The Future of Vapor Intrusion (VI) Monitoring and Analysis

National Environmental Measurement Conference

Bellevue, WA

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Presented by:

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USEPA – Office of Resource Conservation & Recovery (ORCR) Wash. DC

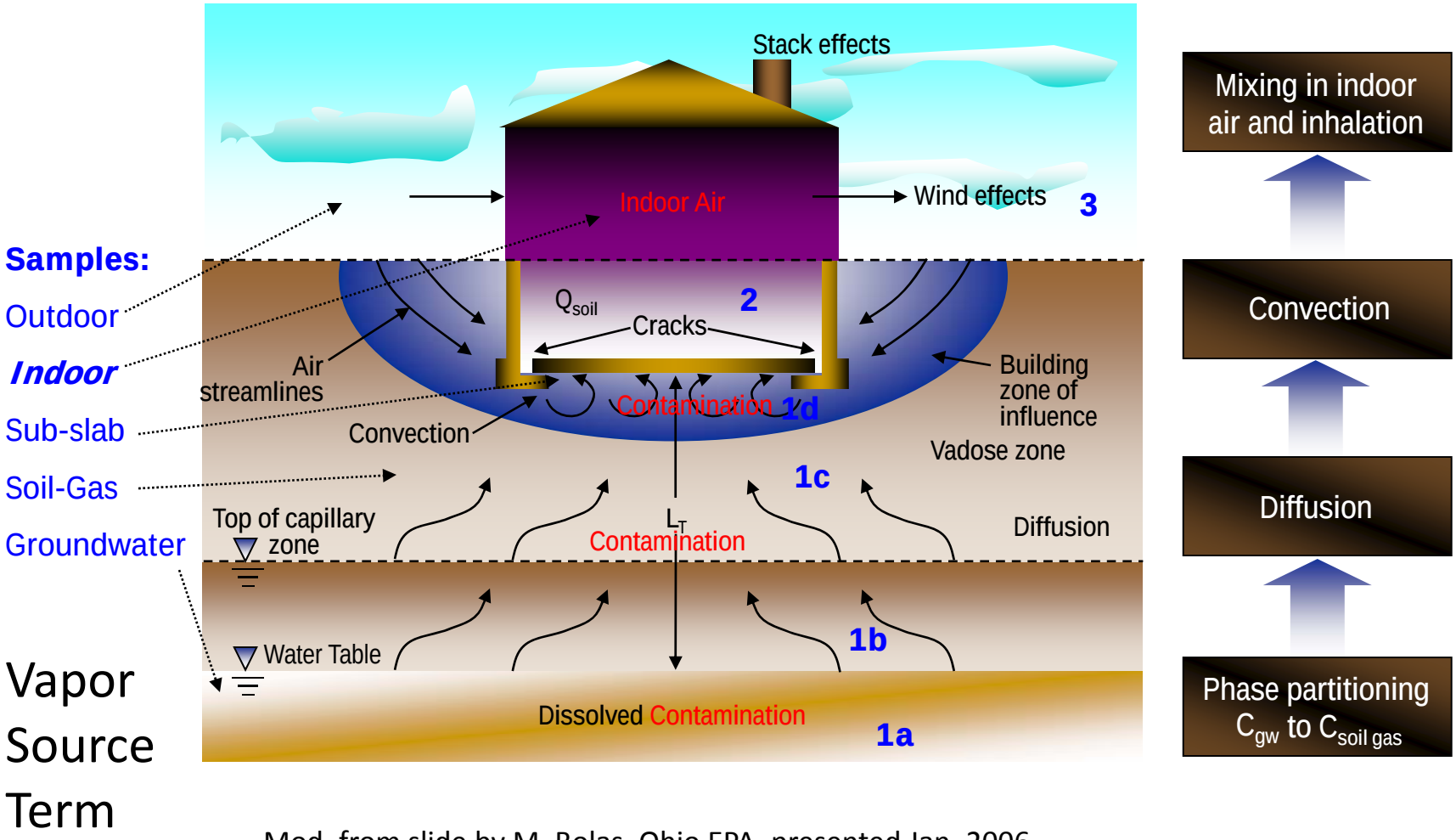
See: http://epa.gov/oswer/vaporintrusion

http://iavi.rti.org & www.envirogroup.com/vaporintrusion

Agenda

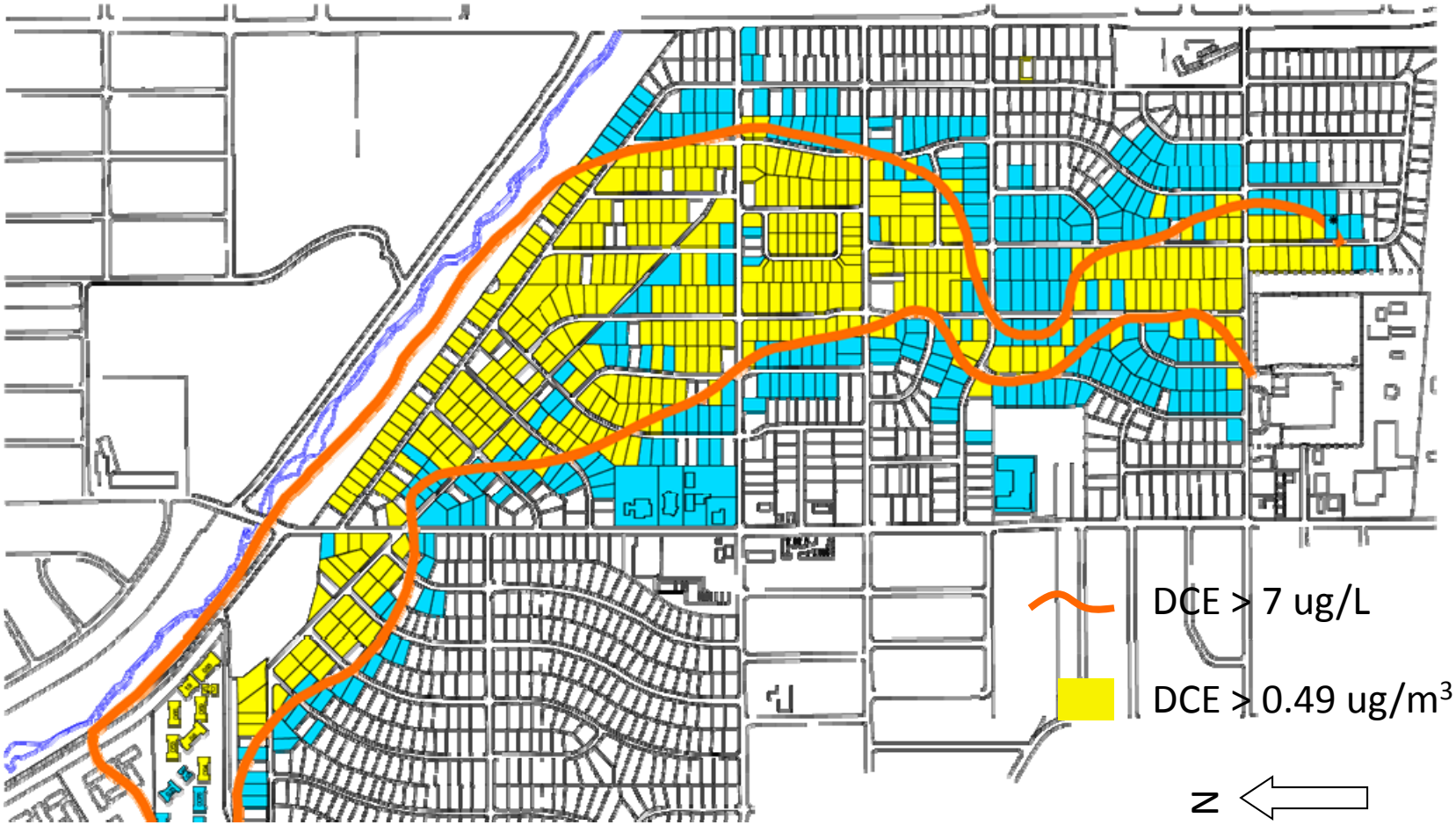
- 1) Summary of Monitoring Observations to-date
  - Variability (spatial & temporal)
- 2) Interpretation & Future Needs
- 3) Potential Evolution of Monitoring & Analysis
  - Including Consideration of Radon in VOC VI ?
- 4) Novel Field Analytical Technique – Mickunas

Simple conceptual model of the vapor intrusion exposure pathway



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

How do you identify which buildings are impacted by VI?

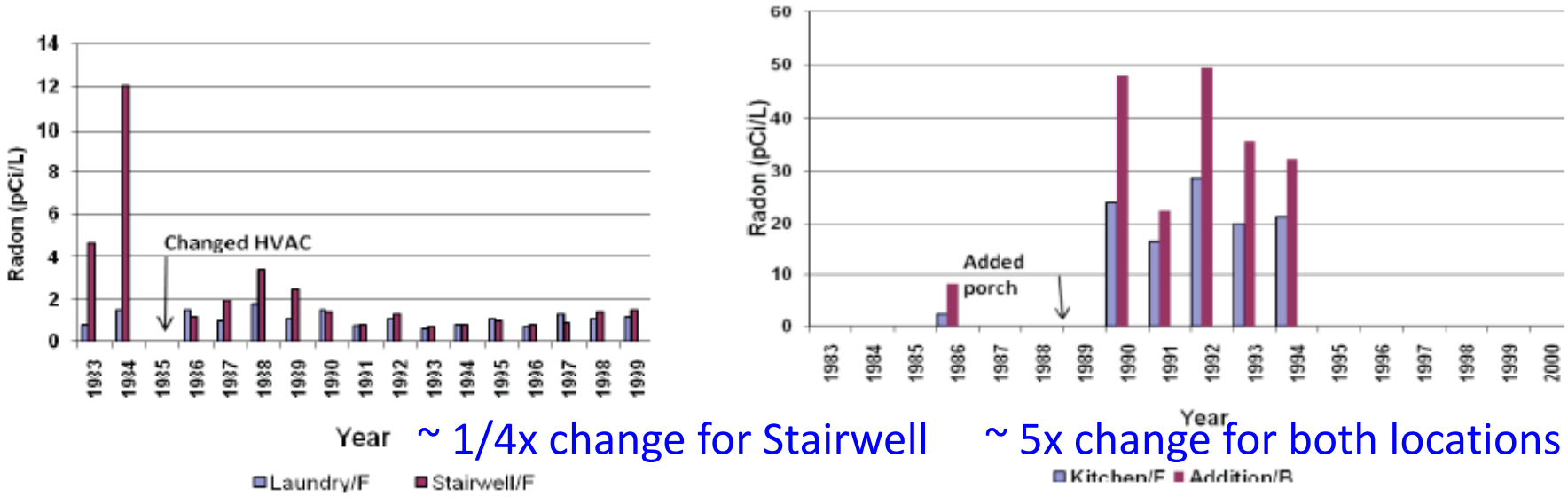


Graphic from Enviro-Group, Ltd.

Radon Studies show each Building can be Unique

Changes illustrating the importance of Building factors

American Association of Radon Scientists and Technologists 2007 Proceedings
Of the 2007 AARST International Symposium Jacksonville, FL, 2008©AARST



~ 1/4x change for Stairwell ~ 5x change for both locations

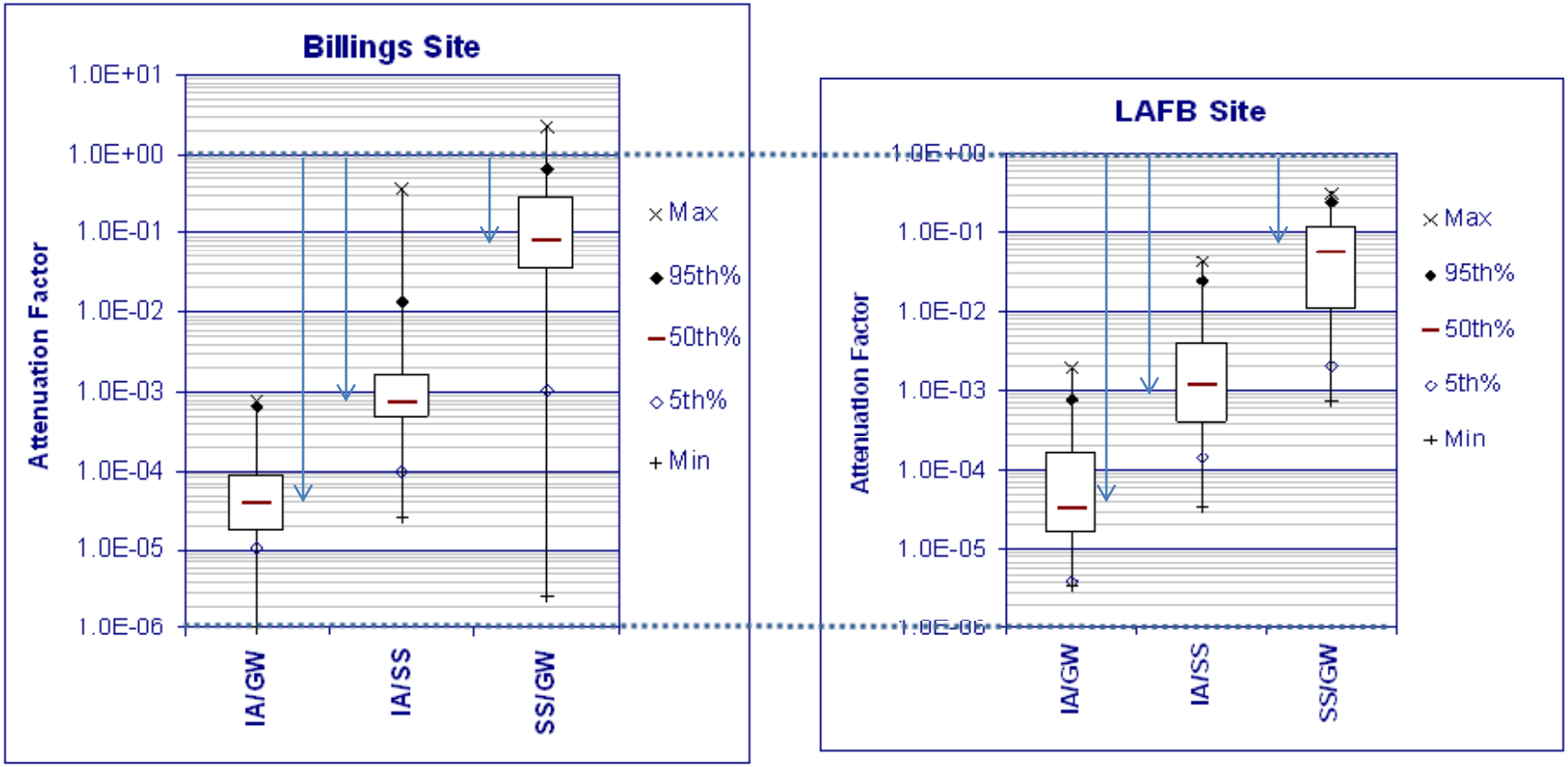
Figure 4 Examples of large radon changes created by house modifications

Note, the difficulty of estimating changes in heating or air condition or adding porches; and also impacts to VI.

Steck 2007, see: http://www.aarst.org/proceedings/2007/8-SteckYTYRnvariation07.pdf

Groundwater– Subslab – Indoor Air Attenuation – Billings and LAFB

(Lowry Air Force Base, Colo.)



- More attenuation occurs between the subslab and indoor air (~1E-03; 1/1000) than occurs between groundwater and subslab (~1E-01; 1/10).

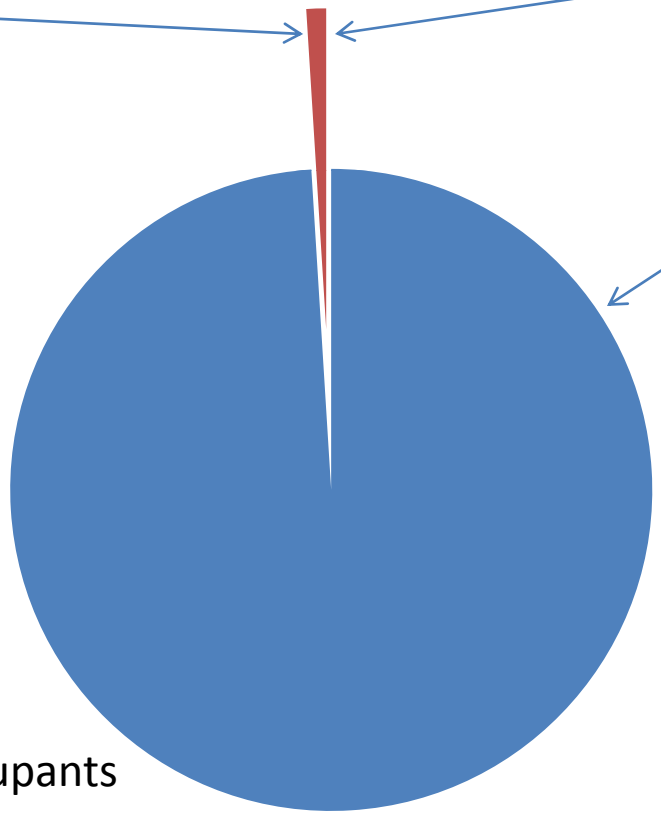
Slide by Dr. Helen Dawson, from AEHS March 2011

Chemical VI data sets now show Where Most Attenuation Happens*

w/ Samples & Possibly Influential & Measureable Factors

Groundwater
Soil Gas
Sub-slab SS
1%
Geology/Soils
Moisture
Utilities…

Median attenuation seen in **GW-SS** (10x) vs. **SS-IA** (1000x)



In the Building

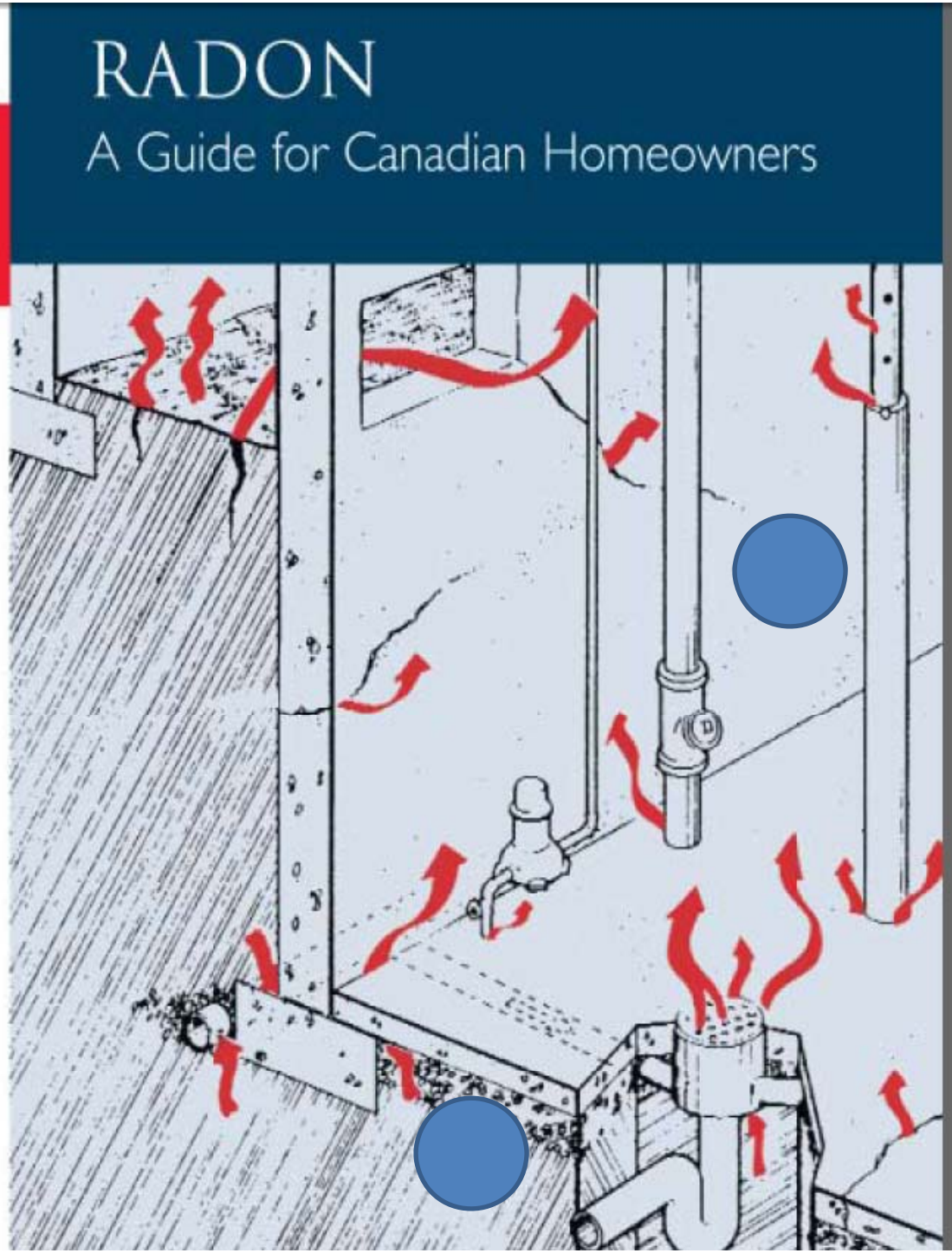
In the Subsurface

Indoor Air
99%
Building:
Design
Construction
Condition
Operation/occupants
Orientation
Weather …

*Based on EPA's (chemical) VI database

Events between the blue dots

Radon workers have long focused on **building-specific factors** - - interacting with environ. variables

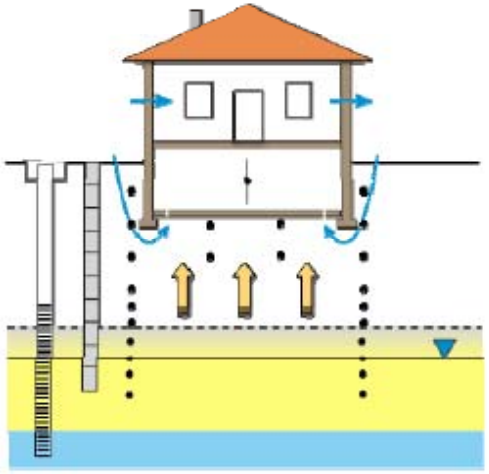


Samples Characterizing the VI Source are Important, but

***Only* Indoor Air** samples are:

- **Building-Specific**
  - &
  - Reflect the full (cumulative) effects of:
    - Source type
    - Subsurface migration factors
    - Building factors
      - (& indoor sources)
    - Atmospheric factors
  - External samples can not or do not include the last two parts of the equation (which represent **99%** of attenuation)
    - i.e., Can be used to screen source-terms (w/ generic attenuation) but
      - **Should Not** play a part in **Exposure** Assessments

Temporal Changes in VI Behavior: Considerations for Pathway Assessment



Paul C. Johnson
Emma Luo
Paul Dahlen
Chase Holton

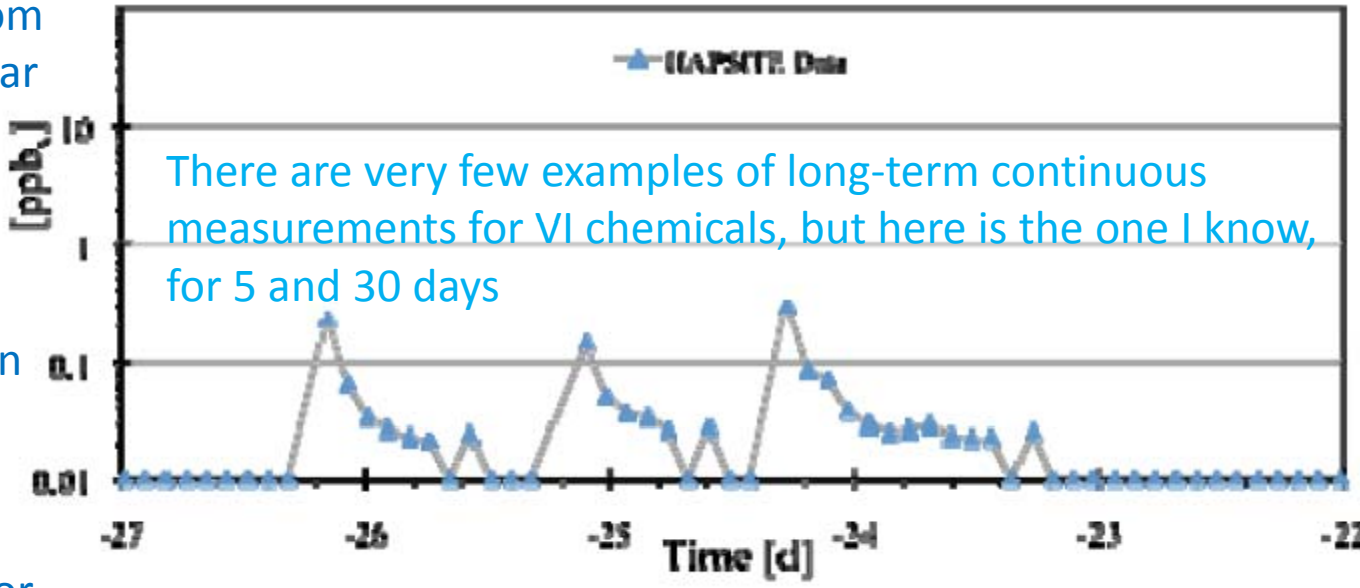
Ira A. Fulton Schools of Engineering

ASU

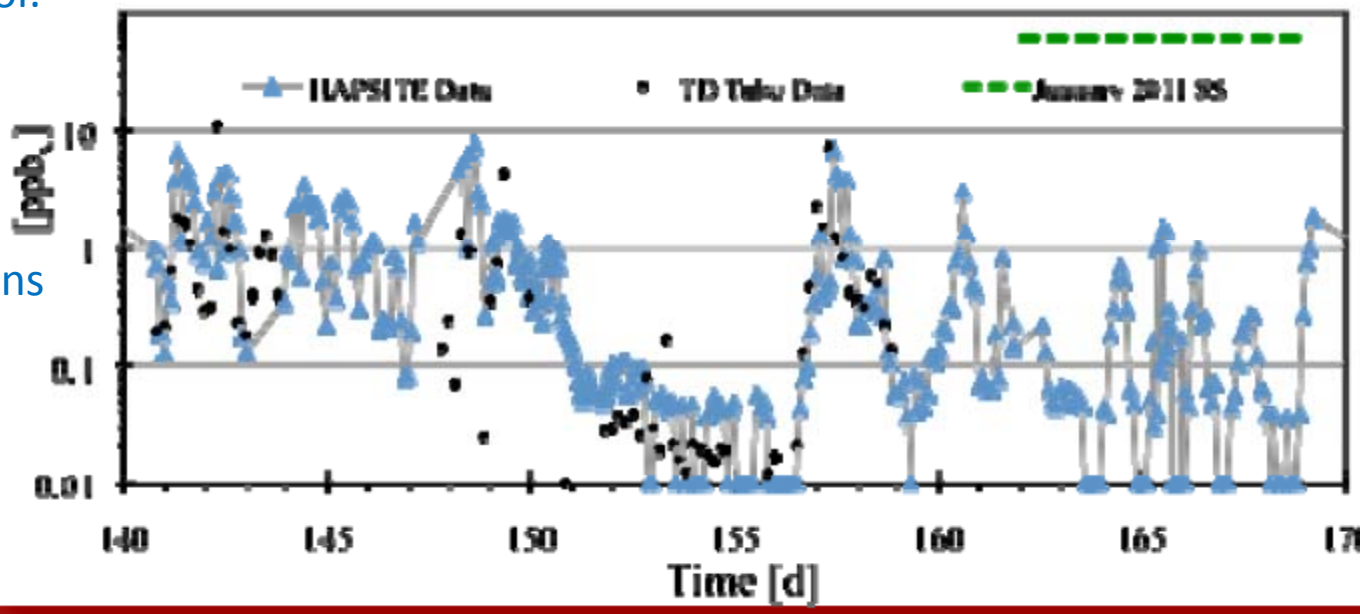
SERDP DOD • EPA • DOE | ESTCP

TCE Indoor Air Concentrations

Non-random but irregular (complex, **episodic**), temporal variability observed in chemicals from VI in ASU's Sun Devil Manor.



Similar to observations of radon.



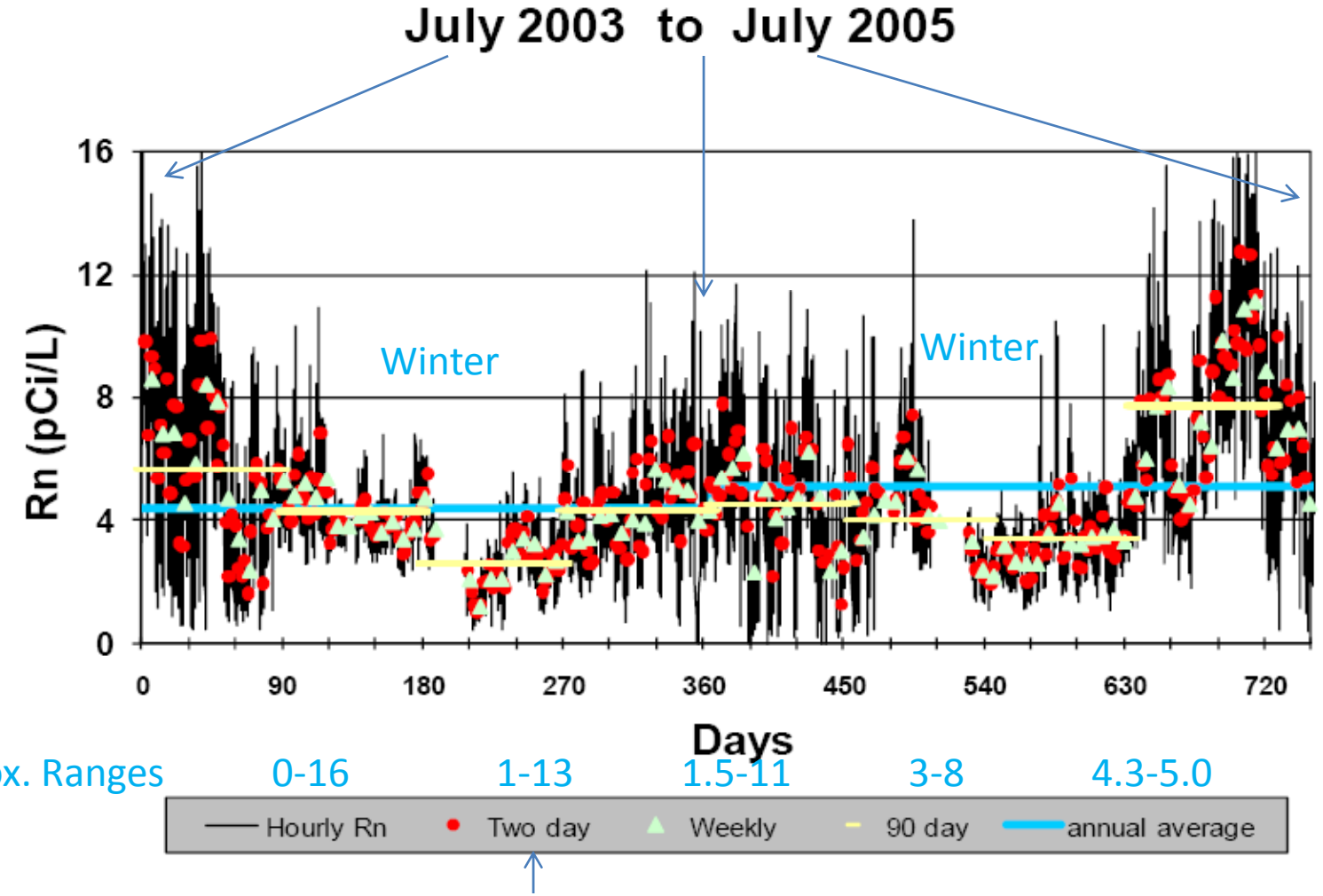
See iavi.rti.org for Dr. P. Johnson's comments for regulators;

Including comments on **need for real-time continuous** chemical indoor air monitoring.

P. C. Johnson 2011

There are many examples of long-term continuous measurements for radon

Temporal variation at the Example house



Approx. Ranges 0-16 1-13 1.5-11 3-8 4.3-5.0

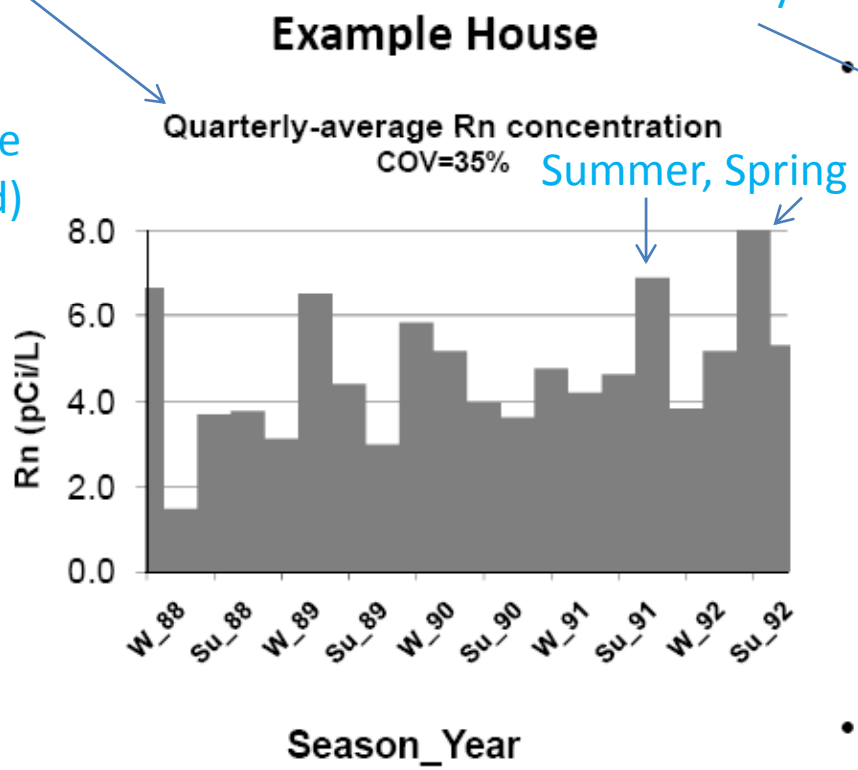
EPA min. 2-day sample duration for Radon

Slide by Dr. Dan Steck, from AEHS March 2011

Seasonal indoor radon variation

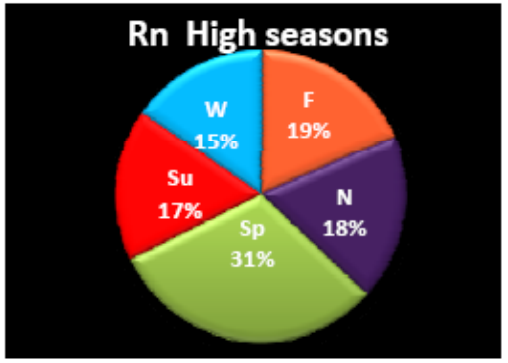
90 day; (WHO min. sample period)

30 day



Surveys

- MN 80 houses (Steck 2004, 2005)
  - Monthly over 1 year



Note, Spring 2x Winter

  - No strong seasonal variation of the group but most individual houses have strong seasonal patterns which vary from house to house

- National 480 houses (White 1994)
  - a 2 day measurement in each season and a yearlong measurement
  - No apparent strong seasonal variation of the group

2 day

References: Steck 2004, 2005 White 1994

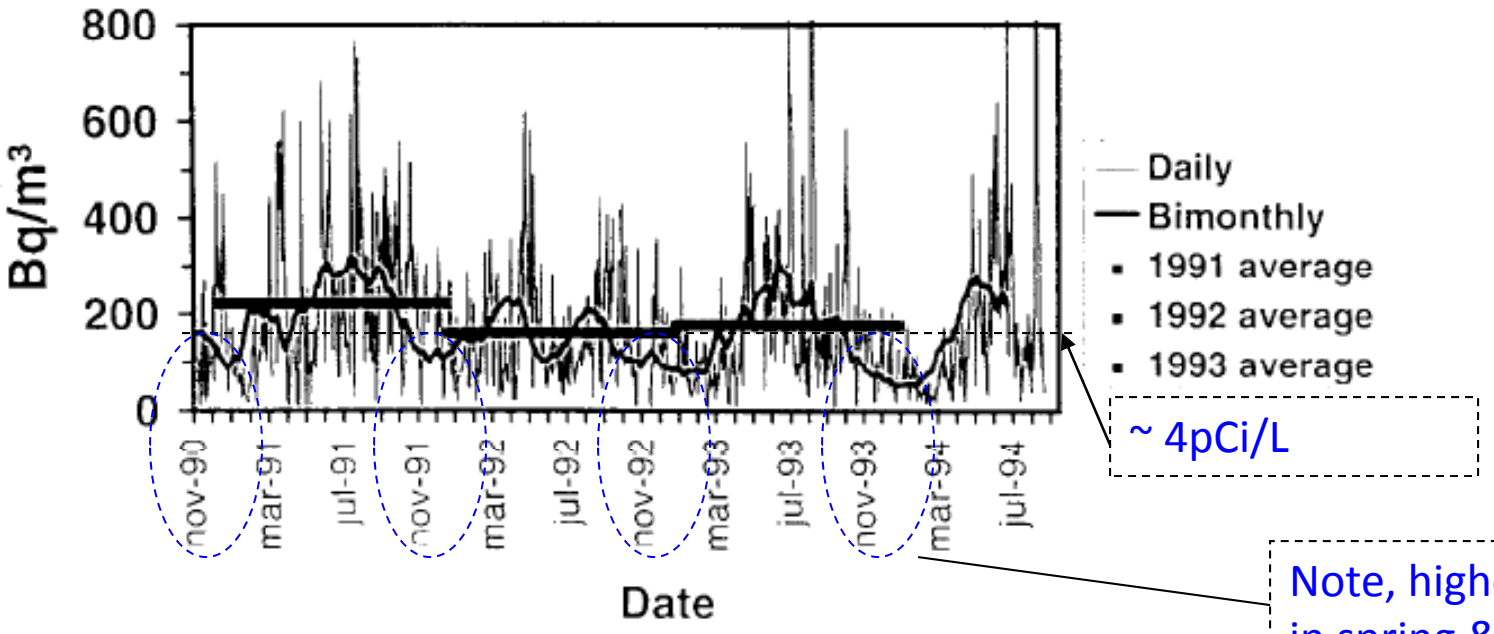
Slide by Dr. Dan Steck, from AEHS March 2011

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

Indoor Air Samples



~ 4pCi/L

Note, highest in spring & fall

Fig. 1. Daily, bimonthly, and yearly averaged indoor radon concentration.

Summary of Radon Conc. (Bq/m^3) Hubbard et al. 1996 (Sweden)

Sample	Factor	Range	Avg.	Period
1-Day	**100x**	~8 to 800	yr.	4 yr. ’90-94
2-Week	4.3x	70 to 300	yr.	4 yr. ’90-94
Year	1.3x	180 to 230	-	4 yr. ’90-94

- ~ four year period Nov. 1990 – July 1994

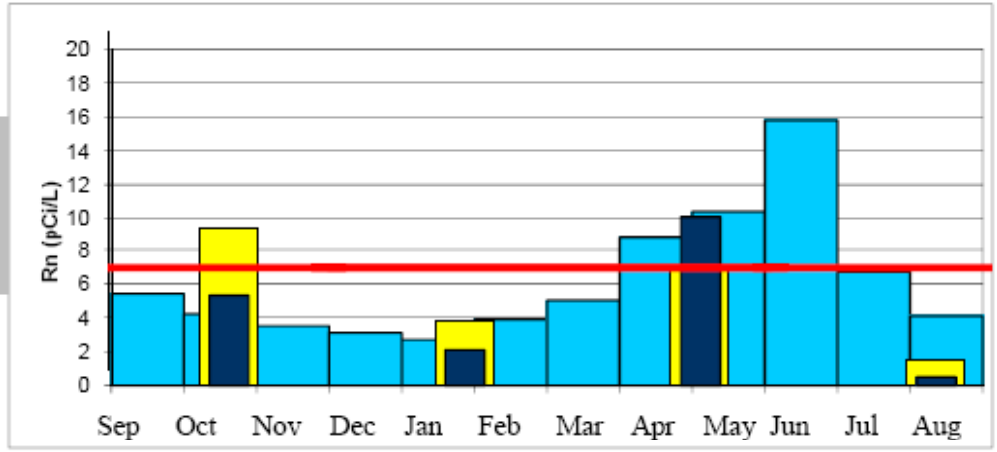
1-Day samples (chemicals)
Folkes et al., 2009

- 715 indoor air samples of 1,1-DCE (***24-hr*** samples)
- 45 unmitigated (**low conc**.) homes
- Data from 2 to 10 years (w/ Qtr – annual frequencies)
  - "The [indoor air] normalized [by property annual average conc.] values ranged [max.-min.] from about *10%* (0.1x) … to about *ten times* (10x) the *annual average* of the home"
  - **Range of variation =** 2 orders magnitude **(100x)**
    - 68% of samples w/n **+/-** 2 to 3x of the homes annual mean
    - Winter concentrations tended to be highest and summer was about 50% lower than the annual mean
  - "Short term variability can overwhelm any seasonal trend" [very similar to comment by Rowe 2002]

Multi-day measurement variation

Example House

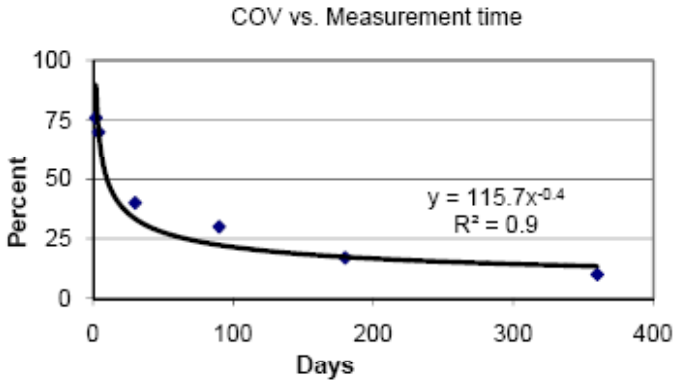
Annual average
Monthly average
Four day average
Two day average



Surveys :

variation around annual average

- 80 MN houses (Steck 2005)
  - 2d COV ~75%
  - 4 d COV ~70%
  - 30d COV ~40%
- 480 US homes(White 1994)
  - 2d COV ~70%;

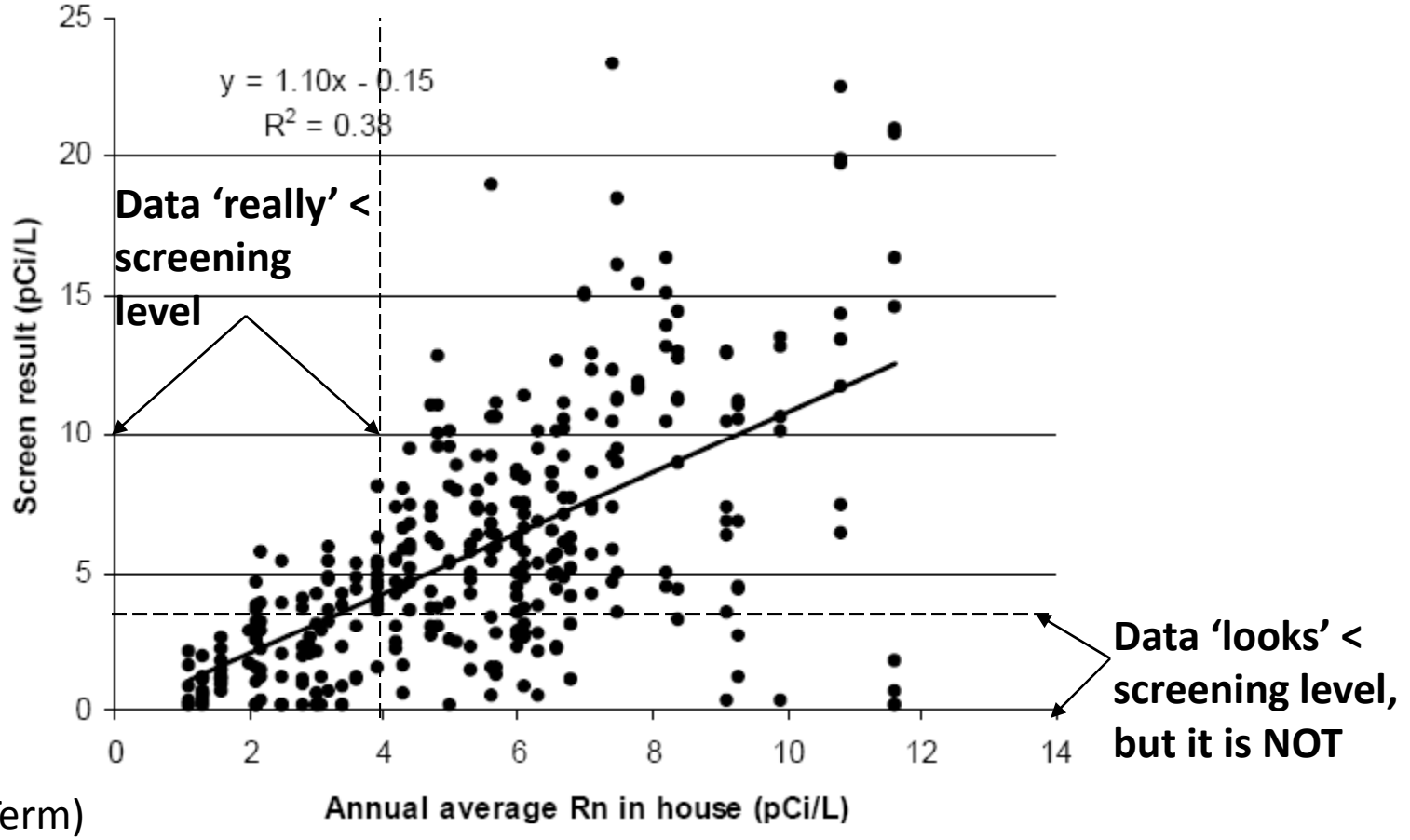


References: Steck 2005 White 1994

Slide by Dr. Dan Steck, from AEHS March 2011

Steck 2005

Residential Radon Risk Assessment: How well is it working in a high radon region?



(2 + 4 day = Short Term)

Figure 3. Linear regression between ST screening measurements and the annual average radon in the house (one high radon house is not shown) in the Temporal survey

Radon Screening Lessons

Steck 2005

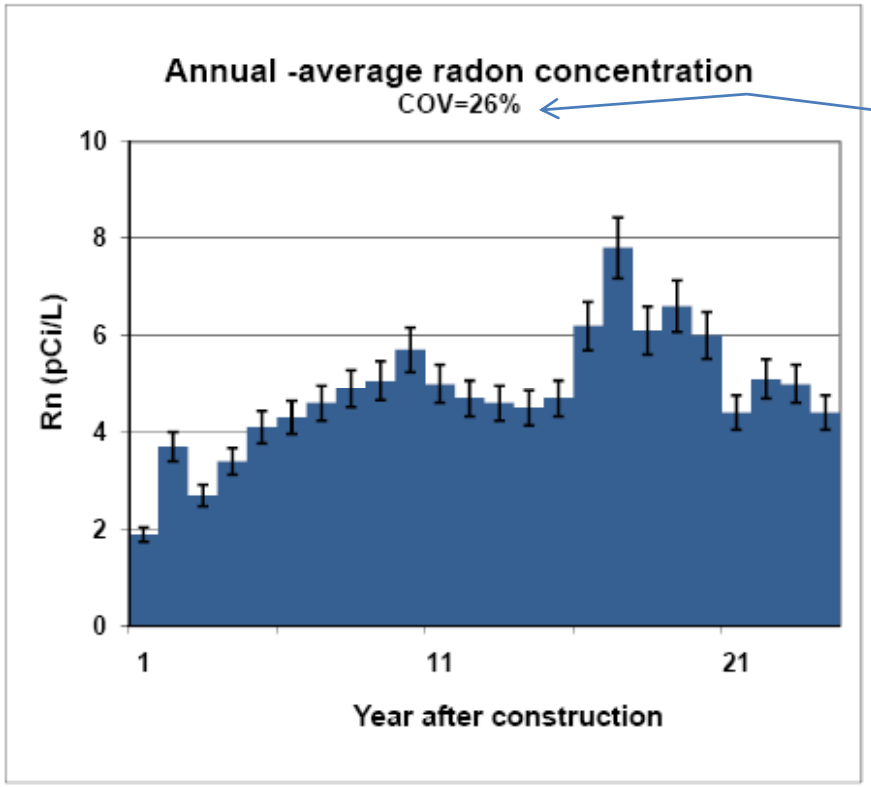
- In an area with a high level of radon:
  - "The efficiency of the [2 to 4 day] diagnostic test is … *not much different from a random* … test's efficiency."
    - i.e., **close to *50 – 50***
  - "homeowners who believe based on their single screening [*2 to 4 day long indoor air*] measurement, that they have a house below the action level are *often mistaken*."

Slide by Dr. Dan Steck, from AEHS March 2011

Non-varying source term (VOCs can vary)

Year-to-year indoor radon variation

Example House



Survey

- Variation in 99 Upper Midwest house over 2 decades
  - COV ~25% (factor of 1.25) persistent trend at 20% of the houses
- Factors affecting annual variation
  - Annual snowfall
  - Wind at site
  - Changes in HVAC, structure and winter window covers
- Factor not affecting
  - Radon concentration, house age, number of floors, heating type, active ventilation…

Reference: Steck 2009

Appears hard to predict future intrusion of radon into an existing house (with a stable radon source) & chemical sources can be more variable

Possible Recommendations for VI from Radon Lessons

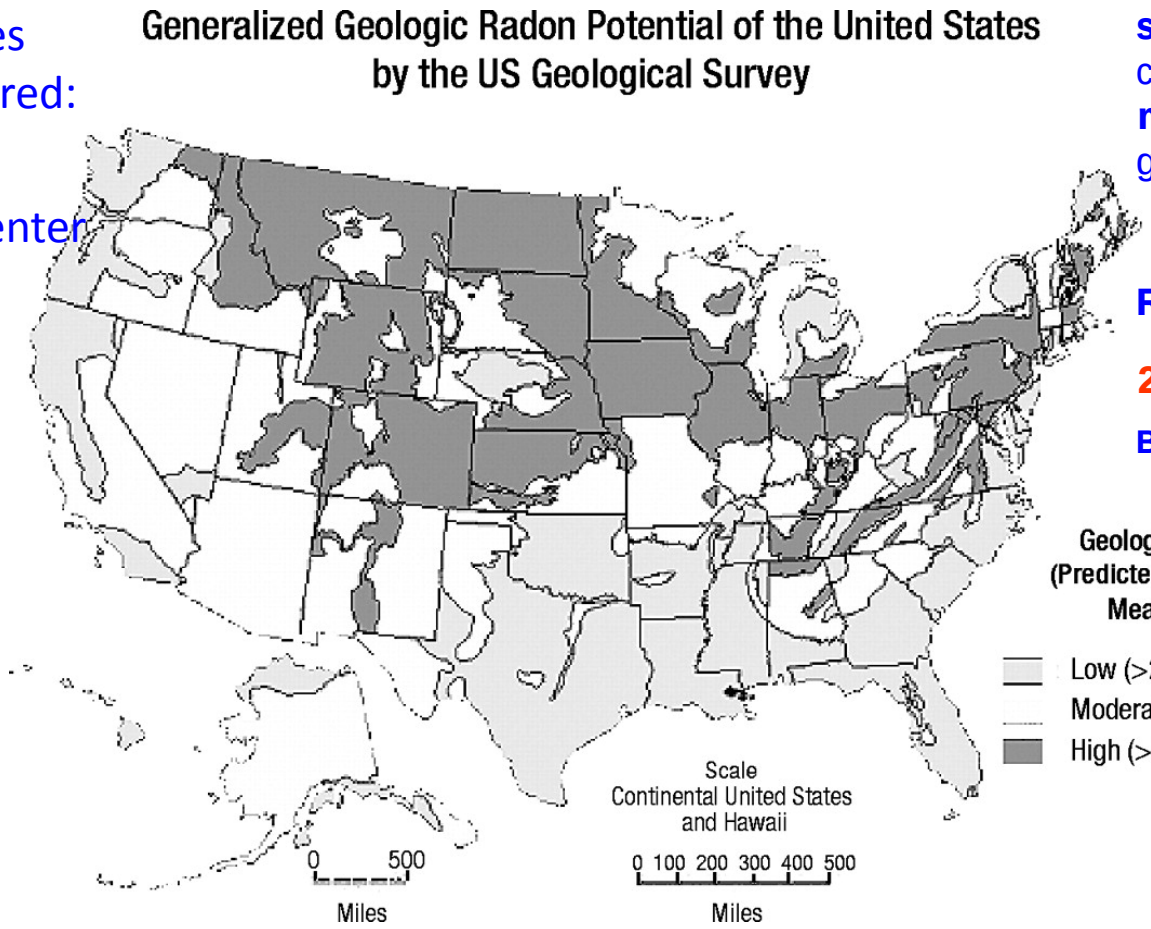
- Use Indoor Air samples
- Take longer duration samples*
  - *Appropriate for the health outcomes of concern (e.g., for windows of vulnerability)
- Use Radon Measurements:
  - As general tracer of soil-gas entry into indoor air
  - If radon gets in, so do other gases + vapors
    - To identify vapor-permeable homes for chemical testing
      - » Indicator of high VI risks (Rn & **low**/**possible** chemical)?
        - Can radon levels help justify 'pre-emptive' actions?
    - To test the on-going performance of mitigation systems

RADON

FIGURE 1

Human Health-based studies (2005) required:

1 yr-long samples to enter



From Frumkin, H. et al.
CA Cancer J Clin 2001;51:337-344.

EPA's Perspective on Risks from Residential Radon Exposure

"Indoor **radon** … **the most serious** environmental carcinogen which the **EPA must address** for the general public" Puskin 1989

Risk* ~ 2.3000 % (4pCi/L)

20,000 Lung* Cancers/yr

But: Complacency & Costs

Jalbert, 2004

* adult cancer

Zones Based on indoor air & geology

The same VI pathway

Real 'background' for chemical VI

With chemical VI you get **BOTH**

CA
A Cancer Journal for Clinicians

Potential Chemical Testing of Vapor Control/Mitigation Systems

- Type of Response Action:
  - Pre-emptive Vapor Controls
  - Definitively-Determined as-Needed VI Mitigation
- Possible Sampling/Monitoring During:
  - Installation
    - Subslab – baseline concentration – location-specific
  - Operation
    - Vent-pipe – on-going concentrations through time – slab-wide
    - Subslab – concentrations through time – location-specific?
  - Termination of Mitigation Systems
    - Vent-pipe and subslab concentrations after shut down?

Thank You

- Questions / Discussion