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USING RADON AS A SURROGATE FOR VOCS TO DETERMINE BUILDING-SPECIFIC ATTENUATION FACTORS IN VAPOR INTRUSION ASSESSMENTS

AEHS CONFERENCE – SESSION #4

Gannett Fleming, Inc

October 16, 2018

Before We Start – Who is Here?

- State or Federal Regulators?
- Stakeholders – Site Owners & Municipalities?
- Consultants?
- Students?
- Anyone experienced in using radon as surrogate for assessing Vapor Intrusion Pathway?

Background Information

- **Volatile Organic Compounds (VOCs) – Suite of chemicals that readily volatilize from a liquid to gaseous state**
- **Vapor Intrusion (VI) – VOCs in soil gas migrating through the soil and floor slab/foundation into a building**
- **Attenuation Factor (AF)- The amount of gas held back by a barrier (soil, concrete slab, etc.)**

Overview of Presentation

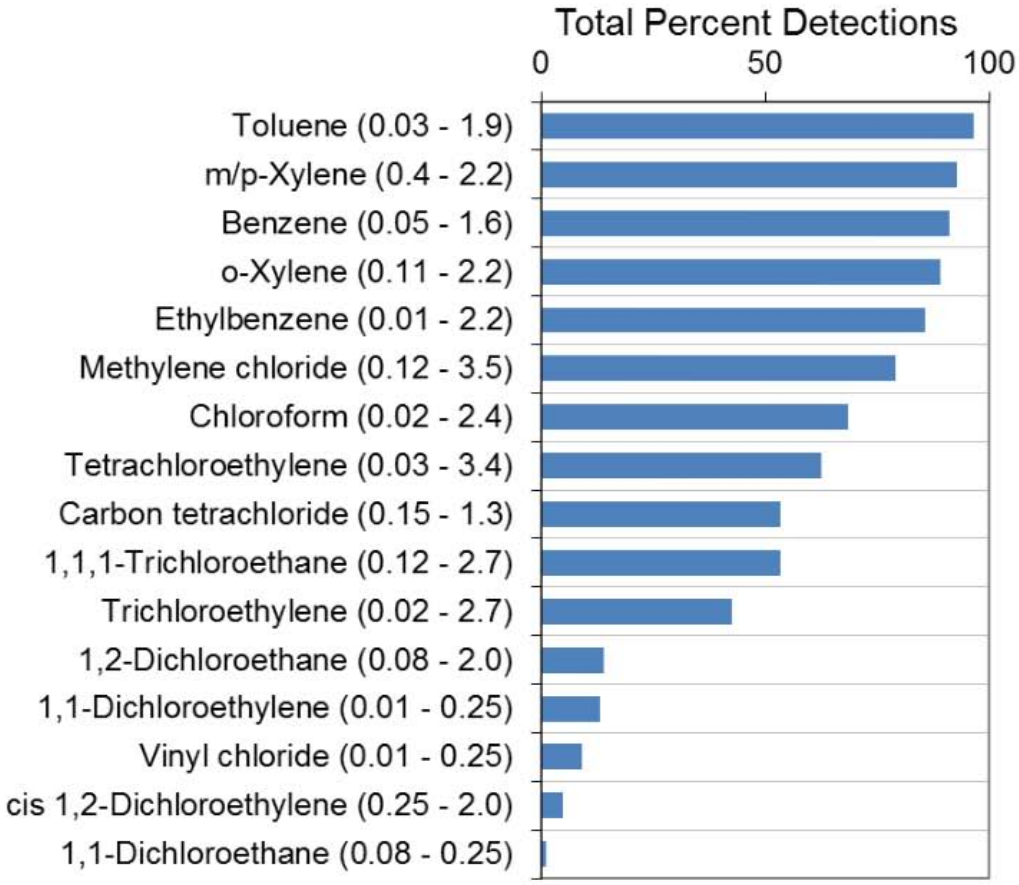
- **What's the problem? –**
  - **Assessing VI Pathway from sub-surface VOCs sources can be complicated by interference from indoor VOC sources**
  - **Indoor VOCs can lead to overestimation of VI risks and expensive & unnecessary mitigation**
- **A solution –**
  - **Use Radon to assess if VI pathway is complete & calculate a building-specific AF**

Statement of the Problem

- **Vapor Intrusion is an increasing concern at sites impacted by VOCs**
- **Many VOCs in indoor air (IA) samples have aboveground indoor & outdoor sources**
- **Many VOCs in subsurface are the same as measured in IA samples and may be from indoor sources (i.e. the earth inhales)**
- **Differentiating above and below ground VOC sources can be difficult**

Compounds Detected in Ambient Urban Air

- Ambient background
  - VOCs in urban air
- Indoor sources
  - VOCs emitted from consumer products and building materials
- Difficult to assess with conventional sampling methods
- Often ignored



Values in parentheses are reporting limits in µg/m³

***Source**: Dawson and McAlary, 2009*

Sources of Background VOCs in Indoor and Outdoor Air

- Paint, paint-thinners, solvents
- Dry-cleaned clothes
- Gas-powered lawn and garden equipment
- Building supplies (glues, asphalt shingles, synthetic carpets)
- Personal Hygiene Products - hairsprays, nail-polish removers, perfume, toothpaste
- Cigarette smoke
- Fiberboard furniture, varnish
- Dish soap & laundry detergent

Sources of Background VOCs in Indoor and Outdoor Air

IN SHORT –

EVERYTHING IN YOUR WORKPLACE, HOME & GARAGE MAY BE A SOURCE OF VOCS IN INDOOR AIR

What to Do?

- **Differentiate between indoor and sub-slab VOC sources using surrogate gas (radon)**
- **Measure radon and VOC concentrations concurrently in soil gas/vapor, and indoor and outdoor air**
- **Use Radon to determine sample locations**

What to Do?

- **Use sub-slab & indoor air Radon concentrations to calculate AF of building foundation/floor slab**

- **Use AF to predict indoor air concentrations of VOCs measured in sub-slab samples, then compare to screening levels**

Why Radon?

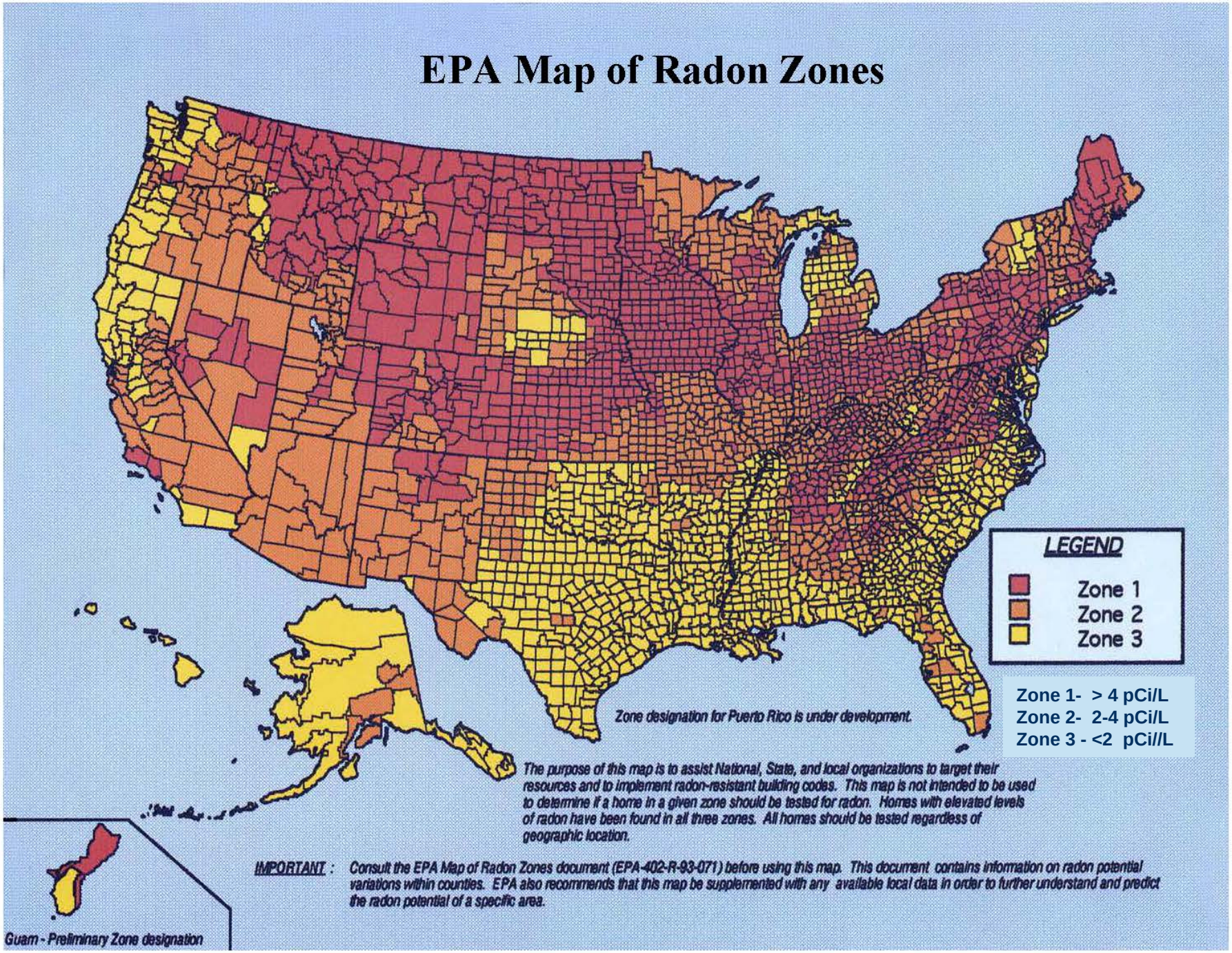
Radon

- Naturally occurring and ubiquitous
- Daughter product of radioactive decay of uranium and radium
- Chemically unreactive inert gas
- Behaves similarly to VOCs in subsurface
- Highly mobile and responsive to physical processes (diffusion & advection)

Rn as a Tracer

- Present in the pore space of all soils
- Does not biodegrade (half life = 3.8 days)
- Concentration in soil gas usually several orders of magnitude > atmosphere
- Not present at elevated concentrations in household products or building materials
- VI is the primary source of Rn in indoor air

EPA Map of Radon Zones



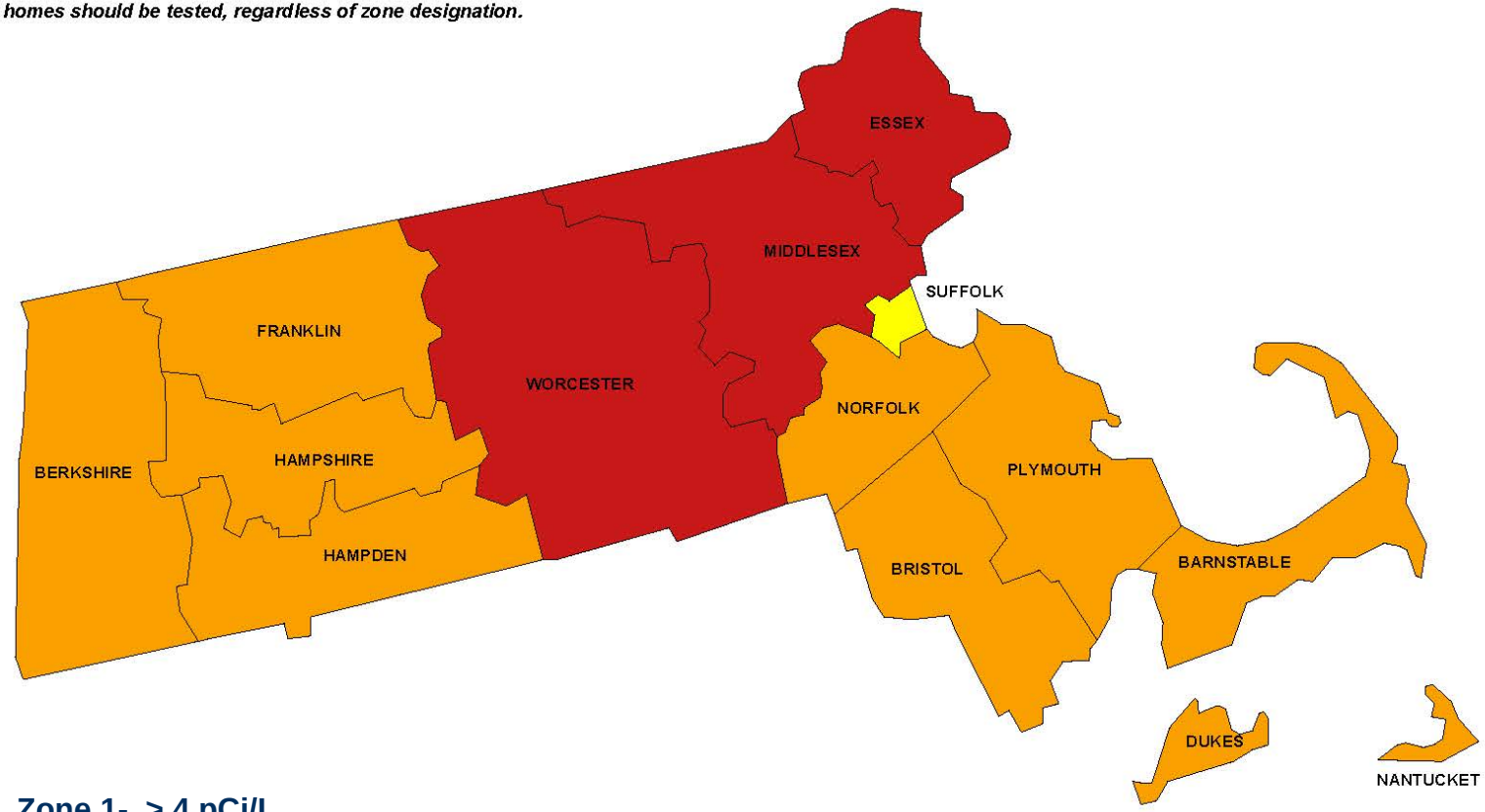
MASSACHUSETTS - EPA Map of Radon Zones

http://www.epa.gov/radon/zonemap.html

The purpose of this map is to assist National, State and local organizations to target their resources and to implement radon-resistant building codes.

This map is not intended to determine if a home in a given zone should be tested for radon. Homes with elevated levels of radon have been found in all three zones.

All homes should be tested, regardless of zone designation.



Zone 1- > 4 pCi/L
Zone 2- 2-4 pCi/L
Zone 3 - <2 pCi//L

Zone 1 Zone 2 Zone 3

IMPORTANT: Consult the publication entitled "Preliminary Geologic Radon Potential Assessment of Massachusetts" (USGS Open-file Report 93-292-A) before using this map. http://energy.cr.usgs.gov/radon/grpinfo.html This document contains information on radon potential variations within counties. EPA also recommends that this map be supplemented with any available local data in order to further understand and predict the radon potential of a specific area.

Background Radon in Indoor Air

Indoor Sources of Radon:

- **Granite, Marble, Concrete & Bricks**
- **Drywall & Ceramics**
- **Water from GW sources - 1,000 pCi/L in water ~ 0.1 pCi/L in air (10,000-fold decrease)**

All these sources give off negligible amounts of radon gas (typically <0.5 pCi/L) that is diluted by IA – (Chen 2010)

Background Radon in Indoor Air

The USEPA states it simply in its Consumer's Guide to Radon Reduction:

"In a small number of homes, the building materials (e.g., granite, bricks, and certain concrete products) can give off radon, although they rarely cause radon issues by themselves. In the US, radon gas in soil is the principal source of elevated radon levels in homes."

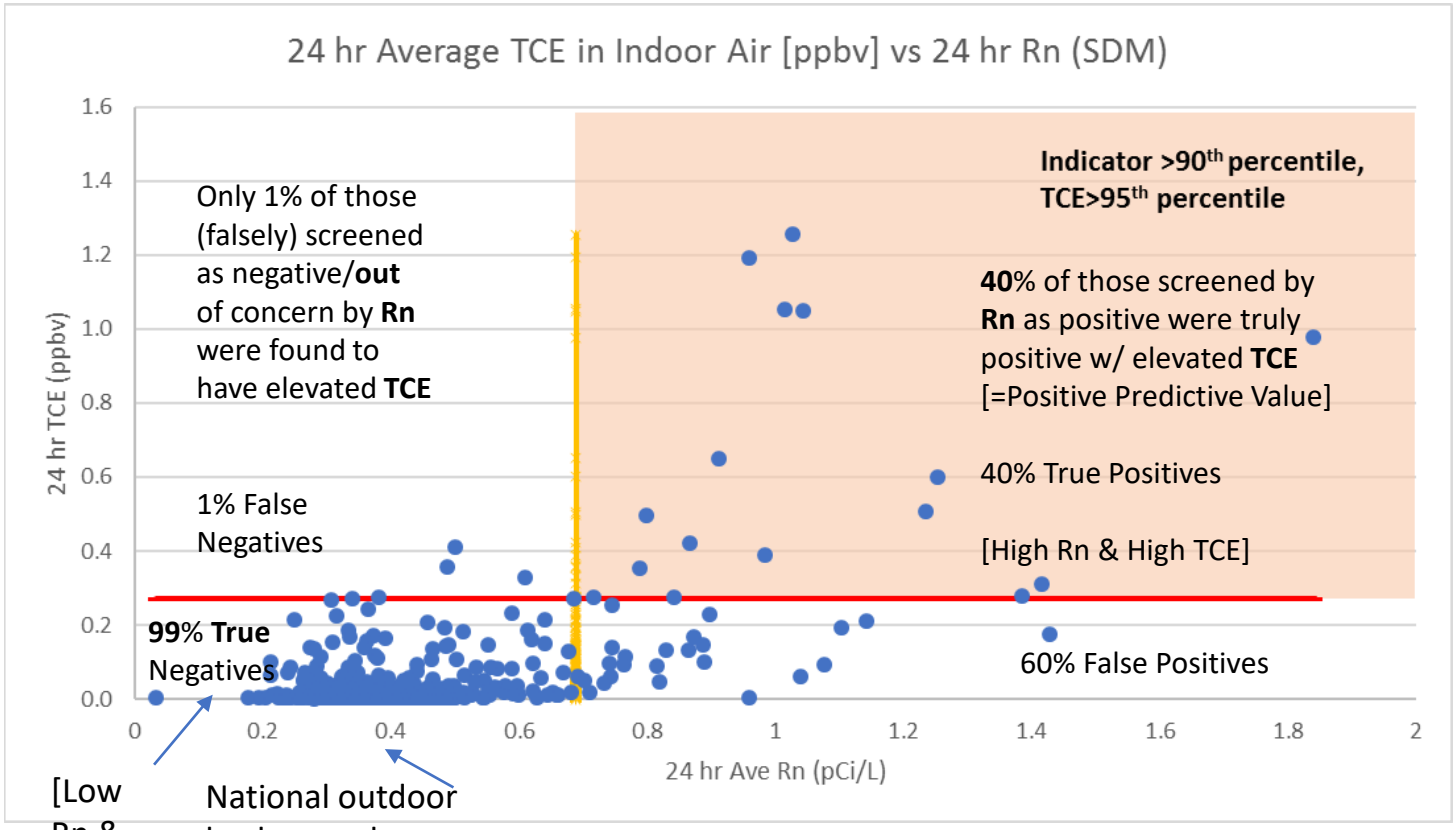
Conclusion – If there's radon above background concentrations in indoor air, it's indicative of vapor intrusion

Correlation Between Radon & VOCs

- **Radon and VOC concentrations from subsurface vapors are greatest in IA when:**
  - There is a wide indoor to outdoor temperature differential (Holton et al, 2012)
  - During a low pressure front (exhalation event)

- **Numerous studies have shown a strong correlation between elevated Radon concentrations in IA & Vapor Intrusion (Schuver, et al)**

Radon concentrations in Indoor Air as Indicator of TCE



Diagnostic (Exposure) Screening

of SDM house data, statistics by J Kurtz

Schuver et al - 2018

Attenuation Factor Calculation

$$\alpha = \frac{C_{Rn}(indoor) - C_{Rn}(outdoor)}{C_{Rn}(Soilvapor)}$$

- α= Attenuation factor
- C_{Rn}= Concentration of radon
- Correct for decay between collection & analysis if sample analyzed by laboratory

*Equation adapted from Fischer, et al., 1996

Predicted Indoor Air Concentration

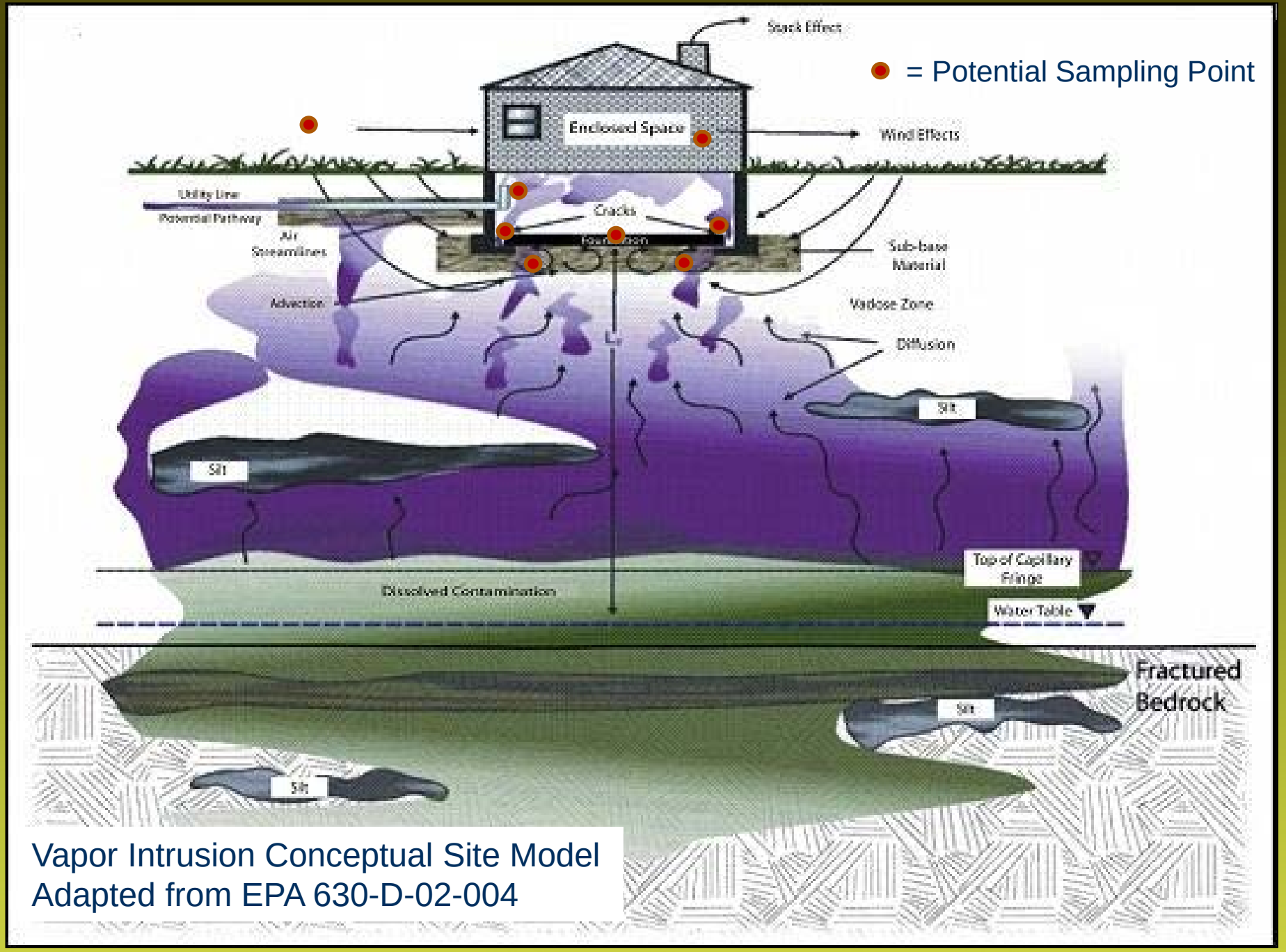
$$C_{building} = C_{soilvapor} \times \alpha$$

- $C_{soil\ vapor}$ = VOC concentration in soil vapor
- $C_{building}$ = Predicted indoor air concentration due to soil vapor intrusion

*Equation adapted from EPA, 2003, J&E Model Users Guide

Attenuation Factors

- **Attenuation Factors are affected by:**
  - Integrity of media – cracks/openings in floor slab & foundation, porosity of soil, root channels, borrows, etc.
  - Preferential Pathways – sumps, floor drains, utility lines penetrating foundation walls
  - Building Dimensions – size matters if indoor air VOC & Radon concentrations are affected by air exchange rates
  - Pressure & temperature differentials + wind



Vapor Intrusion Conceptual Site Model
Adapted from EPA 630-D-02-004

Attenuation Factors

- **Most regulatory guidance use conservative default AFs that may overestimate the risk of vapor intrusion**

- **Overestimation of the vapor risk can lead to unnecessary and costly sampling and mitigation costs**

Attenuation Factors

- **Lower AF Values = Greater Attenuation**
- **Default AFs used by Various Agencies:**
  - Crawlspace = 1 (i.e. no attenuation)
  - Sub-slab Vapor = 0.03/0.01
  - Deep Soil Gas = 0.01/0.001
  - Groundwater = 0.001/0.0001

    residential/industrial

  AFs based on 1 in 100,000 carcinogenic target risk or non-cancer health risk of 1

Measured Attenuation Factors Using RN

- 0.00031 (Scrafford, et. al., 2008)
- 0.0016 (Little et. al., 1992)
- 0.004 from a study of 10 single family homes in NY (Mosley, et. al., 2004)
- 0.004 from a study of 9 single family homes in CT (DiGuilio et. al., 2006)
- 0.0004 to 0.006 Hill AFB: Range (McHugh et. al., 2008)
- 0.004 to 0.008 (Hers, et al – 2017)

Problem

The science and regulatory guidance for using radon in vapor intrusion assessments are:

- **Evolving**
- **Not always at the same pace**
- **The science is usually several years ahead of guidance**

STATES WITH VAPOR INTRUSION GUIDANCE DOCUMENTS

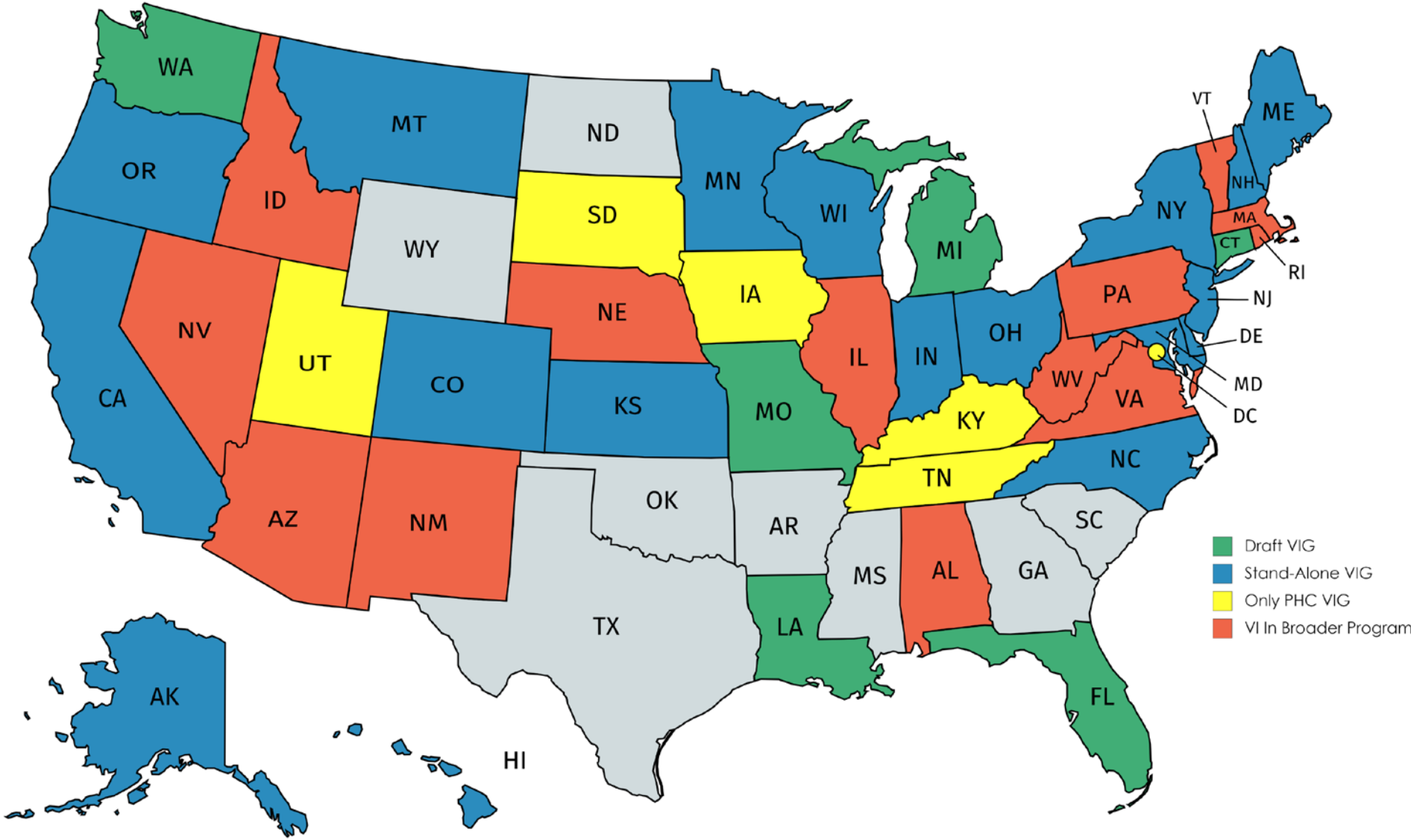


Figure Courtesy of Brad Eklund/AECOM - 01/2018

STATES USING RADON FOR ASSESSING ATTENUATION FACTOR

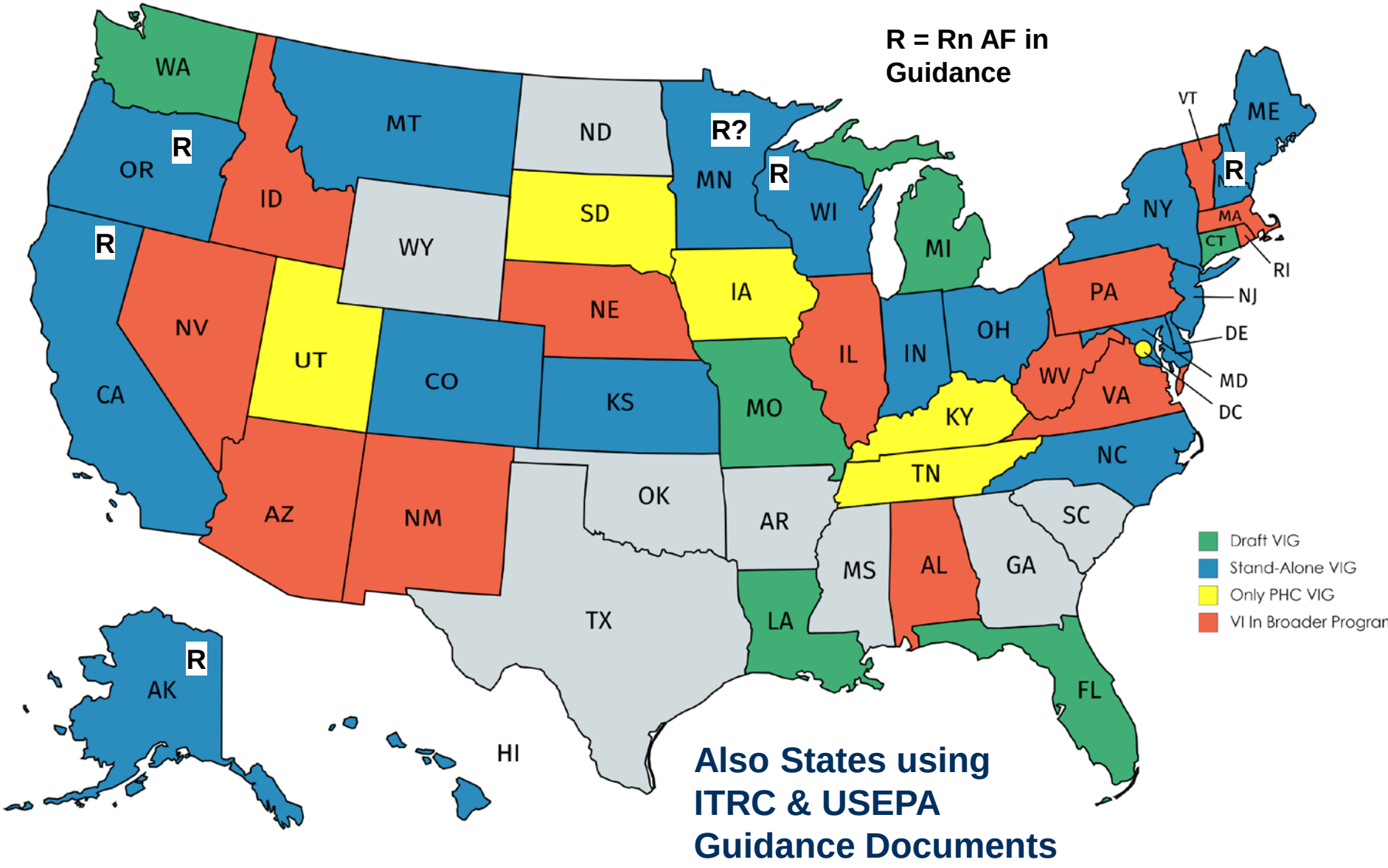


Figure Courtesy of Brad Eklund/AECOM – 01/2018

Summary

- Radon is a sensitive tracer for the movement of soil vapor across a building foundation
- Calculated AFs with Rn are small; often > 1 order of magnitude < default values
- Can predict the contribution of soil vapor to indoor air
- Can help differentiate VOC sources & develop a comprehensive CSM

SUMMARY - CONTINUED

- **Radon analyses is less expensive, more accurate and precise than VOC analyses**
- **Radon can be analyzed in field or lab**
- **Can conduct more field measurements with Radon than with VOCs due to low sampling/analytical costs**

SUMMARY - CONTINUED

- **Field-screening with Radon can be used to determine VOC sample locations & reduce overall number of VOC samples**
- **Radon can be used to assess SSD mitigation effectiveness**
- **USEPA & other Regulatory Agencies recognize benefits of Radon sampling to calculate AF & assess VI pathway**

LIMITATIONS

- **Elevated VOC & Radon concentrations in sub-surface are not necessarily co-located – may need to assess VI and calculate AFs at several locations in building**
- **Radon decays, so its concentration relative to VOCs may be lower during periods when it is not being replenished (i.e. earth is inhaling)**
- **Use temp & pressure differentials to time sampling event when earth is exhaling (both VOCs and radon) during heating season &/or low pressure front**

LIMITATIONS

- **Radon is 8-9 times heavier than air and may have higher concentrations at floor surface than in breathing zone where most/many Radon measurements are collected**
- **Some Regulatory Agencies are not receptive to using Radon to develop AFs (esp. homes)**
- **More research and discussion needed – please share**
- **Treat & Teach Your Regulator Well**

Questions?

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