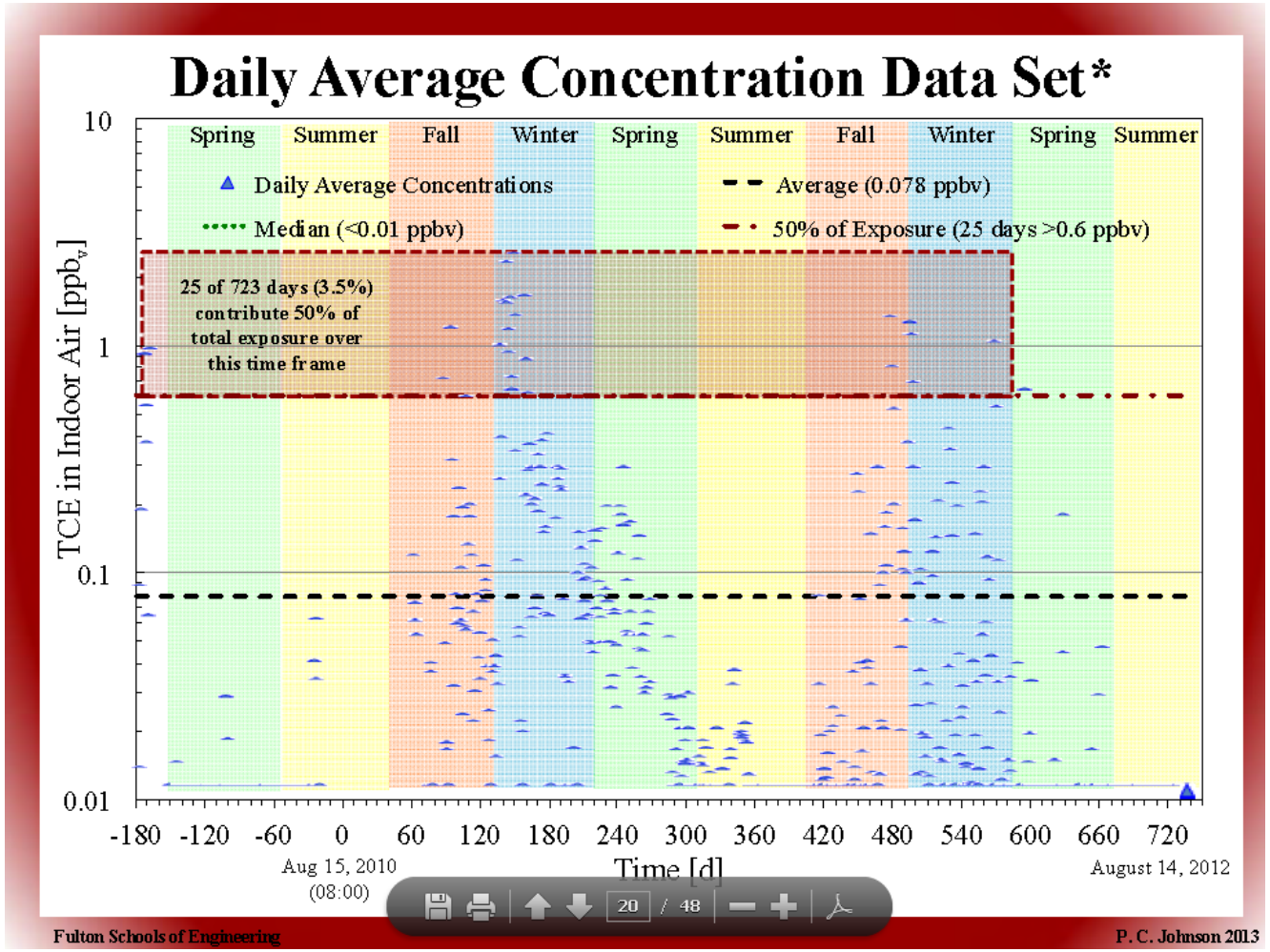
- **Chronic** risk
  - Long-term Average (95%UCL)
  - Typical quarterly ~ OK ?
- **Sub-chronic** (developmental) risk
  - Reasonable Max. Exposure (RME)
    - ~ 95th%ile
  - Could be as short as 1-day



Indoor air is *variable* & Episodic Peaks can Drive Exposure

25 days (*3.5%*) present more exposure than the other 698 days

One building w/ 2-hr indoor air samples for ~ 2 years



Chemical VI (TCE) at ASU's 'Sun Devil Manor' (SDM) CVI research house

Dr. Paul Johnson's slide 20/48 - Note audio recording of presentation also available at:
https://iavi.rti.org/attachments/WorkshopsAndConferences/05_Johnson_03-19-13.pdf

Disease Assoc.*

Short-term-effects

- TCE plume (70 block) area:
  - ~2615 residents, 1090 births ('
    - 248 effects ~~ 1/4
  - 117 Small for gestational age
    - RR = **1.23** (95% CI = 1.03-1.48)
  - 76 Low birth weight
    - RR = **1.36** (95% CI = 1.07-1.73)
  - 37 Term low birth weight
    - RR = **1.68** (95% CI = 1.20-2.34)
  - 15 Cardiac defects
    - RR = **2.15** (95% CI = 1.27-3.62)
  - 3 Conotruncal** defects
    - RR = **4.91** (95% CI = 1.58-15.24)

ehp ENVIRONMENTAL HEALTH PERSPECTIVES

ehponline.org

"Conclusions: Maternal residence in both areas was associated with cardiac defects. Residence in the TCE area, but not the PCE area, was associated with low birth weight and fetal growth restriction."

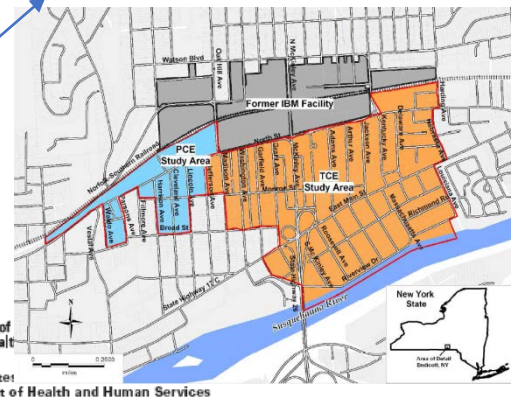
Maternal Exposure to Tetrachloroethylene and Trichloroethylene through Soil Vapor Intrusion and Adverse Birth Outcomes in New York State

Steven P. Forand, Elizabeth L. Lewis-Michl, Marta I. Gomez

http://dx.doi.org/10.1289/ehp.1103884

Online 5 December 2011

3 mos. after TCE in IRIS



NIEHS National Institute of Environmental Health

National Institutes of Health
U.S. Department of Health and Human Services

Week 3: 15-21 days from fertilization - "Primitive **heart** tube is forming"
Week 4: 22-28 days from fertilization - "The heart bulges, further develops, and **begins to beat** in a regular rhythm."

* Also a similar paper on increases in adult ***cancers***

** "abnormal formation of the outflow tracts of the heart"

(RR) Rate Ratios relative to the rest of NY state (excluding NYC)

http://ehp03.niehs.nih.gov/article/fetchArticle.action?articleURI=info%3Adoi%2F10.1289%2Fehp.1103884

How many samples do I need?

- **Indoor**-air chemical concentrations

- To be confident of your decision

  1) Where — which (RME) building(s)

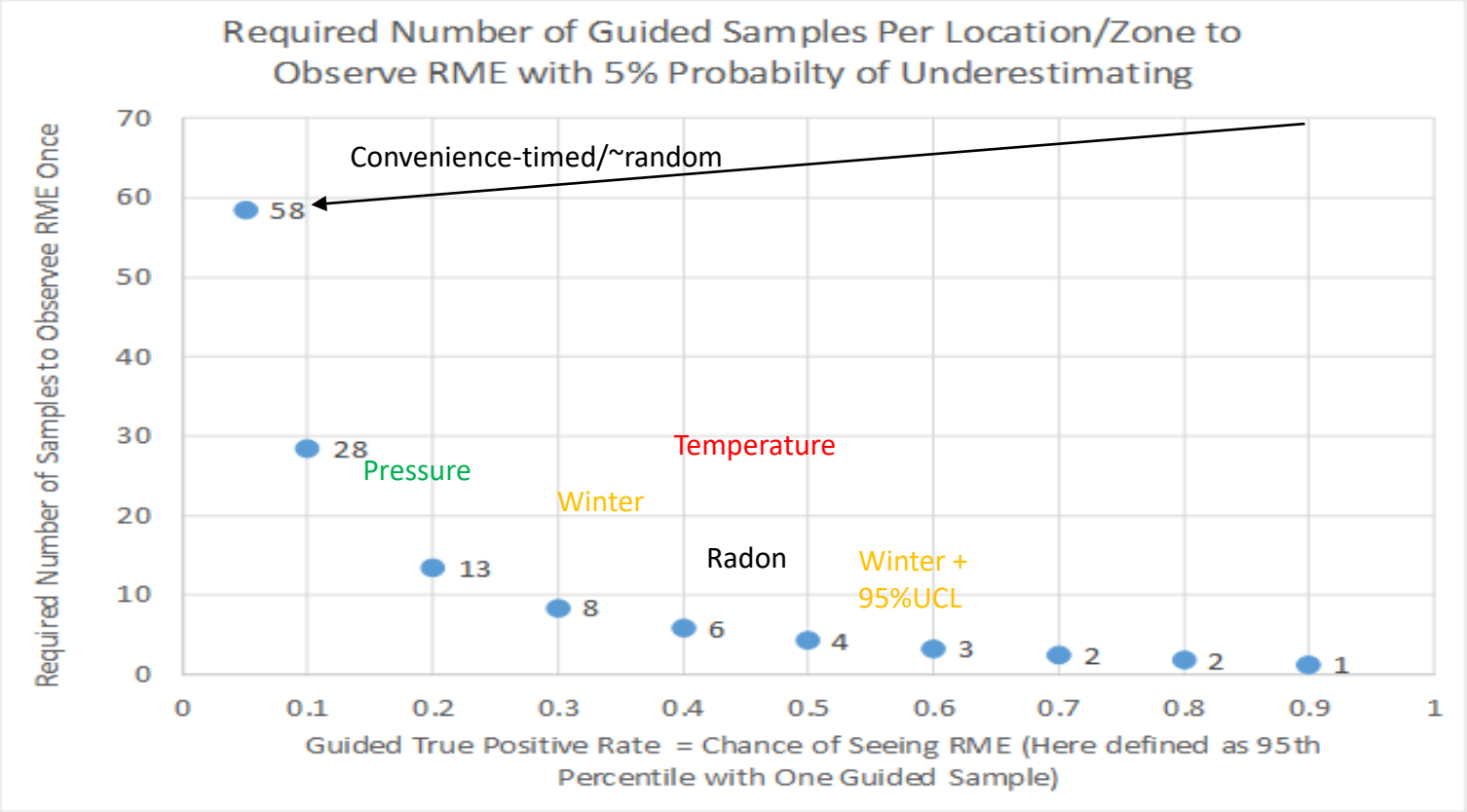
  2) When — to represent RME

  3) How many

  e.g., If CONTINUOUSLY unacceptable concentrations – Only 1

How many Samples are Needed?

for **Temporal variability** (***per bldg***.) to represent **95th%ile (RME)**



Note:

To observe upper 5%thile expect ~1/20 samples by random chance,

for 95% conf. need ~3 x 20 (58)

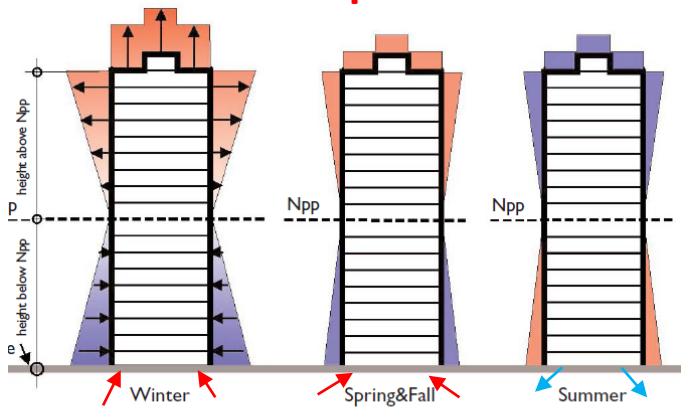
Indicators, Tracers and Surrogates (ITS) as VI-*associated* ***measurable physical features***:

- Relatively
  - Low cost, to measure
  - Practical measurements (as supplemental sampling evidence)
  - Can be statistically compared to Indoor CVOC conc. for possible statistical **Associations**
    - Temperature
    - Pressure
    - Radon (Rn)
- Measurements revealing conditions/forces Driving or Tracing VI at your site :
- Provides *insight into* VI *driving forces & building-factors* ***operating at the time of CVOC sampling*** (i.e., concurrent non-static measurements)
  - **Improves *interpretation* (meaning/value)** of *contemporaneous* **CVOC samples**
  - Could focus sampling on times & places most likely to have exposures of concern
  - **Reducing #** of indoor CVOC **samples needed**; i.e., to make decisions with **quantified/doc.** percentile (%ile) of exposure represented & Confidence levels

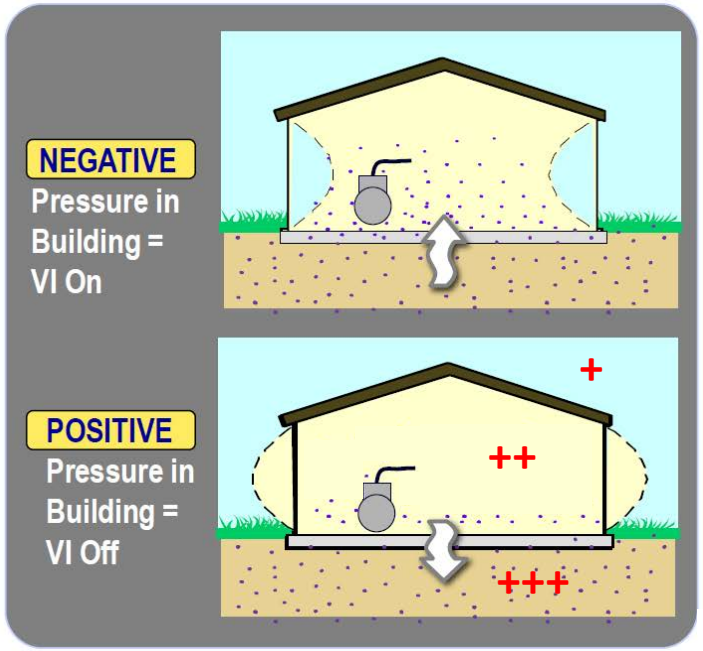
Indicators, Tracers & Surrogates (**ITS**) generic Conceptual Site Models (**CSM**) for *Measurable evidence* – ITS

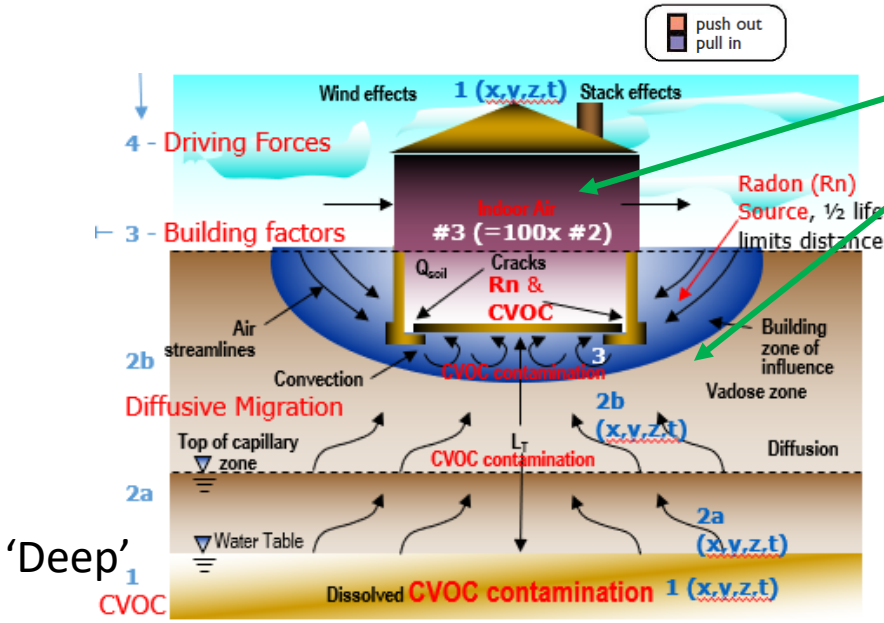
- Conceptual Model/Understanding for potentially useful applications
- **Temperature**, Out- & Differential
- **Pressure**, Out-, Indoor vs. Out- & SS
- **Radon**, Indoor, Diff. (In- vs Out- & SS)

Temperature - condition



Pressure - Force





Mod. from slide by M. Bolas, Ohio EPA, presented Jan. 2006

Radon - Tracer [conc.]

Building-specific Conc. *integrating*:
1-Intrusion
2-Mixing
3-Retention - of 'near-building'
SG, Rn, VOCs

Indicators, Tracers & Surrogates

Supplemental Lines of Evidence are ***Not*** Equal

Summary of conceptual relationships (as of Sept. 2019)

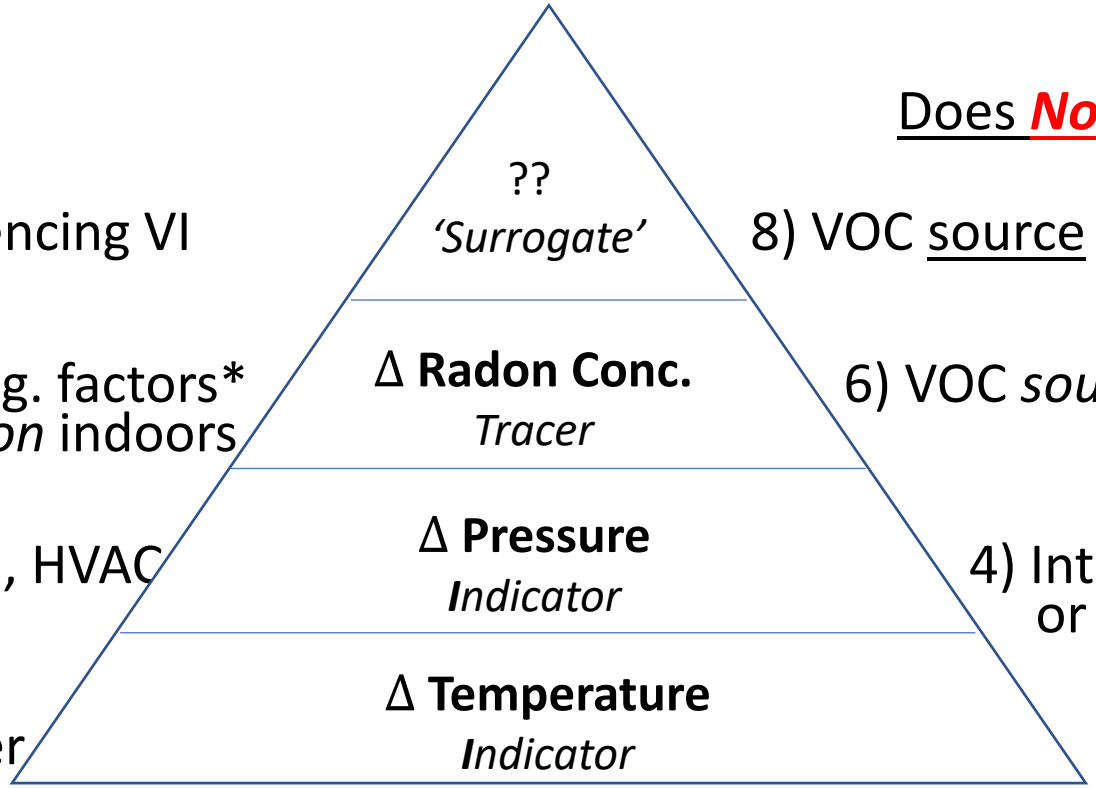
Includes:

7) All factors influencing VI

5) All nearby & Bldg. factors* mixing *& integration* indoors

3) Wind (sp. & dir.), HVAC

1) Primary VI Driver



Does ***Not*** include:

8) VOC source variation? (Space & Time)

6) VOC *source* vari. & Deep migrat./path.

4) Integration of Areas (SubSlab) or Time, Air Ex. Rates (AER)

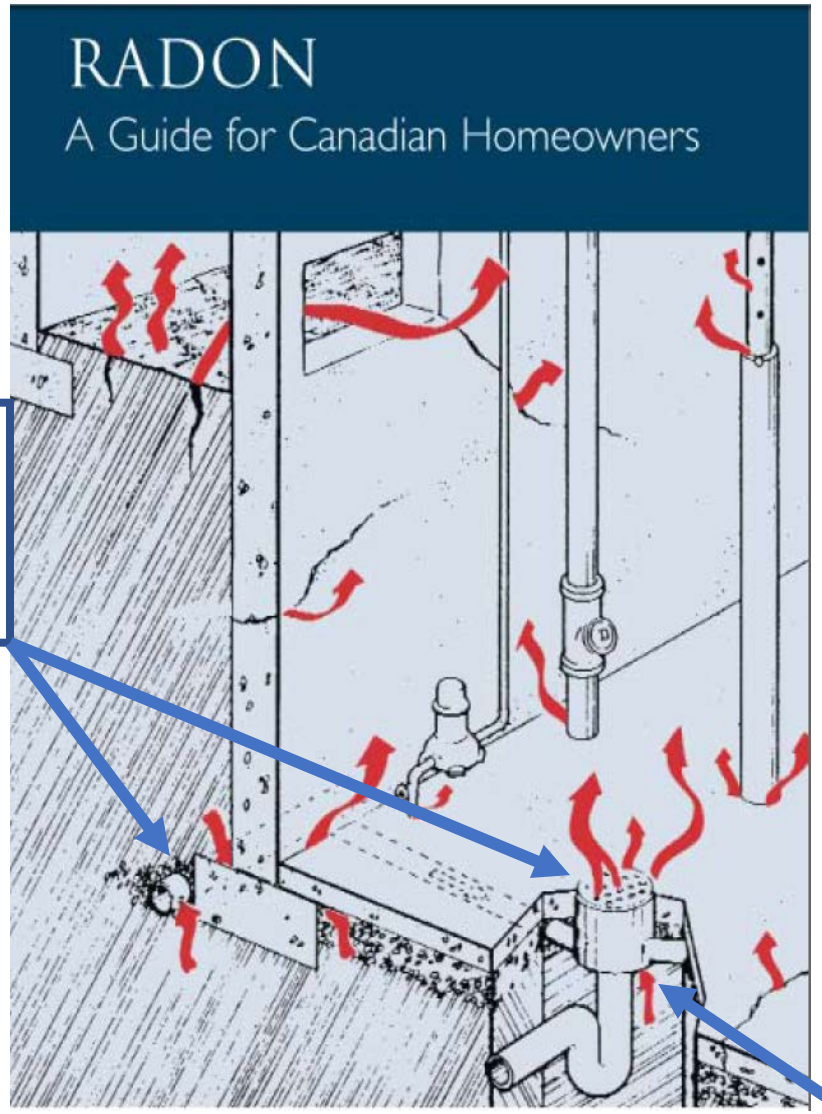
2) Wind (sp. & dir.), HVAC

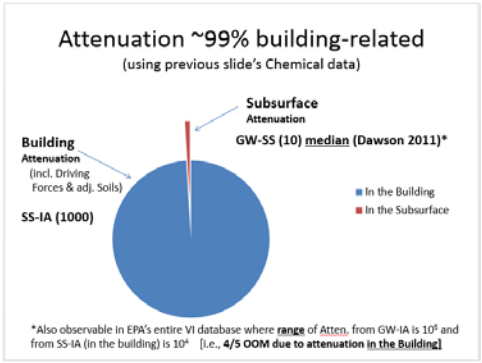
*Indoor **conc**. **when** Rn is sampled

USEPA Radon polices recognize Differences & Changes in Buildings: *Sample indoor air in all buildings, & through time*

1) Design
   - Ground contact
   - Heating type, HVAC
   - Height, elevation, orientation …
   - Vegetation?
2) Construction
3) Condition
4) Occupants/Operation
5) Natural changes
6) Man-made changes

Radon reflects **ALL pathways**, including 'alt.'/ anthropogenic





Attn: 99% SS-IA

Also, *not* shown here, building-specific ***exit*** paths above ground

It's Entry, Mixing & ***Retention***

See:
What is the Evidence for Stopping All Monitoring for VI? (Sept. 10)
What is the Evidence for LTS vs. Stopping All Monitoring (SAM)? (Nov. 19)
https://iavi.rti.org/WorkshopsAndConferences.cfm

Statistical Assoc. of Conc. across **Time**

Using Time Series (Linear) Regression; results for Two components:

Time Series Regression *Not practical*, computationally for typical-site application – But highly informative when applied

1) Direction of Conc. change. (*Qual.*)

99% (EPA-IN)
99.9% (SDM-UT)

Changing conc. direction together

Note Background (outdoor) Rn & < Det. Limit for TCE

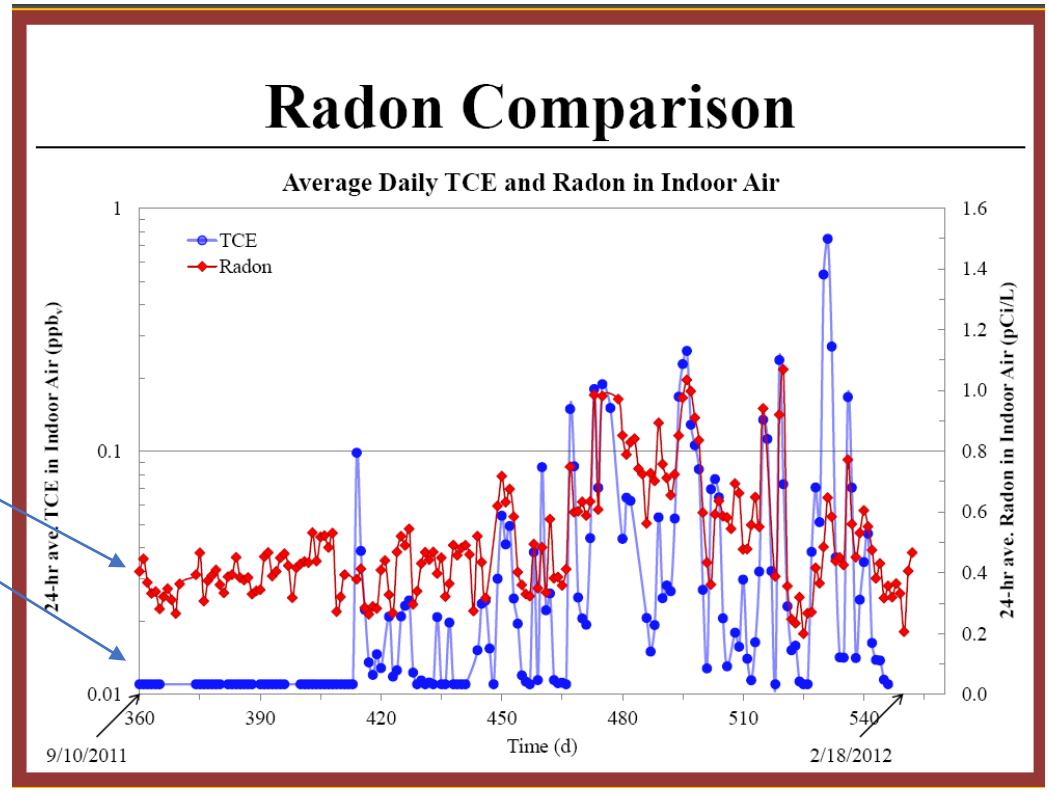
2) Magnitude

*Quant*itative 'proportionality' of conc. change

40% (EPA-IN)
25%-60% (SDM-UT)

~ ½ of change in TCE Conc. 'explained by' the change in Rn conc. (R^2)

Not confident enough for risk decision making



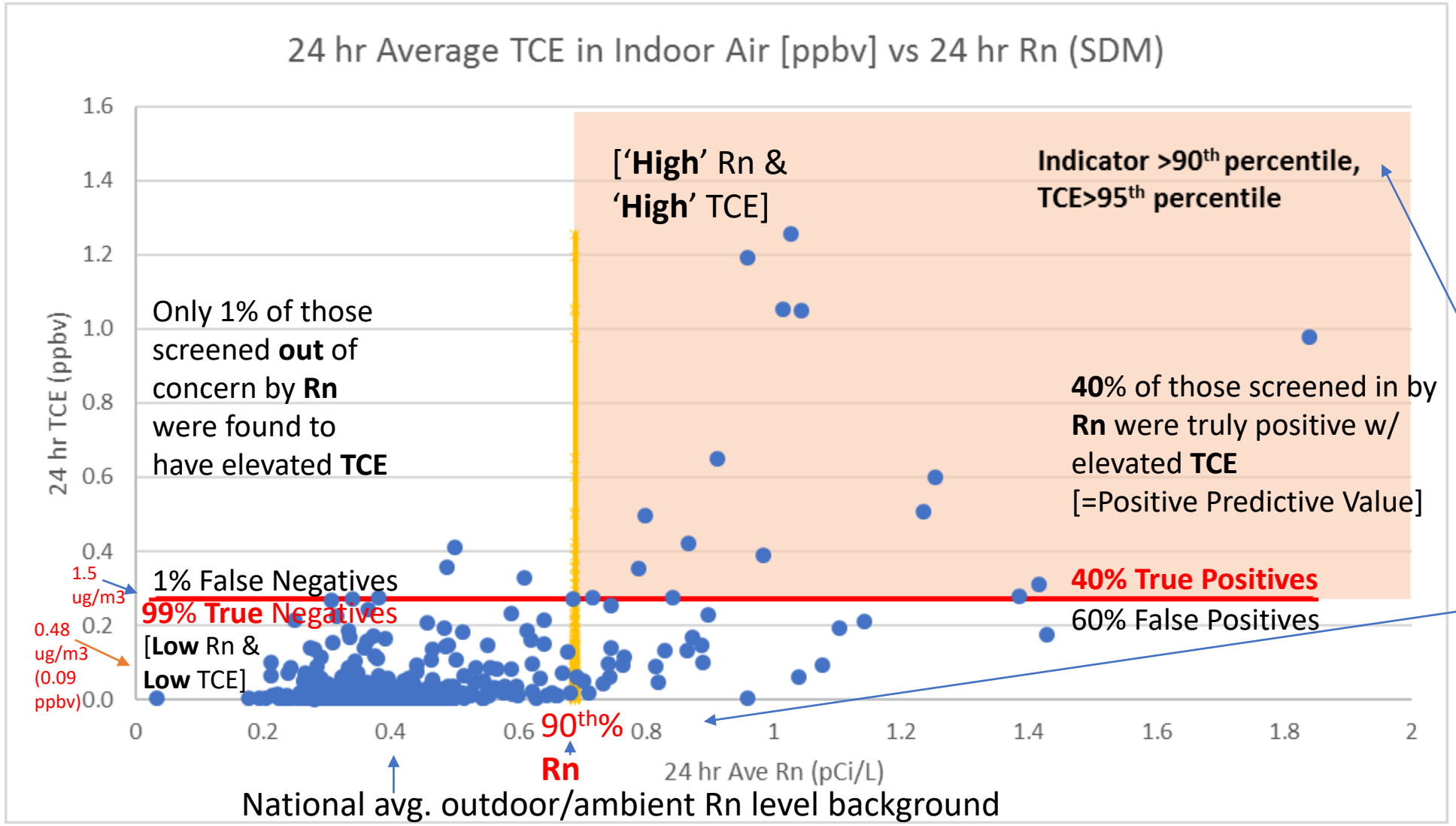
Sun Devil Manor (SDM), Layton, Utah

For Site application Tried Next:

Medical-screening / decision approach using categories of numbers (2x2 tables)

Not Diff. Radon *conc.* (indoor) as Indicator of TCE RME; at any Time order

Not practical; Trying to estimate and then time the chemical sample collection when Rn is elevated (>90%ile**) is difficult**



SDM has **Very-Low** Radon

90th%ile = **~0.7 pCi/L**

& preferential (pipe) pathway!

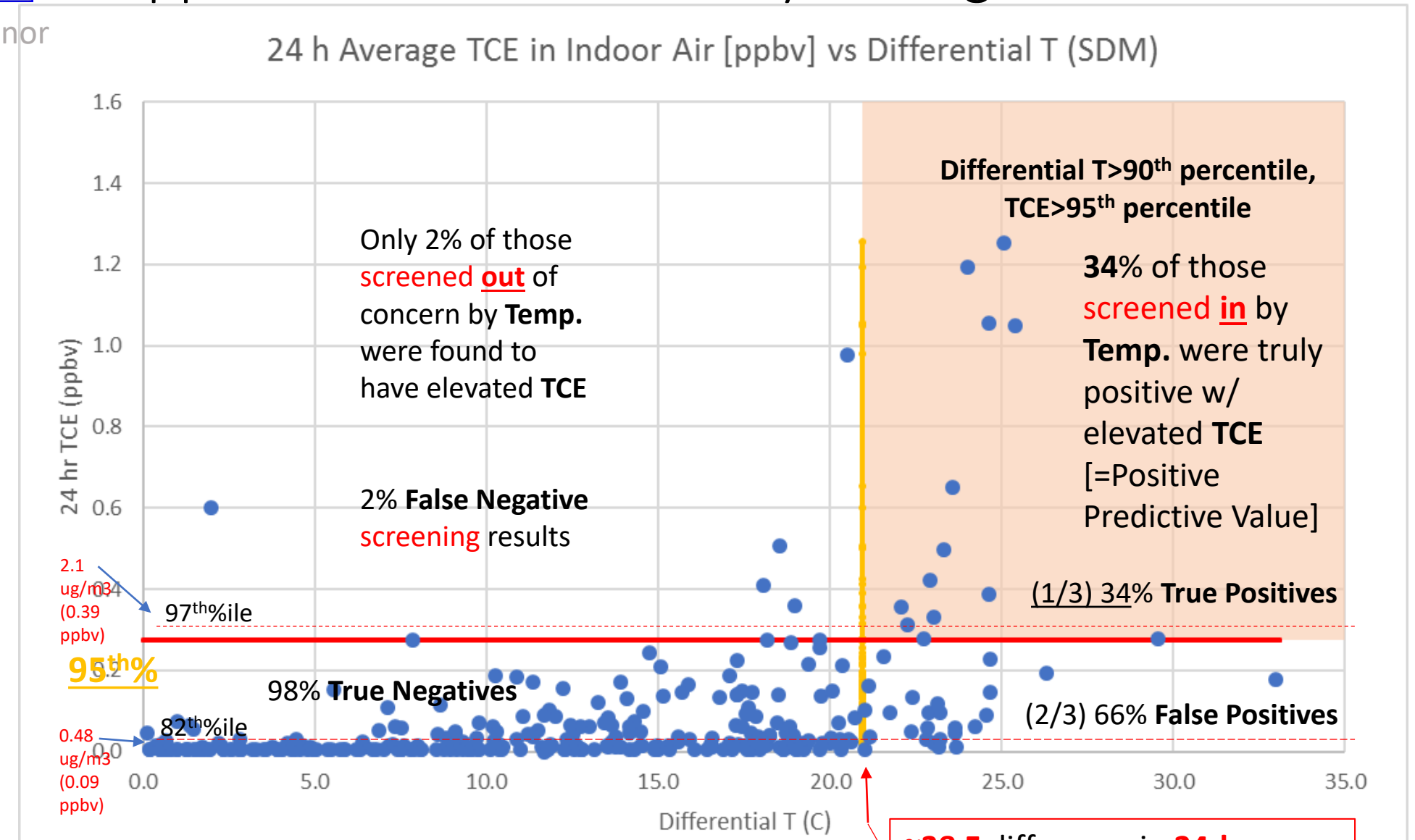
Diagnostic (Exposure) Screening of SDM house data, statistics by Kurtz

Looking for >95th% conc. of TCE, **99%** of the data 'Indicated' by non-elevated (<90th%) Rn were **correctly** 'screened **out**'

Sun Devil Manor

Differential Temperature Indicator (>90th%)

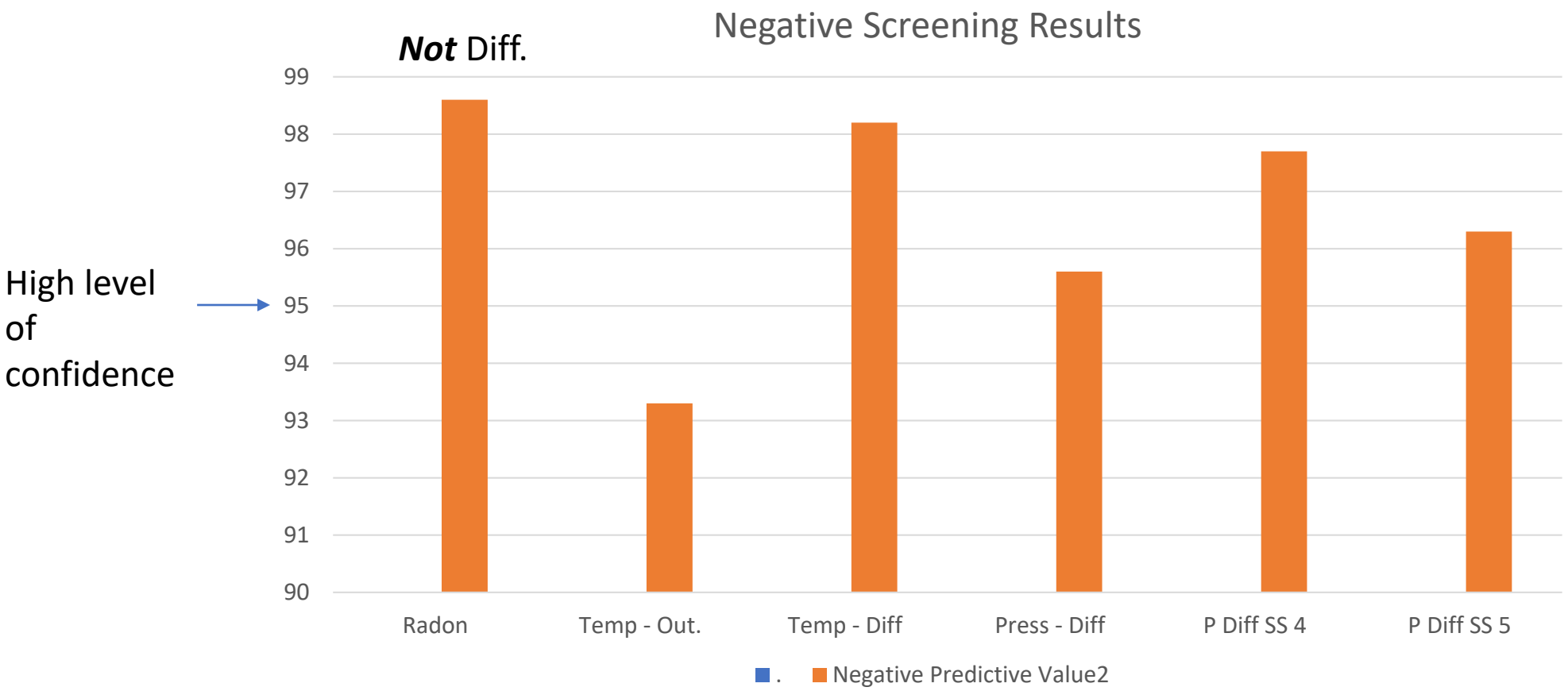
Approach for RME – Validity Testing



Dashed lines are Post-Work. 'cut' points

Note: If indoor temp. ~68 degrees F outside would need to be <30 degrees F as 24 hr. avg. to meet the 90th%ile for temp. (in UT)

Diagnostic (Exposure) Screening Results
Negative Predictive Value – SDM [one house]
(probability of '**Low**' ITS samples identifying '**Low**' chemicals (<95%ile RME))



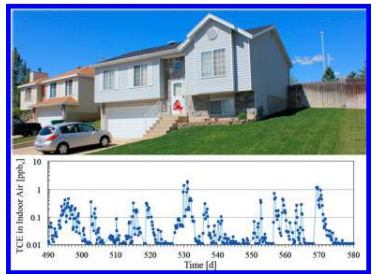
Most Obvious Observation/Conclusion (from March '18 Workshop)

All three ITS metrics (T, P Rn) show *highly-confident* ***Negative*** Predictive Values:

- That is, >95%* confidence that sampling for CVOCs when these ITS metrics are NOT 'elevated' will find:
- The CVOC sample conc. also NOT 'elevated'
  - Using **Rn**, this is almost certain (99% confident) for >95th%ile
- This evidence suggests it is no longer useful (for regulators) to sample for CVOCs when these ITS are Not 'elevated'
- Possibly enough evidence to be 'Actionable' (sample times) now?
  - How Generalizable?
  - From two houses (dated 1915 & ~1995)

EPA's Indianapolis Duplex

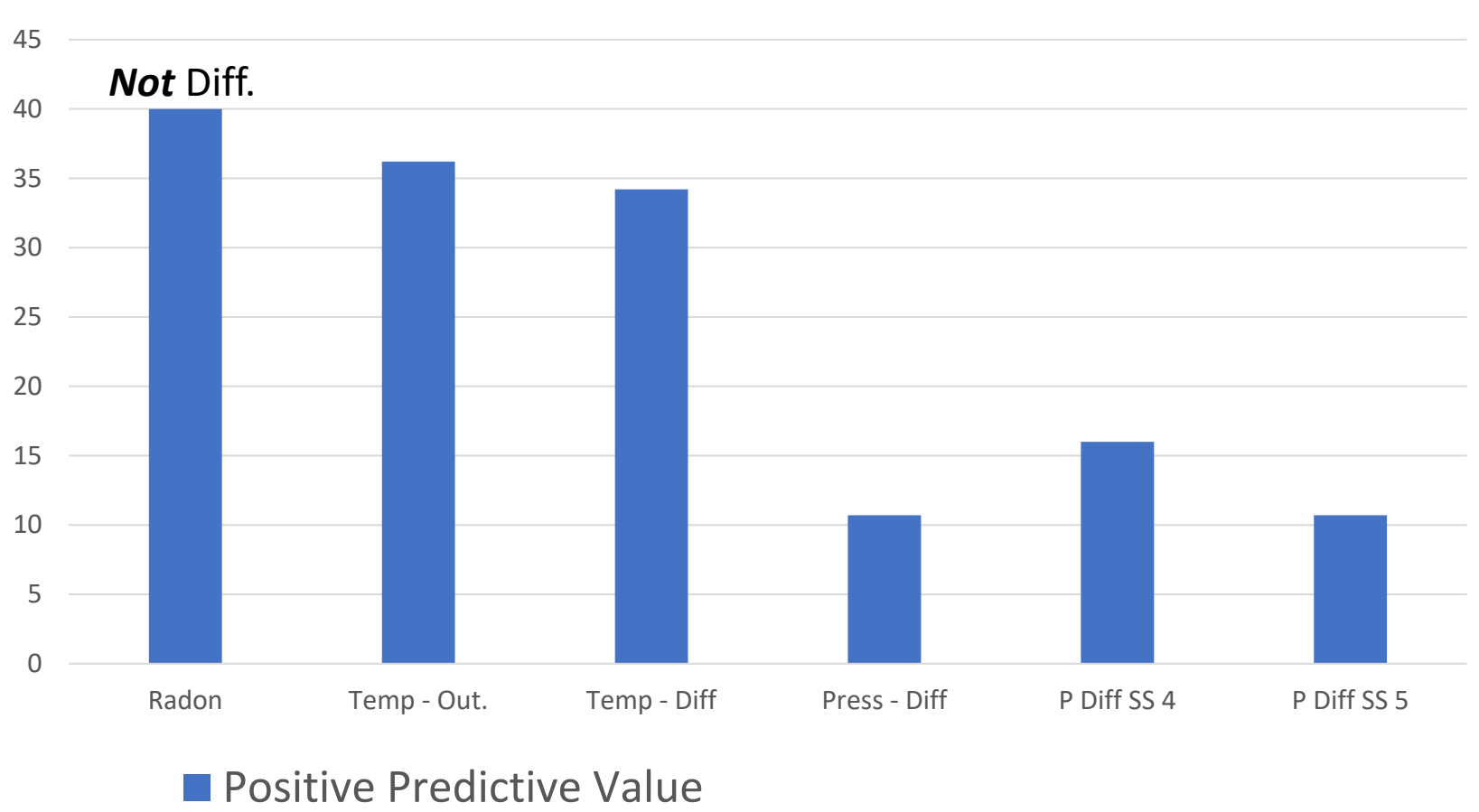
Sun Devil Manor



Diagnostic (Exposure) Screening Results
Positive Predictive Value - SDM

(probability of '**High**' ITS samples identifying '**High**' chemicals (>95% RME))

Note: PSA & Mammography ~30% Positive Predictive Value

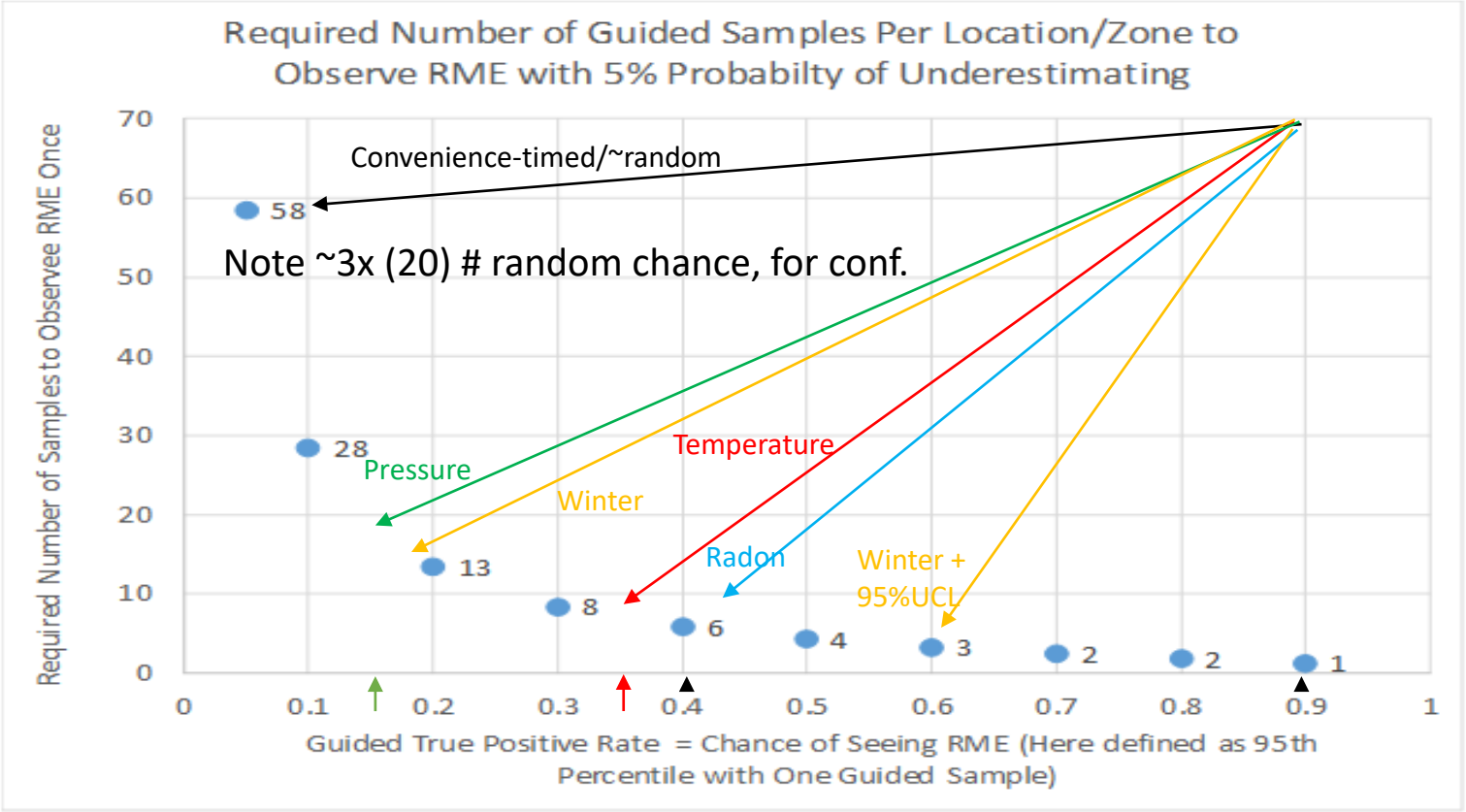


Random chance

Rn allows 8x higher chance (58/8 ~ 7 samples)

How many Samples Needed to represent 95th%ile (RME)

Using ITS' Positive Predictive Values Lowers Sample # Needed w/ High (95%) Confidence - Using *ITS-Guided* IAQ samples



Note: Winter + 95%UCL Means 3 VOC samples in winter and then calculating the UCL for those values – typically results in risk conc. > than any observed; PRP use unlikely?

Number of samples needed to 'know' you have one sample > target TCE conc. of 95th%ile (1.5 ug/m3)

[at a house, Sun Devil Manor – VI research house (formerly ASU), Layton, UT]

Trying to Schedule and Collect CVOC samples **when** ITS are **elevated** is ***Not easy****

- But, **Abundant/Continuous** *VI-assoc.* ITS data **can** be documented

  - **Δ Temperature**
    - Outdoor, **retrospective** weather **records**
    - Indoor-outdoor (ΔT) – relatively easy measurements

  - **Δ Pressure**
    - Outdoor, **retrospective** weather **records**
    - Indoor-outdoor (relatively easy); Sub-Slab (SS)-indoor (IA) – more difficult and intrusive

  - **Δ Radon**
    - Indoor & Indoor-outdoor – relatively easy measurements

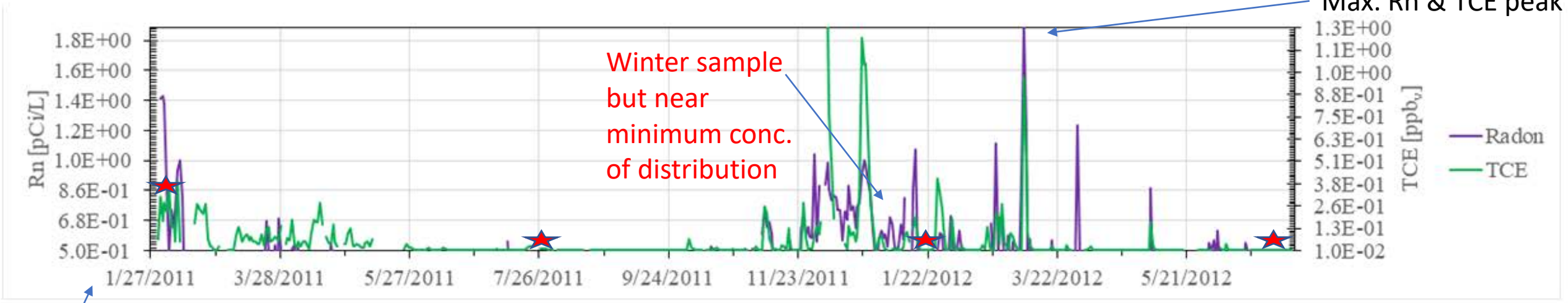
*estimating future ITS trends, gaining access, clearing 'background' sources, & placement & collection of sample devices

'*Continuous*' Distributions of ITS (Rn & TCE)*

Shows history & picture of a building's (soil gas/vapor) Intrusion behavior

Continuous **Rn** levels are **possible/practical**

Provides **soil gas** intrusion **context** (%iles) for few chemical grab sample events



*Rn & TCE each plotted on their **respective** (Y-axis) **ranges** observed during baseline study – **research** house

Reasonable winter sample but not peak conc.

★ Hypothetical chemical grab sample event at scheduled interval

Rn curve provides context for chemical results and how ¾ ★ were Not from periods of concern for RME

Indoor Rn & TCE at **SDM-UT** 2011-2012 (naturally-varying conditions) –

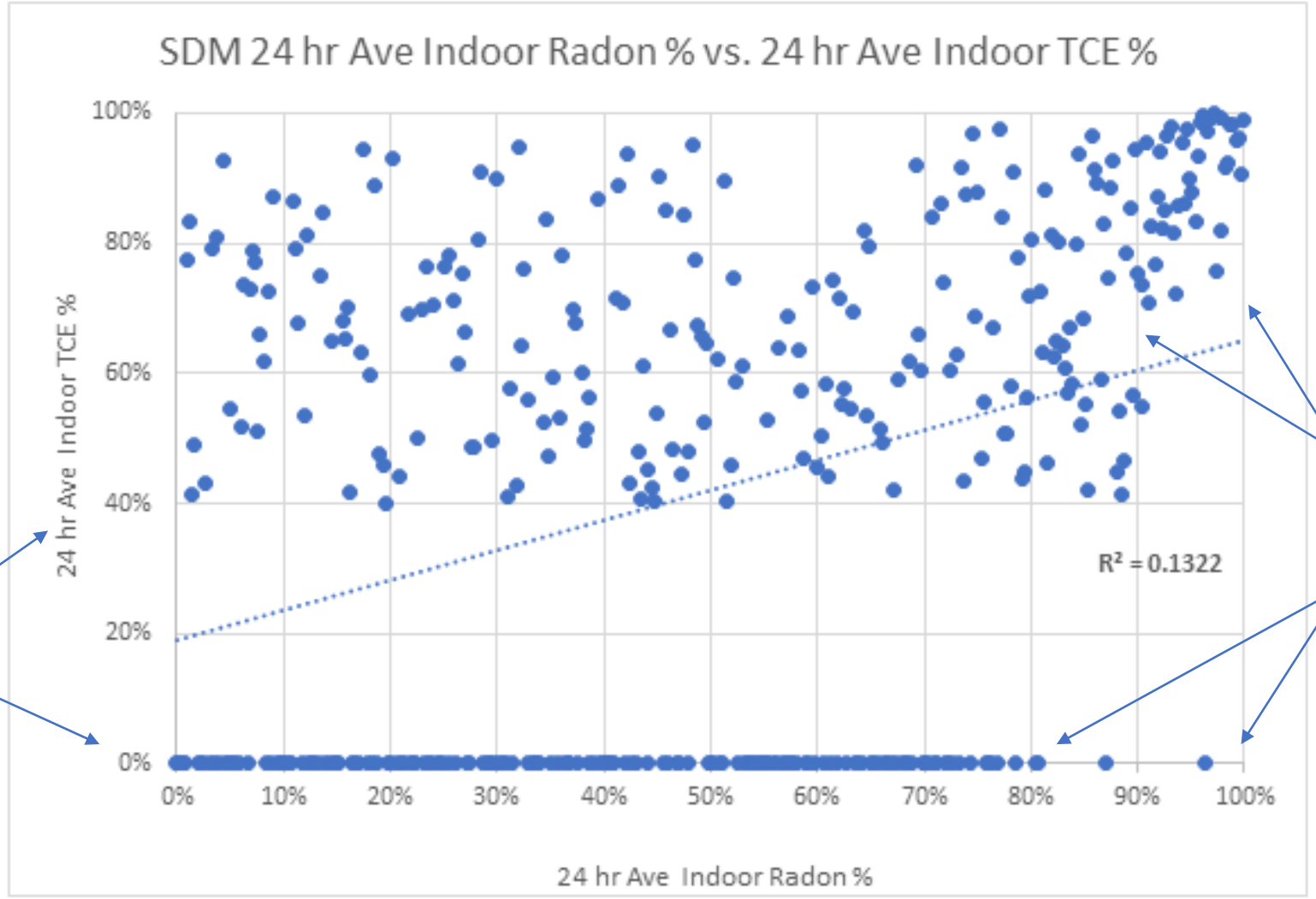
TCE & Rn Each presented over Range conc. found – to approximate their %ile of conc.

TCE conc. above reporting limit (0.011 ppbv) and

Rn conc. above the lower confidence limit of the RAD7 (0.5 pCi/L)

Calculated Percentiles – w/o regard to sequence

Calculated Percentiles (%iles), <u>including</u> No-Detected (ND) values



~ 40% of the TCE levels are Non Detected

When >90th%ile Rn, almost all TCE levels >70th%ile & up to 100th%ile (Highest TCE levels)

At >80th%ile Rn near-lack of ND levels;

Sampling for TCE **when** the **Rn** level is <80th%ile gives a >**40% probability (~1/2)** of finding a **ND TCE value!**
You **need to know** the **building's %ile** of **Radon** conc. **when chem. sample is collected** to **understand** what chemical conc. found represents. When sampling when Rn was > 80th%, or even better >90th%, you could find much higher TCE levels

Measured ITS **%ile** can document* Positive Probability of finding TCE in levels of interest – Individual & Multiple samples

e.g.,

Rn *%ile*	*Prob TCE > 95%ile*	*~# Samples Needed**
50th %	10%	28
75th %	19%	13
90th %	41%	6
95th %	55%	4
Total Probability for all four samples	**81%**	

Note

Having Rn percentiles can allow <u>probability of multiple samples to be **combined** for a (higher) total probability</u> of having one or more samples from within the Exposure Levels of Interest – for regulatory decision making

* And guide/help samplers decision to analyze chemical samples (or not)

*If all samples have the same probability of finding <u>a</u> sample w/ TCE above the given target %ile (w/ 95% conf.)

We could use '*continuous*' Rn data to 'know' the extent (%ile) of soil gas intrusion which adds meaning to occasional chemical sample results*

- Grab sampling 1-day indoor air for chemical VI assessments, at:
  - Some random **Time** is:
  - Unlikely to find RME (i.e., >95th%ile) - & **would have No Way of Knowing it, if you did**
- The **meaning** and **context** of even multi. grab sample results will be **unclear**
- **We need** to **know When** VI is turned 'ON'

- Knowing Rn levels around VI chemical samples will **maximize** their **meaning**
  - by placing the chemical samples within the soil gas intrusion **history of the building**
    - & this makes possible:

Quantitative Probability/Confidence levels for small sample #'s

*based on SDM house, more buildings being studied in Oct. workshop

Two highly-studied buildings suggest: Possible Updates to EI-VI - footnote 2

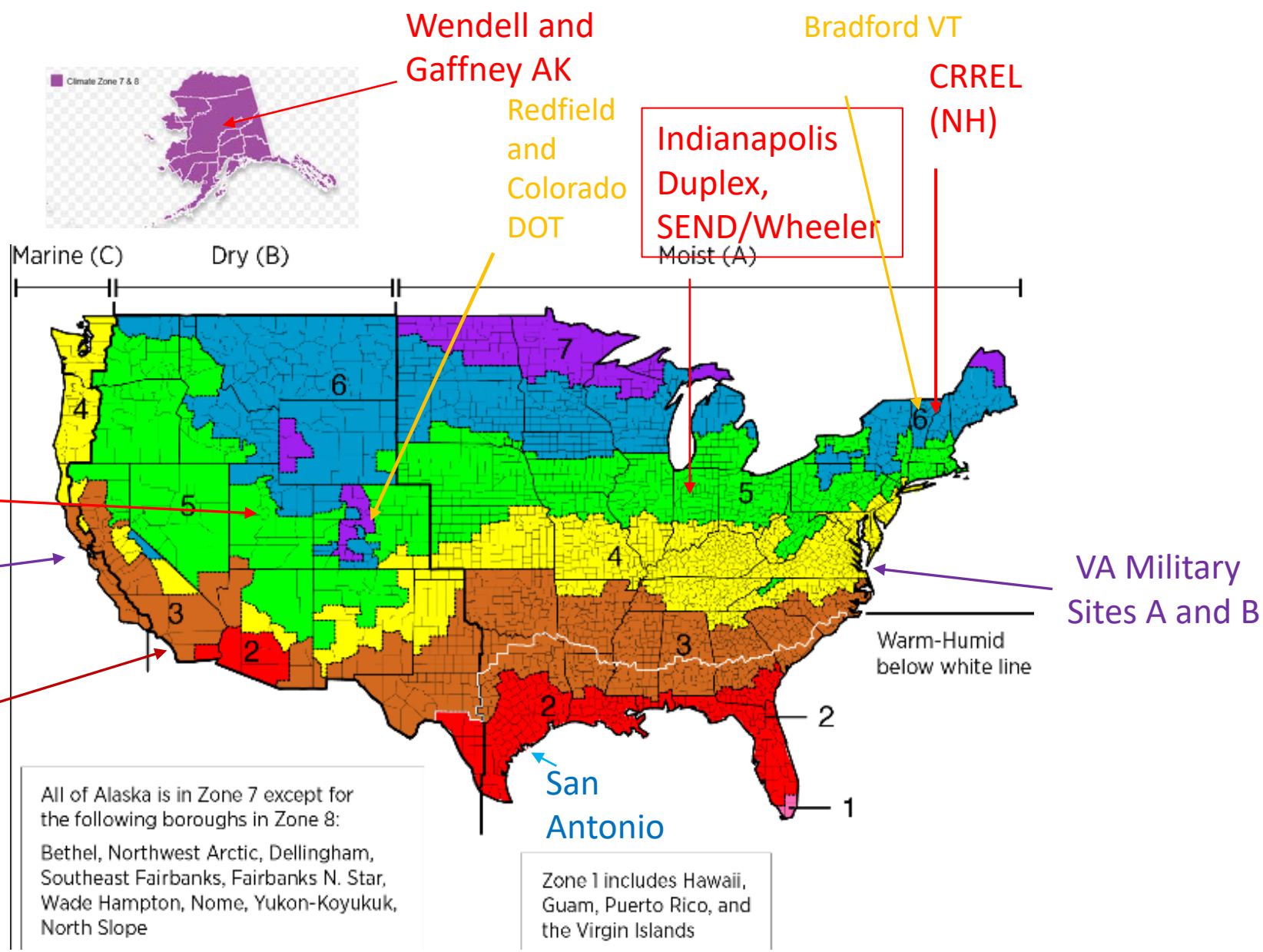
- Quantitatively estimate your confidence (e.g., ___%) that the indoor chemical sample concentrations collected represent the exposures of concern for the building, and briefly state the evidence supporting that estimate.
    - Or
- Do you have measured evidence that the **soil gas** intrusion was higher than **90%ile** for the building **when** chemical samples were **collected**?
    - **If not** it is **almost certain** the chemical sample would **not** represent the **RME** and
    - **If yes** the probability of the chemical sample representing the RME is **much higher than random** and potentially having **quantifiable confidence** of it's representation.

Evidence from two highly-studied homes shows:

Quantitative Confidence for VI *is Possible*

- Using a **practical number** of chemical indoor air samples
- w/ **measured** evidence from VI-related physical features
  - e.g.,
  - 'Low' Diff. **Rn**, **Temp**., or **Press**. predicts 'Low' Chemical VI with **97** to **99%** confidence
  - 'High' Rn increase probability of representing >95th%ile by **8 times** (over random chance)
- The **More** VI-related (i.e., ITS e.g., **Radon**, **Temp**., & **Press**.) the **Better**
- This **Workshop** presents **Std Op. Prod.** for ITS measurements & tests **New data**
- For:
- **Measurement-Based Methods for Protective & Defensible Chlorinated VI Exposure Determinations**

Today's Workshop – New data from new sites across the IECC Climate Zones



Slide from Chris Lutes, Jacobs

IECC zones Reprinted form https://basc.pnnl.gov/images/iecc-climate-zone-map