Field Testing

Soil Gas [Vapor] Safe Communities

Approach

for Vapor Intrusion (VI) Assessment & Management*

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Disclaimer*: The opinions expressed do not represent Agency policy*.

Assoc. of Vapor Intrusion Professionals (**AVIP**) Inaugural Conference

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Nashville, TN

*May not include vapors **100%** contained in 'pipes' from source to bldg. & discharging directly into indoor air

Acknowledgements

- Chris Lutes
- Chase Holton
- Andrew (AJ) Kondash
- Alan Williams
- Klara Crincoli
- Alana Lee

&

- Thanks for comments from EPA Region 5 & States e.g., WI on a draft

Thank you, Tom Hatton, et al.,

- Invitation to participate
- Forming this Association of Professionals
  - Increasing the effectiveness & efficiencies
- Public health Professionals keeping _#?_ people out of the hospital*
  - By public health 101: **Preventing Exposure.**

*An unknown I hope we can explore in the future

Overview

- **Testing** an **Alternative approach (w/ Options):**
  - **Quantitative**
  - ***Non*-Quantitative**
- **Continuous measurements** to **improve sampling-times**
- **Knowing when:**
  - ***Soil Gas* Intrusion** is **'turned on'**
    - &
  - **Indoor chemical-VI conc.** are **more likely** to be **'elevated'**
    - &
- **Collect samples** of **Peaks** to **better represent exposure**

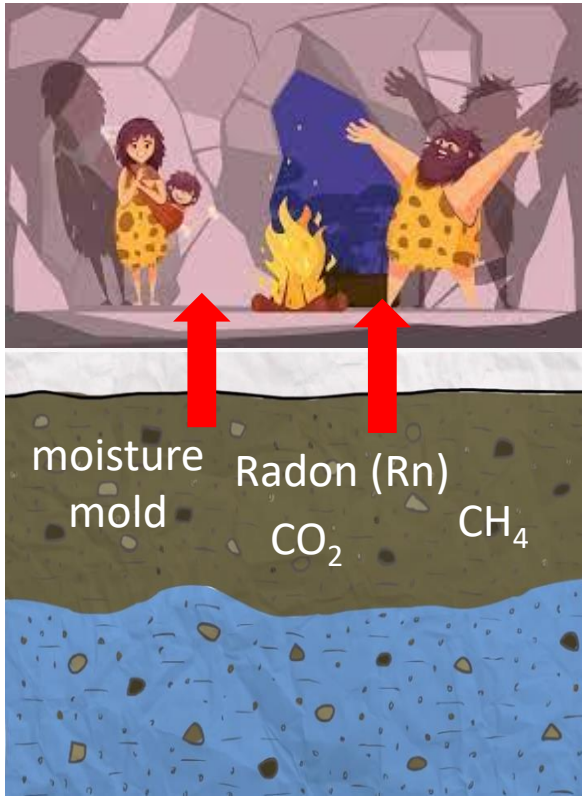
But first

A **Public Health Announcement**

Soil gas / vapor has been in intruding into 'indoor' air since we lived in Caves

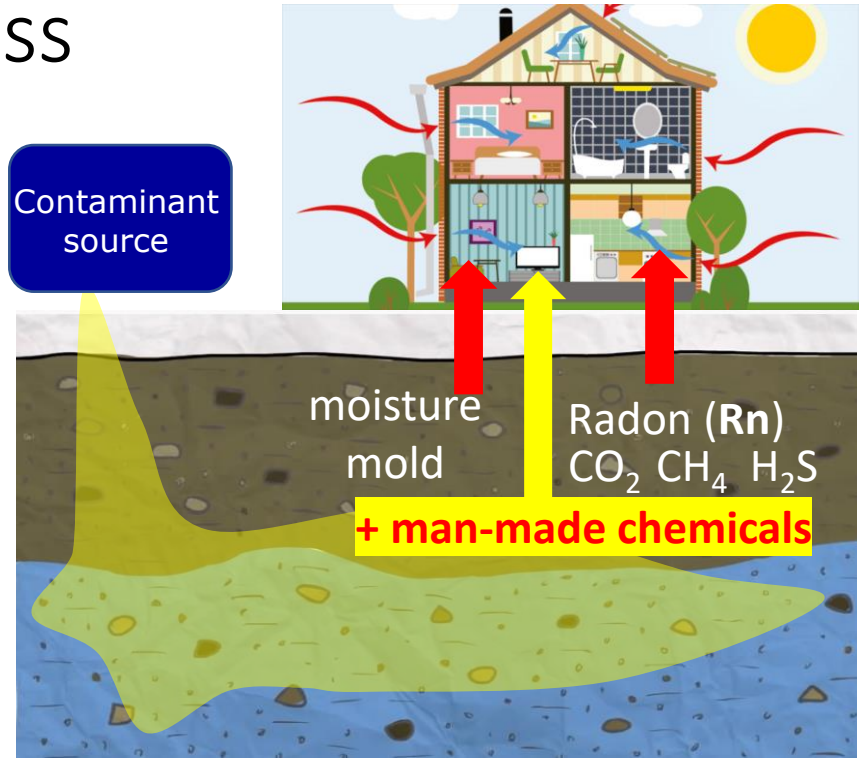
Now[1]: Our buildings/homes are increasingly tighter/weatherized for low/lower indoor air/energy loss

Summary:
Need to Stop soil gas Exposure is Increasing



Big Picture
VI Across the Ages

Generally, **can't**:
See,
Smell,
Hear,
or
Avoid
this Intruder



But typically* still allowing soil gas entry – from below

Conc. **were** minimized by high exchange rates with 'cleaner' outdoor air

Same natural hazards, but at increasing concentrations as it is 'trapped' indoors longer & Now: Petro- *Chloro-* & **Fluoro- +?**

Outline of Presentation

- **Background/Objectives**
  - Traditional/VI assessment **business-as-usual**
  - Evidence in few highly studied bldgs. suggest Traditional approaches have a **high probability** of ***under***-representing exposures
- **Approach/Activities**
  - **Field testing** traditional/VI 'business-as-usual' compared to a new **Targeted** approach
  - 'random' versus 'targeted' ***timed* sampling** in field tests (research) ***in a Community***
- **Results/Lessons Learned - & New Directions**
  - **Sample Timing matters** – almost more than anything else
  - A new approach (**SGSC**) is designed to incorporate the science and empower the occupants themselves with ***continuous*** measurements of ***soil gas*** intrusion

Background/Objectives

- Traditional/VI assessment ('business-as-usual')
  - **2-3 randomly-timed** indoor samples/bldg.
  - in ~**10-25%*** of selected/available *believed* representative buildings
    - These **# can not meet EPA's** quantifiable **confidence goals** (e.g., **RME** w/ **<5% error** rate**)
      - **Unless** *nearly-**continually UN-acceptable*** indoor conc.
  - Evidence in the few highly-studied bldgs. suggest Traditional approaches have a high probability of **under**-representing exposure levels (*in the bldgs. sampled* + NOT Sampled*)*
- USEPA is working towards improving cVI assessment:
  - Accurate & Verifiable confidence (for short & *Long-term* protection)
  - Cost-effectiveness & most importantly increasing;
  - **Community Understanding & Acceptance** of the importance of **stopping Soil Gas intrusion** (*via* their active **Participation** by making measurements of **SGI**)

*Errors in measured bldgs. can be multiplied by **4-10x** in un-sampled bldgs.

This criteria implies we need 100% accuracy of RME in **≥19/20 bldgs. 'at risk' of VI

What we believe we 'know' so far

and following slides will illustrate

- From many bldgs. w/ some data & **~12 buildings** with **'data rich'** studies;
  - We see chlorinated Vapor Intrusion (cVI) appears to be:

1) **building-specific**
2) **highly variable** across time
   - ~Unpredictable **episodic Peak** events **determining majority** of **exposure**
   - Timing of indoor air sampling matters
     - 'convenience'/consultant accessible/~'**random**ly'-timed samples will **under**-represent exposure

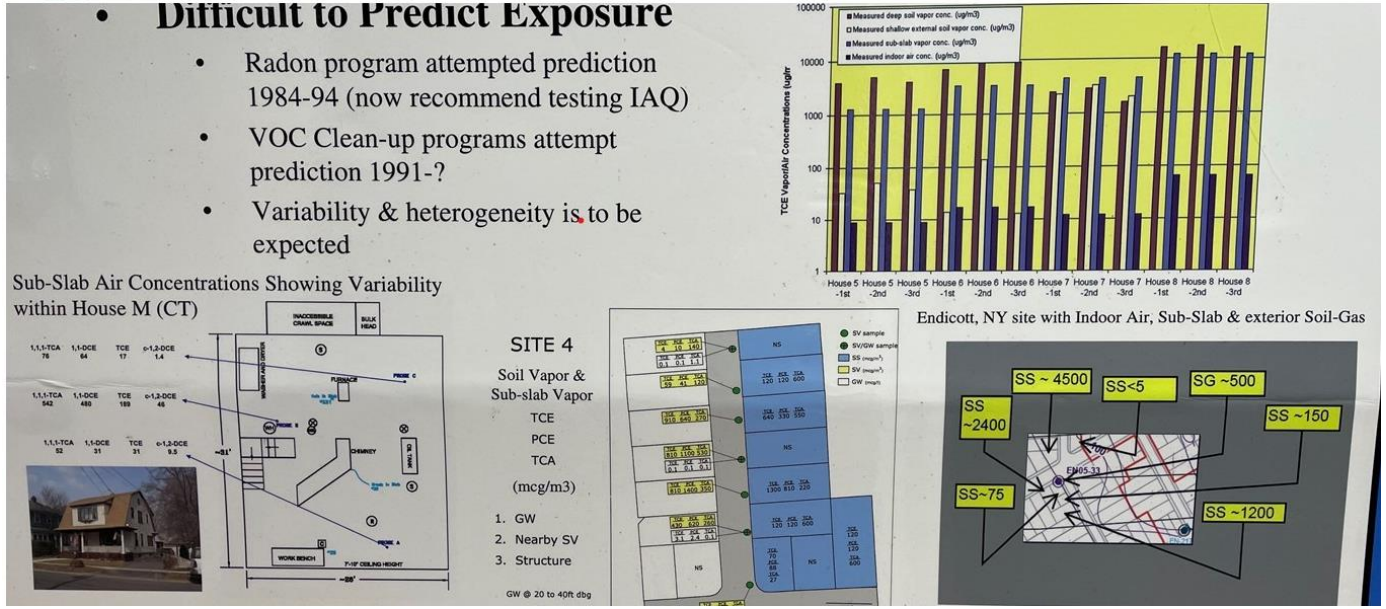
3) Using **Radon (Rn)** as a **Tracer** of **soil gas** movement along with **Indicators**, **T**emp. & **P**ress., [ITS (Rn+T/P)]:

Can ***help*** **identify when** *soil gas* intrusion is '**turned on**'

& is *often* when indoor cVOC exposure **concentrations peak**

Bldg.-Specific Variation – in (my) 2005 Poster

- >10x variation in **SS conc.** across ~10 ft of small house (CT 1999-2000)
- >10x variation in **SS conc.** across adjacent homes (NY, 2000-03)
- 75-4500 ug/m3 in **SS conc.** across adjacent homes (**Endicott**, NY, ~2003)
- **Shallow *external*** soil gas is *poorly* related to indoor **conc.*** (NY ~2003)

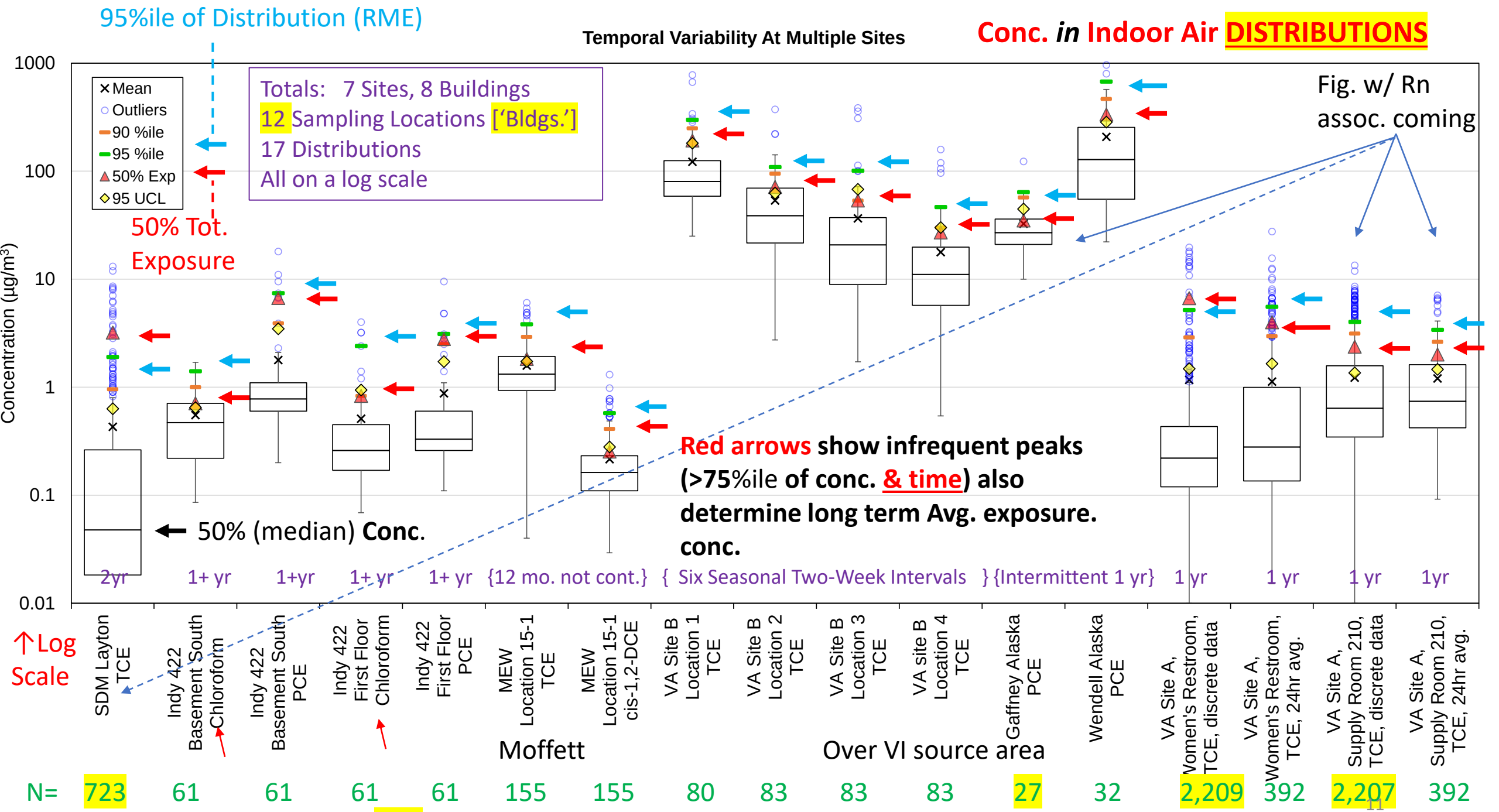


*SS only somewhat better, but indoor at ‘random’ times

95%ile of Distribution (RME)

Temporal Variability At Multiple Sites

Conc. *in* Indoor Air DISTRIBUTIONS



Often 90% of the samples contribute less than half of the total exposure

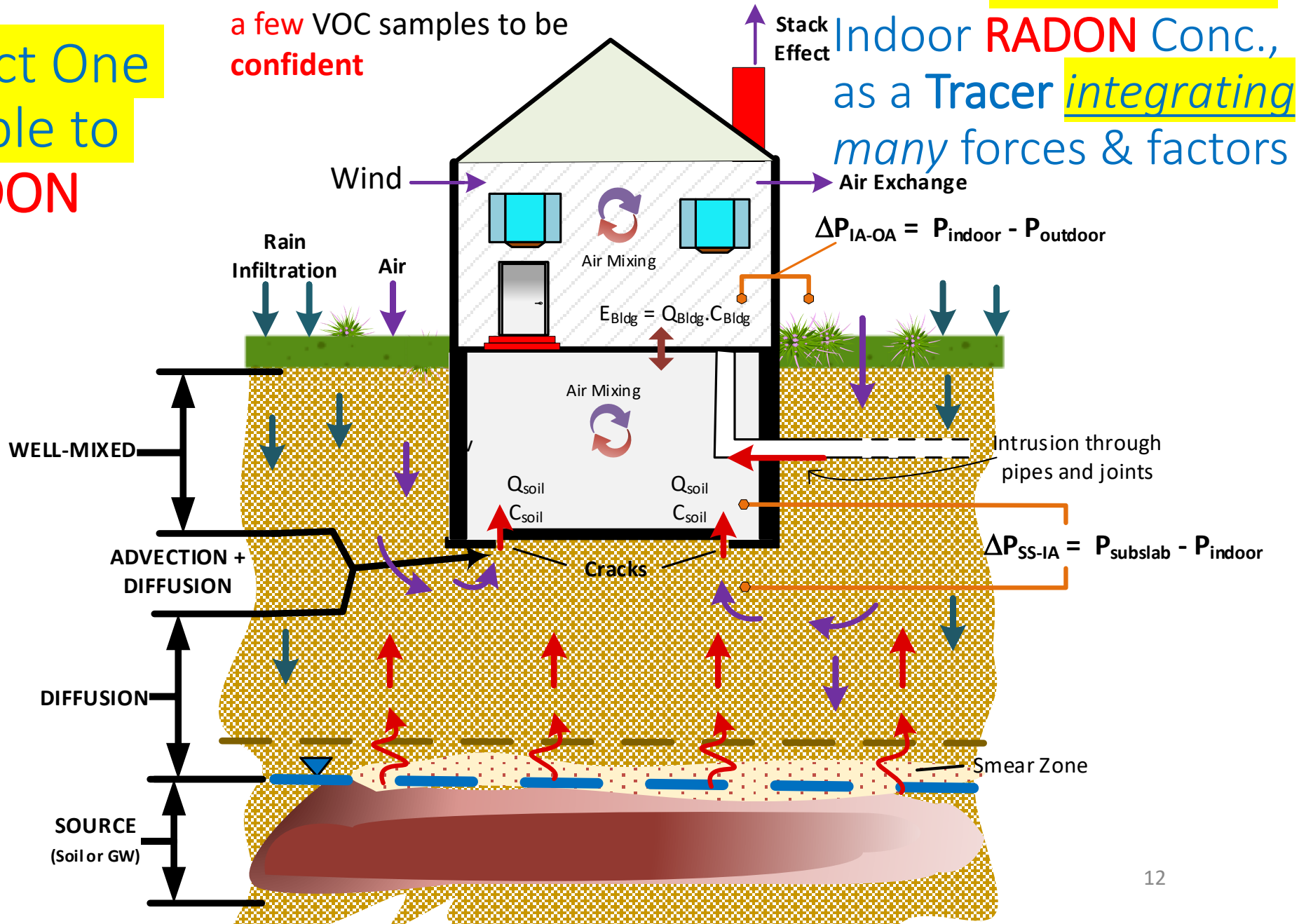
[Radon VI is simpler than cVOC VI & …]

We Shouldn't Expect One Independent Variable to Control Indoor RADON Concentration

Our challenge: We want a few VOC samples to be **confident**

But we Can Measure Indoor **RADON** Conc., as a **Tracer** *integrating many* forces & factors

*"This paper identified about **thirteen** factors that can affect **radon**: …soil moisture content, soil permeability, wind, temperature, barometric pressure, rainfall, frozen ground, snow cover, earth tides, atmospheric tides, occupancy factors, season and time of day."*
Lewis & Houle, A Living Radon Reference Manual (2009)



Radon as an Indicator, Tracer & *poss.* Surrogate;
Continuous **Radon** Meters - **Consumer**-grade – given out

- **Specifications**
  - Indoor radon
  - Most need to be plugged in
- **Cost:** $125-300
- **Uses**
  - Tracer of **soil gas** intrusion
  - Temporal variation of radon
  - 'Surrogate' for soil gas entry
  - Spatial radon in a building
- **Observations**
  - 'Good' correlation with elevated cVOC vapor intrusion locations
  - *Less* (but still) useful when indoor radon is <0.5 pCi/L

Also measuring & using supporting Indicators of **Temperature** & **Pressure**

Slide mod. from: ORD & R9 April 13 presentation on VI entry to R5 team call

Radon - Statistical Assoc. of Indoor 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-Duplex)
99.9% (SDM-UT)

Changing conc. direction together

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

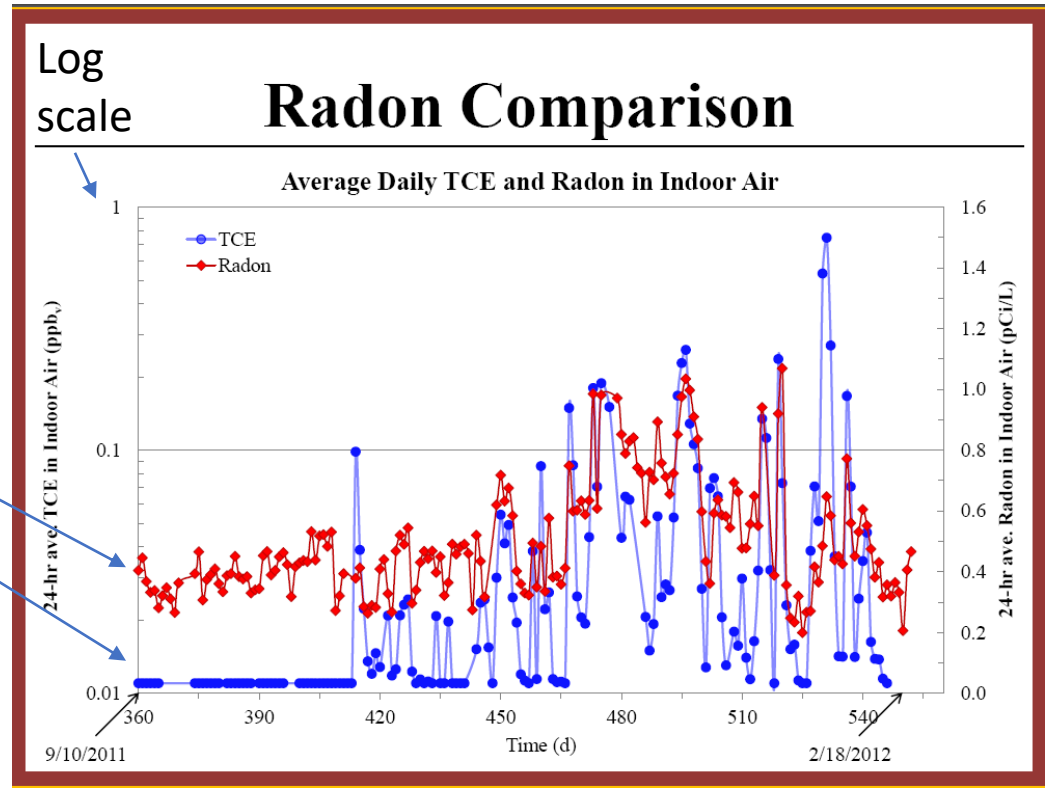
2) Magnitude

*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 quant. risk decision making



For Site application tried Next:

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

Sun Devil Manor (SDM), Layton, Utah

EPA's Indianapolis IN

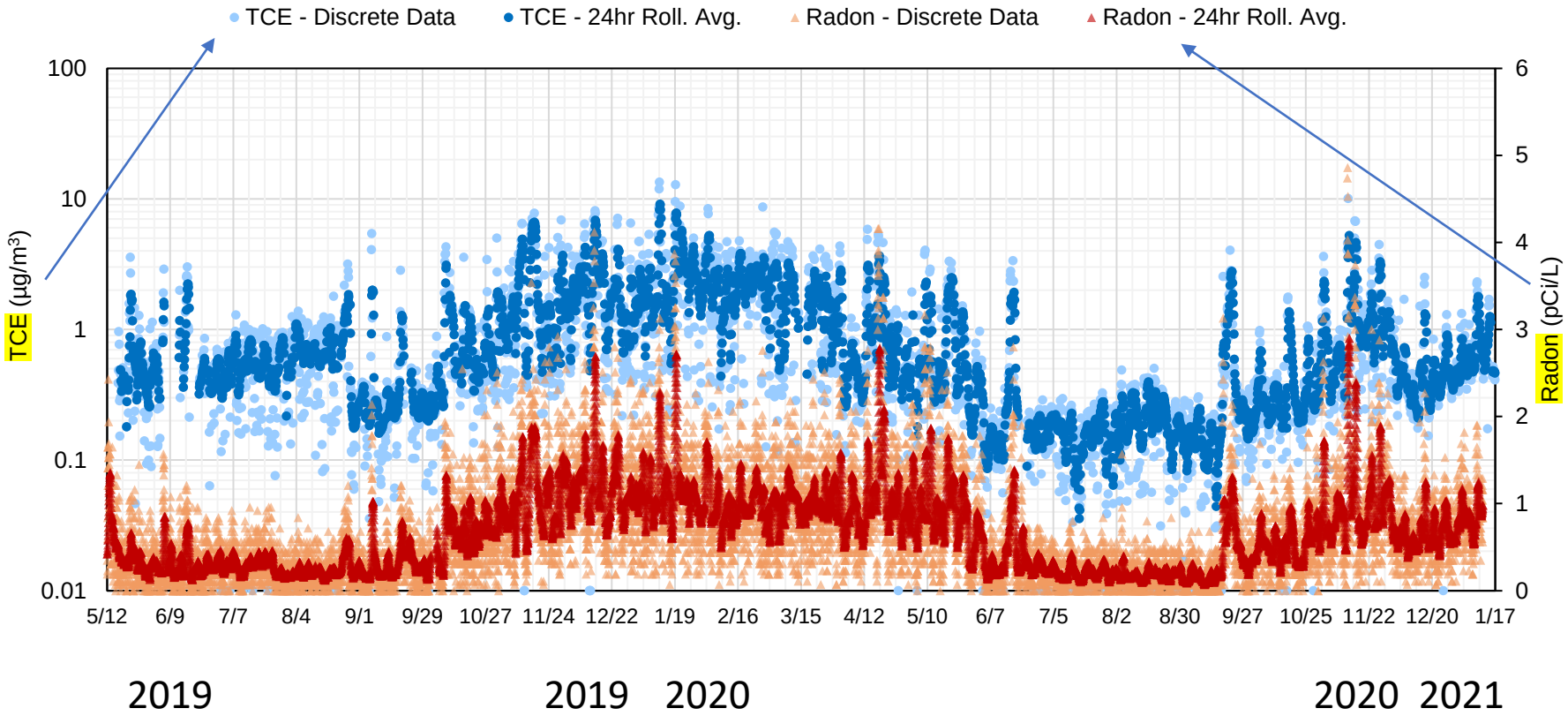
1) **Direction** of Conc. Change for Rn & cVOCs ~100%
2) But, **Magnitude*** of Conc. < 100% correlation;
Some Differences btwn Rn & cVOCs *being looked at*

- Background (out-/in-door) levels
- Typical Range of conc., Log vs. Linear
- Spatial stability vs. mobility & variability of 'Source' conc.
- Half-life (cVOCs ~>6 mos. vs. Rn 3.8 days)
- Flux rate (VOC partitioning vs. Rn "emanation" & "exhalation")
- Moisture in pore spaces
- Saturated/Liquid water
- Volatilization from water: cVOC yes; Rn ~No, …

TCE vs. Radon Stack Effect Pattern at Supply Room – VA Site A

Key Points: Seasonal variation in VI for both pollutants consistent with stack effect pattern at this location. Stack effect more likely in heating season. The stack effect is when warm air moves upward in the building, potentially drawing in soil gas.

Continuous On-Site Measurements



Log (shallow source under bldg.)

Linear

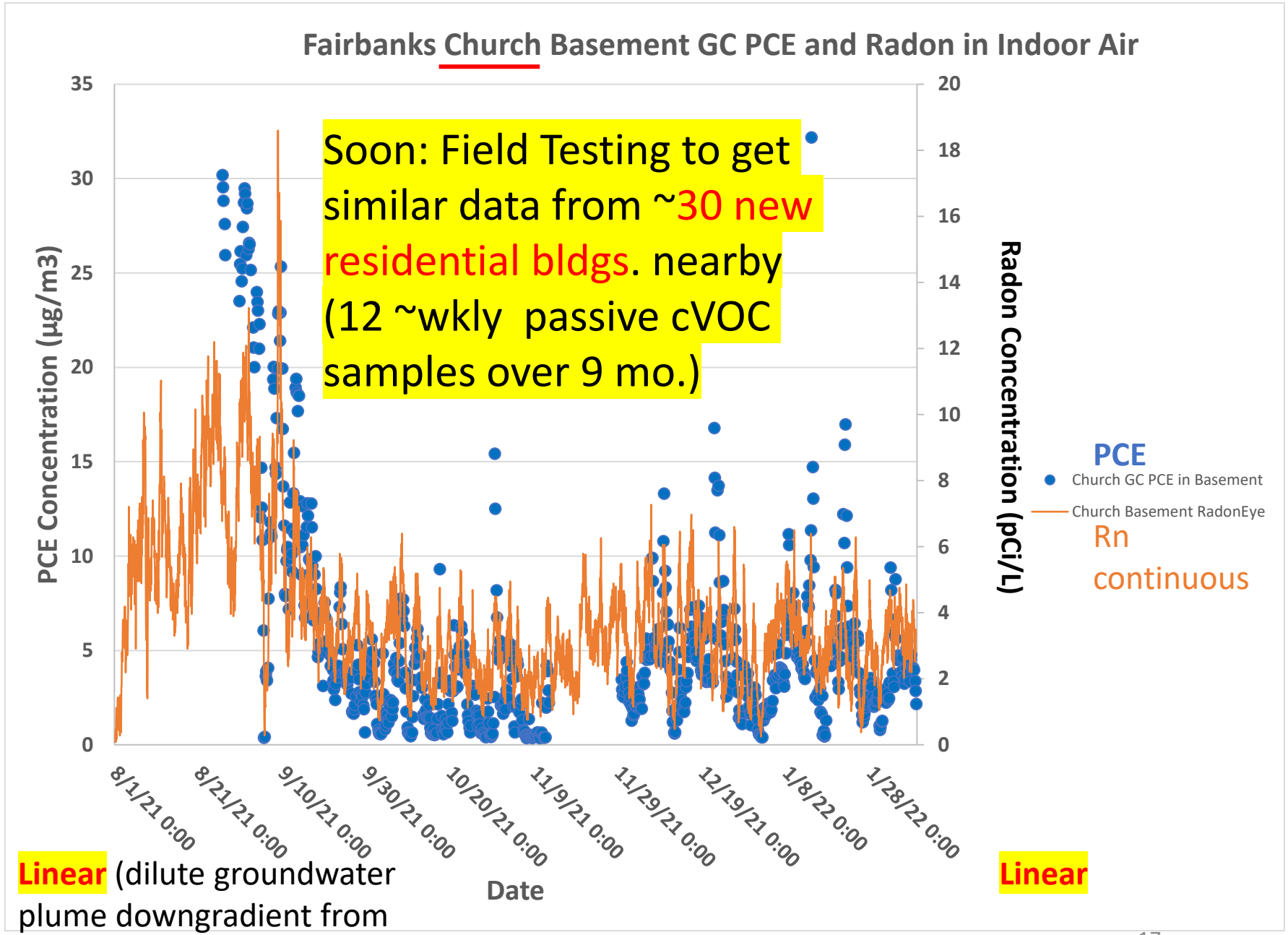
TCE Descriptive Statistics

Sample ID	EIA-11
5 %ile	0.09
10 %ile	0.14
25 %ile	0.25
Median	0.47
75 %ile	1.14
90 %ile	2.60
95 %ile	3.63
Maximum	13.4
Average	0.97
StDev	1.27
Coeff. Var.	1.31
% Detected	98%
Count	3,473

PCE vs. Radon at Gaffney, Alaska 'New' Data

PCE decline in late summer into winter similar to Barnes published data at same site (different building and different year). Suggests soil temperature effect.

Radon correlation to PCE suggests similar entry and ventilation mechanisms.



How can ***continuous*** **ITS (Rn+T/P)** measurements (showing when VI is 'turned on') **Help** us with meeting cVOC assessment goals?

- Recall our (EPA): cVOC assessment goals:
  - Reasonable Maximum Exposure
  - **RME** (90-98th %ile of exposure conc. for periods of concern)
    - Recall, Due to highly skewed/~log-normal distributions of VI conc. indoors
    - The **95th%ile ~RME** is for **both**
      - Short-term &
      - **Chronic** (long-term Avg.) exposure concerns

        &
  - Error rate not greater than 5% (i.e., 95% confident)

VA Site A – Four Daily Samples In Supply Room

Concentrations µg/m³:	*0.96*	*1.05*	*1.71*	*1.71*	*3.02*
Rule Description	At least one sample of the four samples taken ≥ true mean	At least one of the four samples taken ≥ the 95% UCL of the mean	*1* ← At least one of 4 samples > the 50th percentile of the cumulative exposure curve	The mean of 4 drawn samples > 50% exposure value of the underlying distribution	At least one of the four samples > the 95th → percentile of the underlying distribution
1 sample in heating season, 1 outside of heating season	77%	73%	39%	39%	19%
Random sampling	**80%**	**77%**	**52%**	**10%**	**19%**
Only sample in heating season	99%	98%	86%	44%	42%
Avg temp decrease of 5F or more	76%	72%	42%	6%	14%
Low temp decrease of 5F or more	78%	75%	46%	7%	15%
Indoor outdoor differential temperature of 15F or more	82%	80%	55%	11%	20%
Day over day radon concentration change of +0.5 pCi/L or more	99%	98%	78%	60%	71%
Radon greater than 90th percentile of full radon dataset	100%	99%	93%	61%	63%

- Four random samples provides reasonable performance with regard to the true mean but not 50% cumulative exposure.
- Radon guided and heating season driven strategies most beneficial.

Probability that by collecting 4 indoor air cVOC samples when Rn shows VI is 'on' We'll find at least one exceeds 95th percentile conc./exposure (~RME) of VOC Distribution – Effect of Radon level Guiding cVOC sample Timing

10,000-run of Computer random selection of 4 (1-day) samples from continuously measured data

Site	Location	Radom (4 samples, ~5% each)	Radon greater than 90th percentile guide for sampling*		Notes
			Weekly	Daily	
Sun Devil Manor		19.4	80.0	77.6	
Indianapolis**	North Basement	24.9	0.0	NA	Why no weekly assoc?
	South Basement	23.8	0.0	47.6	Why no weekly assoc?
	First Floor	21.1	80.0	23.5	Why daily ~ random?
VA Site A	Women's Bathroom	20.2	0.0	9.3	**Pipes & shallow water**
	Office near W. bathroom	19.4	NA	0.0	Pipes & shallow water?
	Supply Room	20.2	89.4	62.7	Classic stack flow
All Datasets Average	Combined	20.7	41.6	36.8	**On AVG. 2x > random**

*full dataset

**dataset lengths differ between daily and weekly data

Peak Radon vs. Peak VOC Conditions Summary – Basement (Indi., IN)

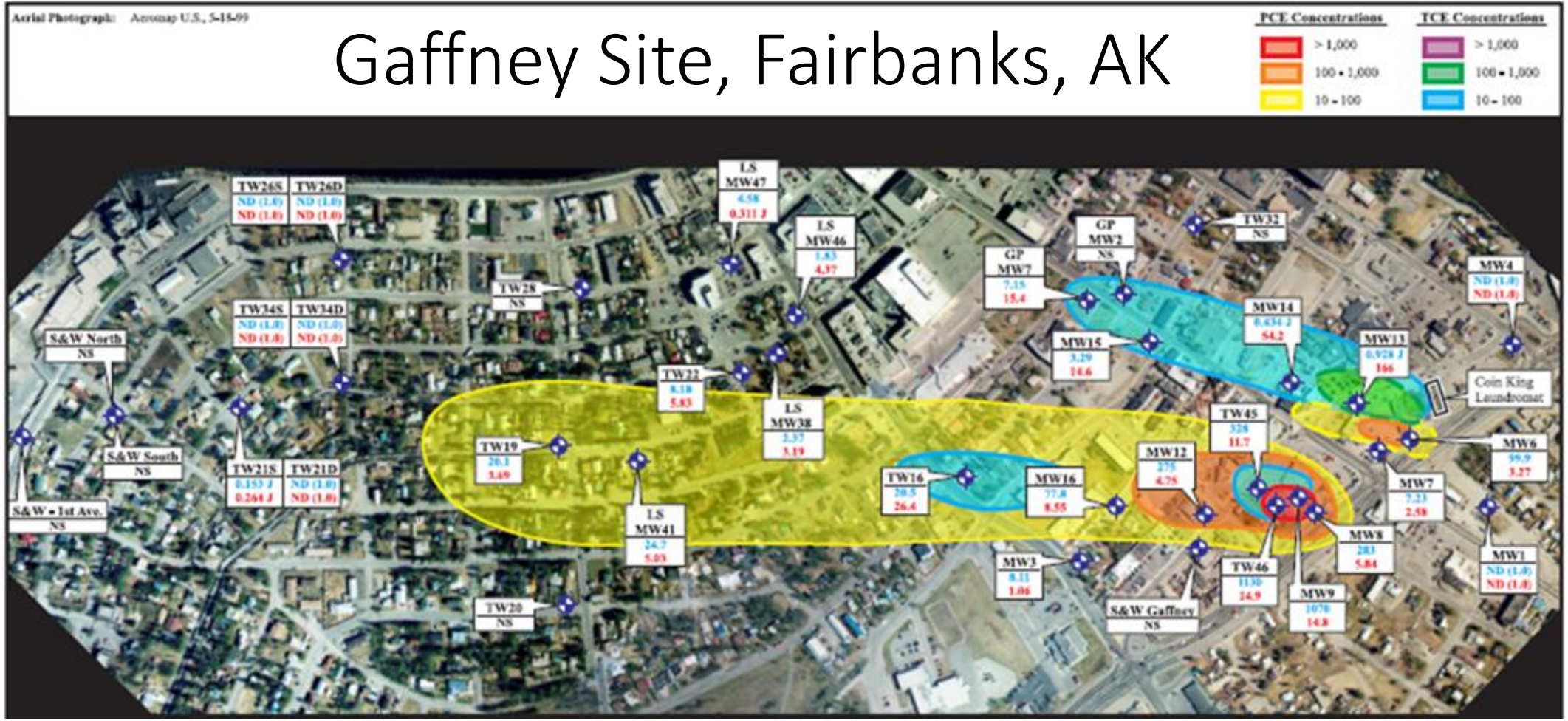
Data Set→ Weather Parameter ↓	Peak for Radon Daily 422 Base North (3/11/11 through 7/23/12)	Peak for PCE Daily 422 Base South (12/2/11 to 2/16/12)
Differential temperature	6-17 F at 422 Base South 7-17 F at 422 Base North	33-42 F at 422 Base South 28-35 F at 422 Base North
Relative Humidity Indoor	42-53%	17-25%
Basement to Outdoor differential pressure	Essentially neutral	< - 3 Pa
Basement to upstairs differential pressure	+0.2 Pa	> 0.7 Pa
Subslab moisture	130 cbar	135-137 cbar
Deep soil temperature (16.5' beneath structure)	15.6 – 16.4 C	14.9-15.1 C
Outdoor temperature	40-60 F	15-25 F
Wind Direction	West or Northwest	Northeast or West
Peak Wind speed	24-33 MPH	Not clear but most in 15-25 MPH range
Snowing?	Not for top six concentrations but yes for some of the higher.	YES - for all of the top six

Approach/Activities – Field Trials

- **Get more** (e.g., **~30** new) **buildings** to expand our observations (~3x)
- EPA's Office of Research & Development (**ORD**) will:
  - Sample Sub-Slab or Exterior soil gas for cVOCs – (to confirm bldg.-adjacent source)
  - Monitor their indoor air ***continuously*** with **tracer Rn +** Diff. Temp./Barometric Press.
  - Sample indoor air for cVOCS (using week-long passive samplers) at:
    - **Random** times (1/season, for 3 seasons)
    - Rn+T/P **Targeted** times (3/season, for 3 seasons)
  - So we can **compare** the cVOC conc. results

- Explore Occupant/Community participation **measuring Rn+** in homes
  - Planned next phase is to have **occupants monitor** their home's **Rn+T/P**
  - **Decide when to start sample for cVOCs & Do IT**

Gaffney Site, Fairbanks, AK



- "Soil Gas Safe Community" project. (AK-state led site (no PRP))
  - (1) Commercial and residential buildings over the same shallow(~15-20') groundwater VOC plume,
  - (2) accessible 24/7,
  - (3) in a **Sub-Artic** climatic zone **different from** Indianapolis and Layton, UT

Results/Lessons Learned - *for Quant. Assess.*

From what have we believe we 'know' so far

- From the **~12 buildings** with **'data rich'** studies; We see:
- cVI is **building-specific**
  - **1) So** it appears, ***every*** ('at risk') ***building*** *(indoor air) should be* ***'sampled'*** **Not** *10-25%*
- cVI is **highly variable** across time
  - Timing of indoor air sampling matters
    - **Episodic Peak** events **dominate exposures**
  - **2) So** it appears, *indoor cVOC* ***sampling*** *should be timed to* **'catch' peaks**
    - **Not** convenience'/consultant accessible/~'**random**ly'-timed samples that **under**-represent exposure
- Using soil gas Tracer **Rn +** Indicators **Temp./Press**. can *help* ID peaks
  - **3) So** it appears, ***Continuous*** Rn+ *Indicators should be used* ***to time*** *indoor samples*

Questions/Lessons to be Learned

- **Questions,** of both **Social** & Physical Science, the Alaska Field Test addresses:
- Will;
  - Community living above historical PCE release site supports our research?
  - Occupants with documented soil gas cVI source in the soil gas immediately surrounding their homes/bldgs. **allow us/them to continuously** measure Rn+ indicators of Soil Gas Intrusion?
  - cVOC samples be easy to collect at times indicated by elevated Rn+T/P measures?
  - Occupants allow us/them to collect cVOC samples **~every month for nine months?**
  - Conc. in cVOC samples collected at times indicated by elevated Rn+ measures be higher (i.e., more representative of peaks) than those collected at 'random' times?
  - A ***Soil Gas Safe Community*** approach provide more protection at lower total cost?

Summary for the VI Industry

- We at EPA are doing everything we can to improve approaches'
    - Accuracy
    - Verifiable confidence (for short & *Long-term* protection)
        - &
    - Cost-effectiveness of protection

    - Our latest efforts can be described as a new approach called:

- *Soil Gas* [vapor] *Safe Communities*

Soil Gas [vapor] *Safe Communities* approach
Can be as simple as **3 Steps & 1 Decision**

- 1) ID Neighborhood/community 'at risk' for chemical VI (cVI)
  - **Proximity** to cVI source
- 2) Sample cVI chemicals in soil gas immediately adjacent/under each Bldg.
  - & ***If*** *VI cVOCs* ***are*** **present**
- 3) *Continuously* monitor Indoor Air for Indicators & Tracers (**Rn+T/P**)
  - To
    - see if *that* Soil Gas is intruding into indoor air,
    - & *If* it is, Reasonable CONCLUSION**: Exposure** to cVI chemicals is **Probable**
- **Decision time:**
  - **Non-Quat. Option - Prevent** *probable* cVI exposures (pro-actively) stop SGI, or
  - **Sample** during **peak conc. & Manage** *confirmed* exposures, + …

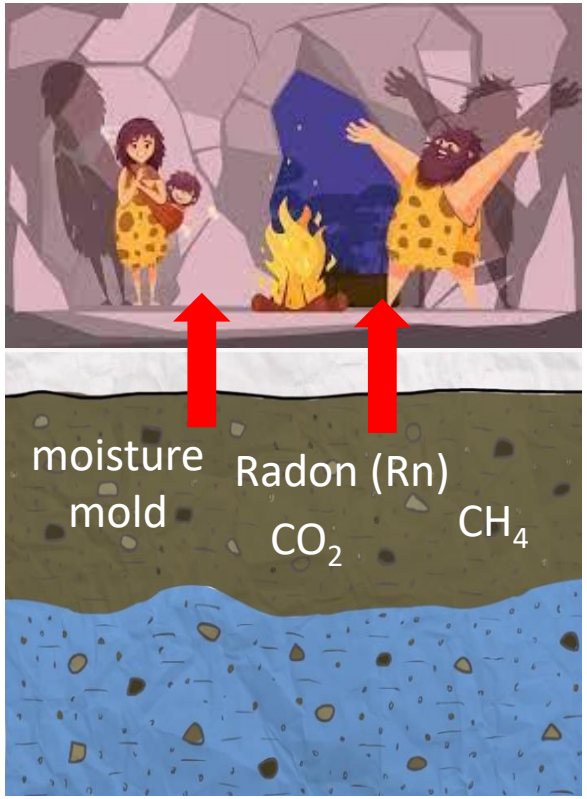
Soil gas / vapor has been in intruding into 'indoor' air since we lived in Caves

Summary
Public Health Recommend-ation:

Don't live like a Cave dweller

Keep soil gas Out of your indoor air

LEED was **right!**



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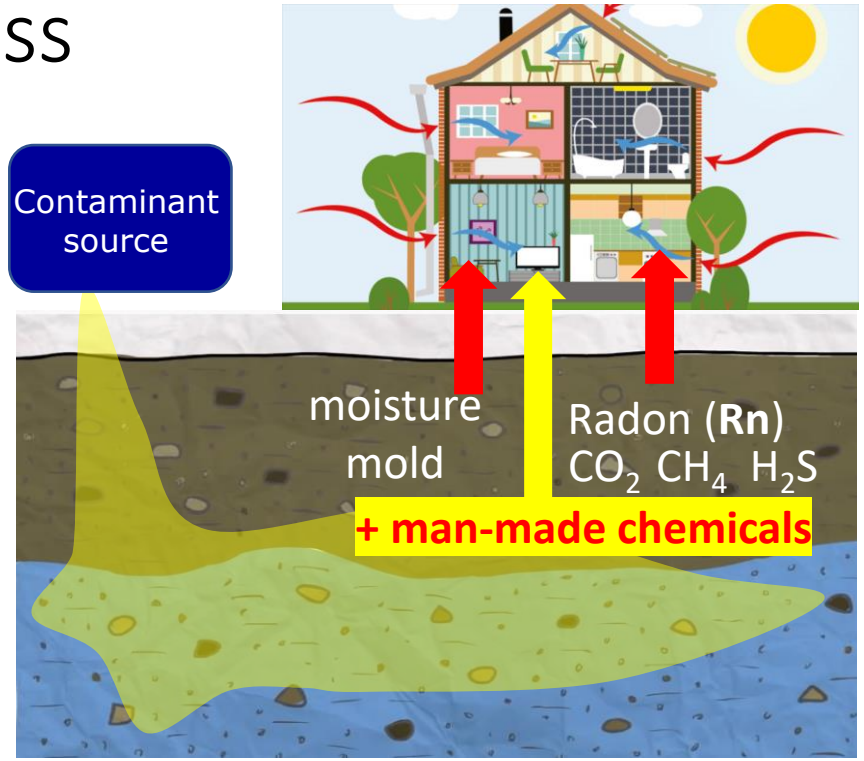

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The End

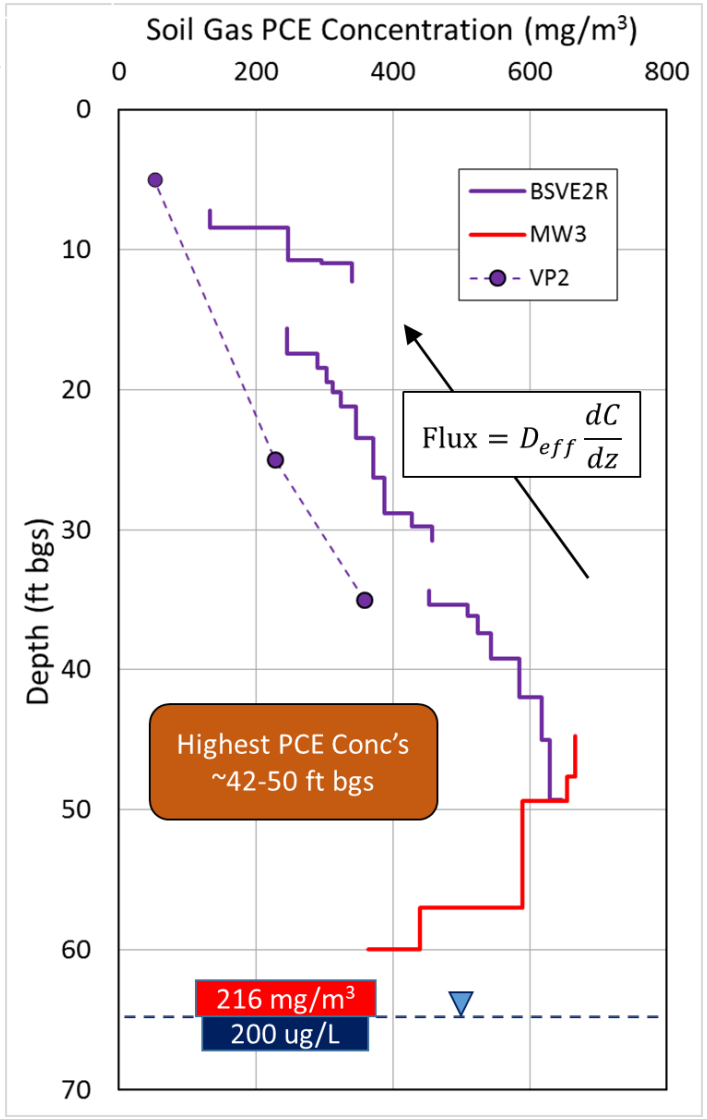
& Thank you for any comments

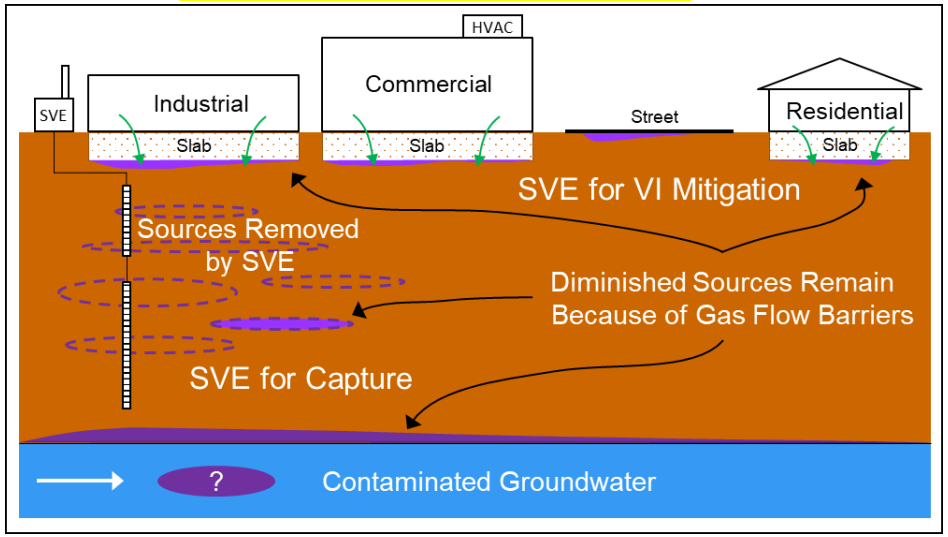
- We'd like to know what you think? [now or schuver.henry@epa.gov]
  - Would Random or 'targeted' (Radon+T/P)-timed samples better represent exposure?
    - This is a Test involving the **physical** sciences
  - How many occupants will want to participate in measurements?
    - This is a test involving the **social** sciences
    - BTW 3 min. of VERY INTERESTING supplemental material

If Extra Time

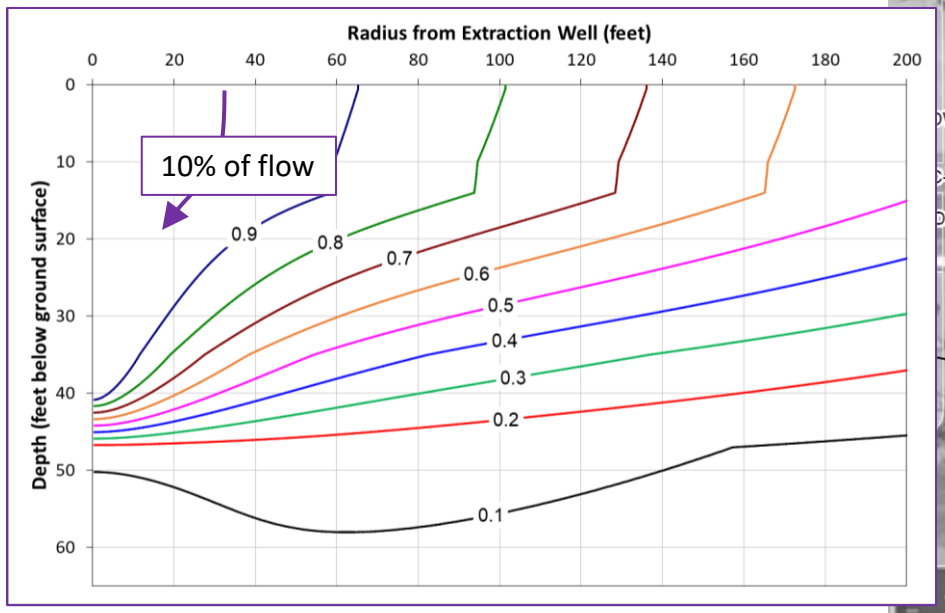
Soil Vapor Extraction (SVE) for VI Protectiveness Across Multiple Buildings

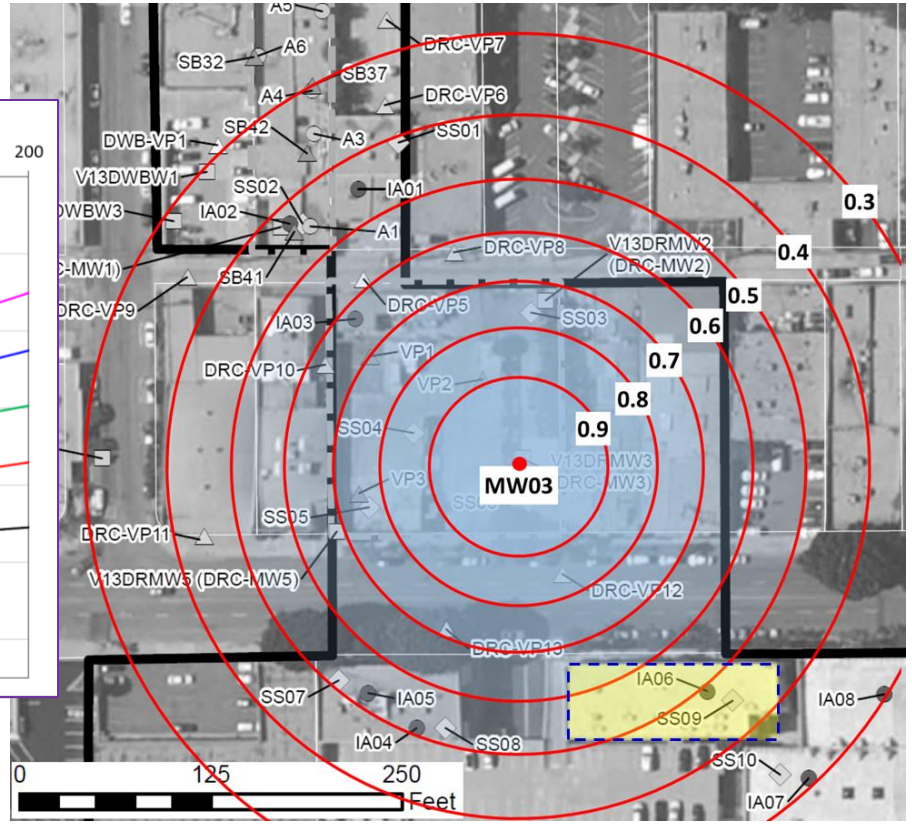
Bo Stewart[2], Praxis Environmental; Robert Truesdale, RTI[2]
John H. Zimmerman, Brian Schumacher, Rebecca Connell, Rusty Harris-Bishop, US EPA[1]
Chris Lutes, Jacobs
[1] funding organization; [2] presenters





Design and Operational Concepts for VI Mitigation with SVE





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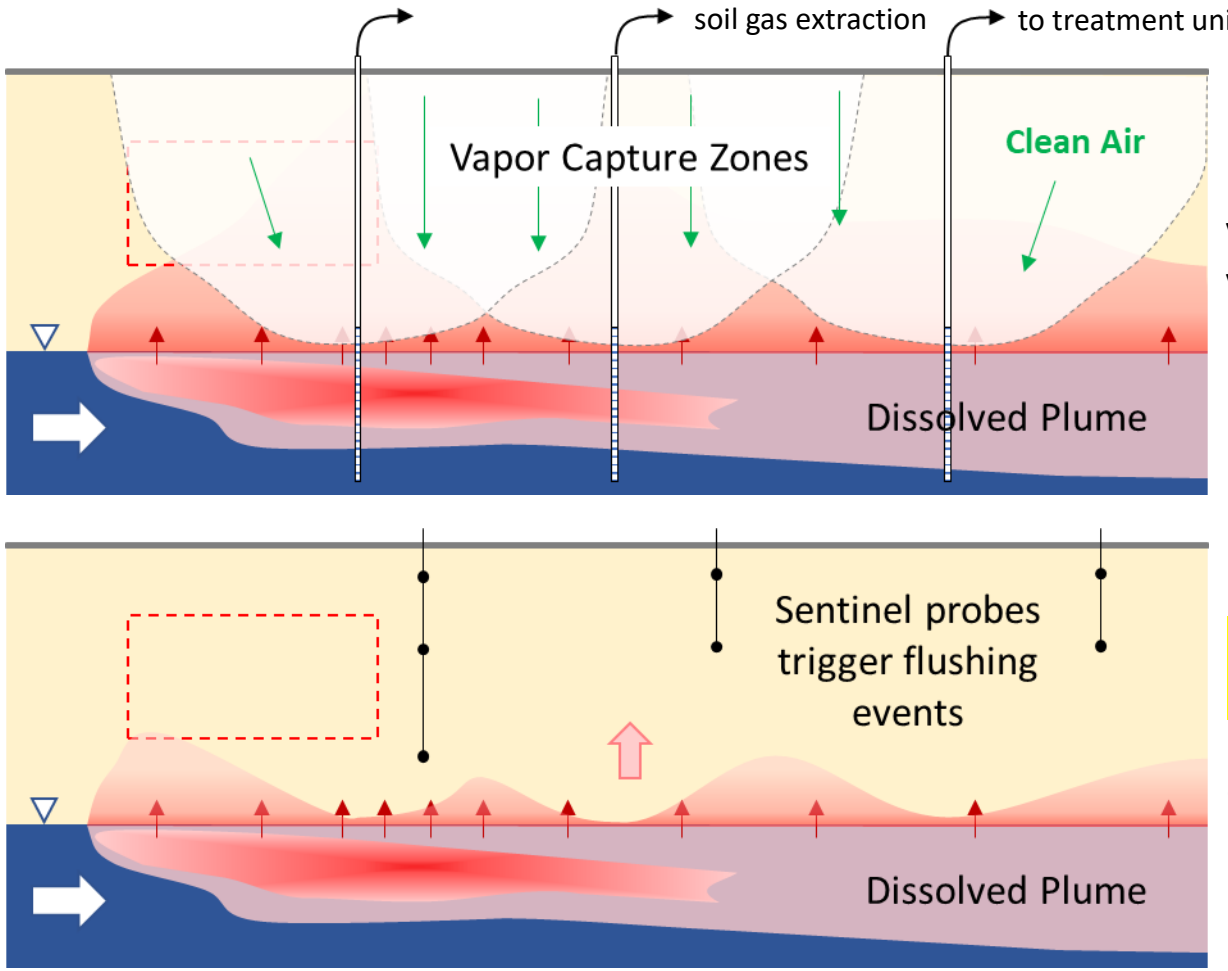

Flushing several soil gas pore volumes suppresses the vapor plume, TEMPORARILY

Periodic monitoring of sentinel probes until a threshold concentration is detected; triggers flushing event

[Could these SG probes be used to replace indoor air samples? e.g., in LTS Once bldg.-specific relationships to soil gas conc. are established?]

Benefits of Using SVE – esp. for RCRA RP decisions

Summary: ***More like groundwater*** responses – external media control/cleanup

- Community:
  - Contaminated media directed/collected toward locations away from personal property
  - Collected contaminated media can be managed/treated as extracted (not into outdoor air)
  - Individual buildings not visually 'stigmatized' as worse than others
  - Less noise, nuisance & bldg.-specific management of controls, as a new o/o responsibility
- Responsible Party:
  - Does not need to 'intrude' into personal lives because they manage/collect their contamination outside-before entering the building envelope
  - Does not need to confirm/document unacceptable indoor exposures, before cost-effective (business-like) & rational decisions can be made to pre-empt more exposure (& sooner)
- Regulators (RCRA):
  - More likely to get RP and Communities to agree to stopping exposures sooner (at lower $)?