EPA Vapor Intrusion Workshop

Why, When, Where, and How You Should Monitor Indoor Radon, Differential Temperature & Pressure During Chlorinated Vapor Intrusion Assessments

Spatial Applications In Initial Building And Sampling Location Screening

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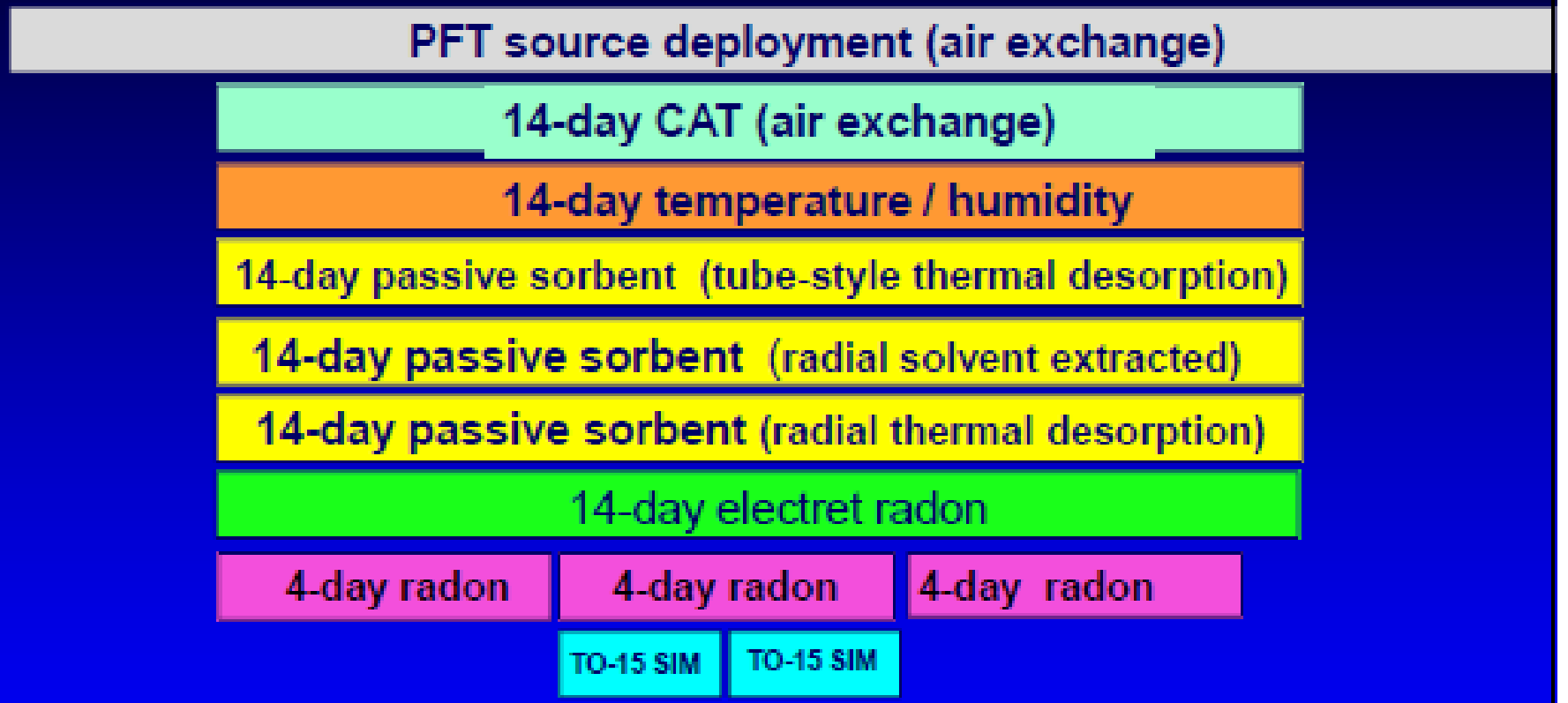
Concept/Objective – Using Radon

- Evaluate the effectiveness of radon as a tracer used in a screening mode to select the most vulnerable locations within a complex structure or single neighborhood to chemical VI.
- Include cases with either single rounds of time integrated data and instrumental continuous measurements
- Future application A: time integrated sampling of indoor air only for radon using passive devices (carbon, electret, alpha-track etc). Then select locations for VOC follow-up
- Future application B: multiweek deployment of consumer grade radon continuous instruments producing approximately hourly data for several weeks.
- Future application C: measure radon attenuation factor using both subslab and indoor air data

Case 1:
Moffett Field, Orion Park Housing, EPA RARE

- Data from July/August 2008
- Townhouse complex, unoccupied so presumably clear of indoor sources; townhouses nominally “matched” designs
- Groundwater-sourced TCE impacts
- 16 locations with paired time integrated samples
- Many of these locations also have a temporal variability history for VOCs with as many as 11 rounds…

Phase 1 Experimental Setup (20 units)

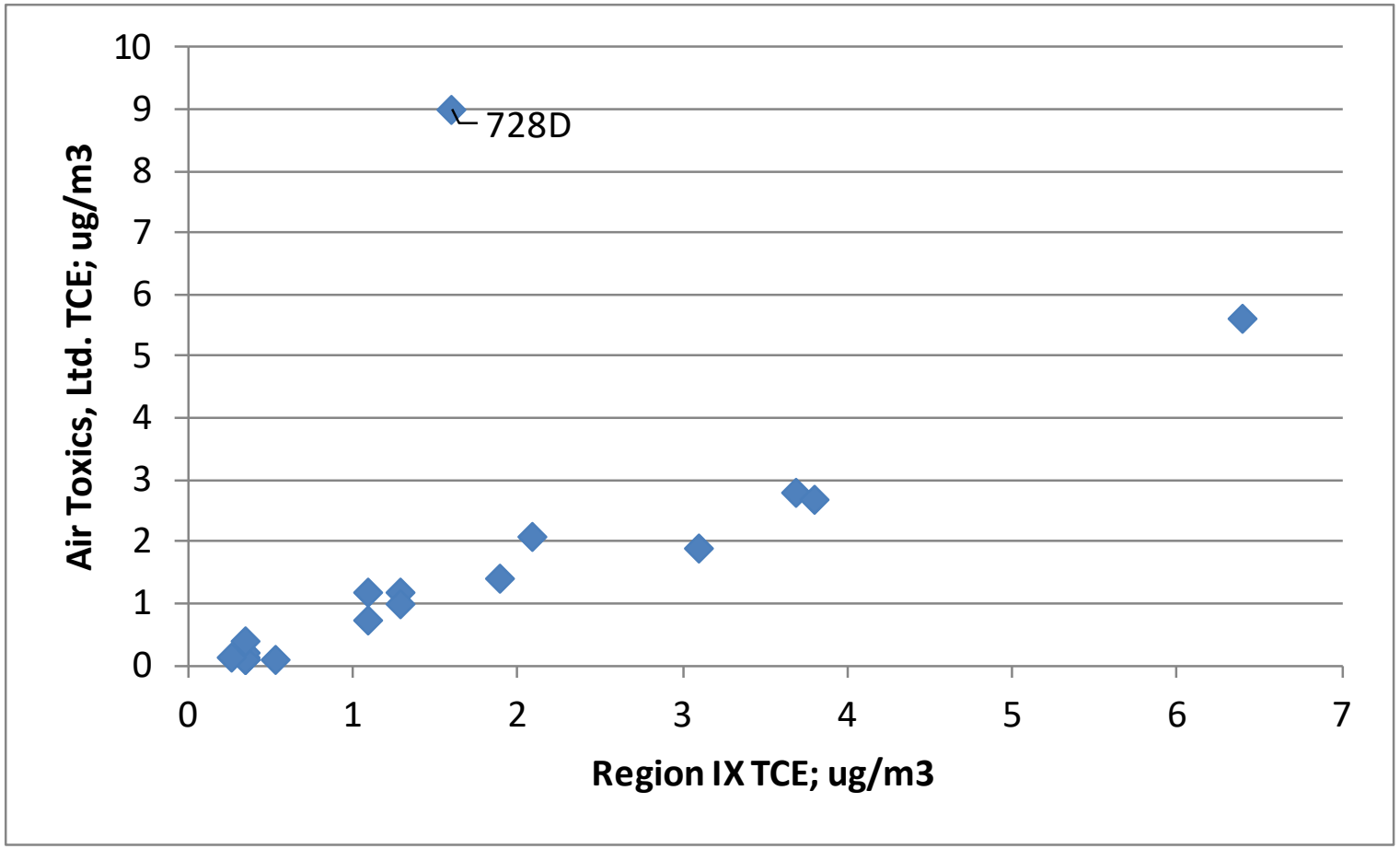


Slide Reprinted from Lee 2010

Moffett Field CA Testing – Indoor Air - Experimental Design

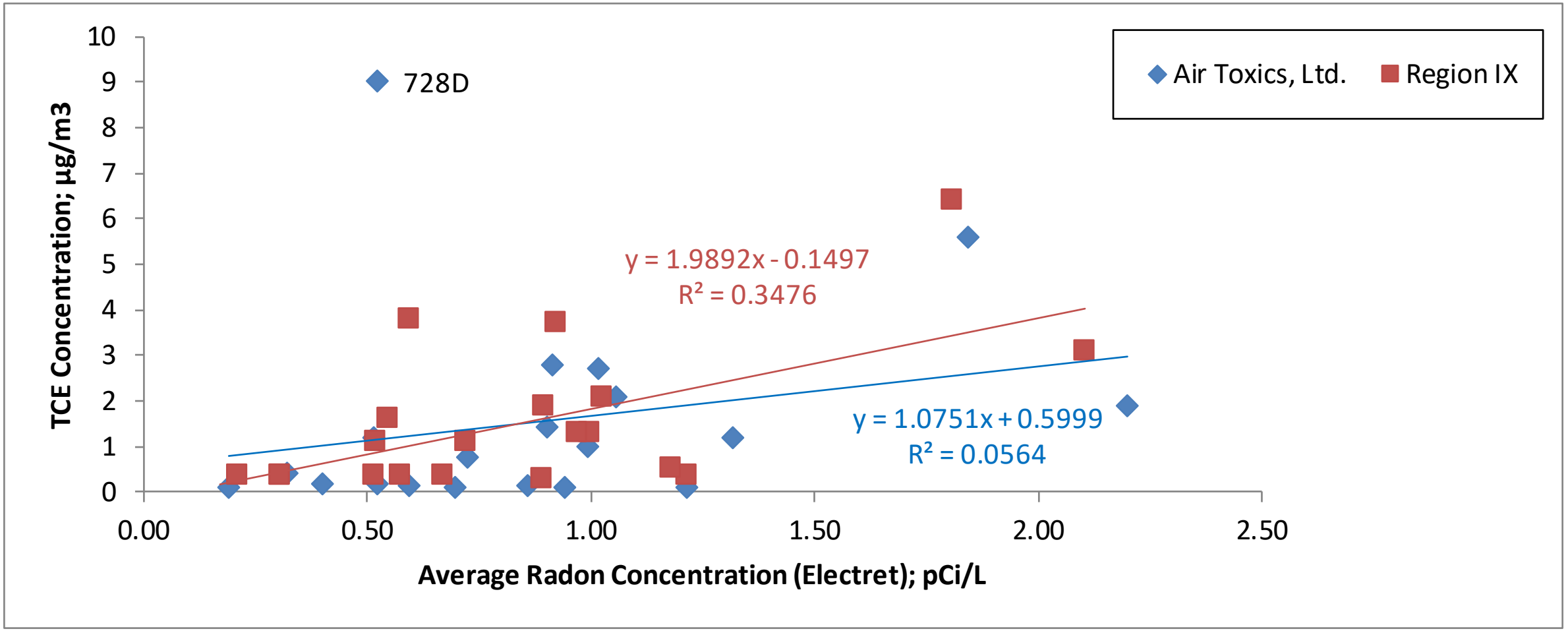
- Phase I – 20 units:
  - 14 day integrated air samples (??) in each unit, Three samplers:
    - Solvent extracted Radiellos,
    - Thermal extracted Radiello
    - Tube type
  - Compared to 2 short term TO-15 Summa samples in each unit, deployed at beginning and end of 14-day period
- Phase II – 8 units
  - 14 day integrated Solvent and Thermal Extracted Radiellos
  - Compared to 2 short term TO-15 samples

Intercomparision of Two VOC Sample Sets, Phase I at Orion Park (Indoor Air TO-15 at Two Labs)



Good agreement between two labs except for one data point, which is at the same location as will be an outlier in the next slide.

Radon as Spatial Tracer? Indoor Air Phase 1 Orion Park



Key Point: Correlation imperfect but higher TCE concentrations generally accompanied by elevated radon.

Case 2: SEND/Wheeler Site History – Indianapolis

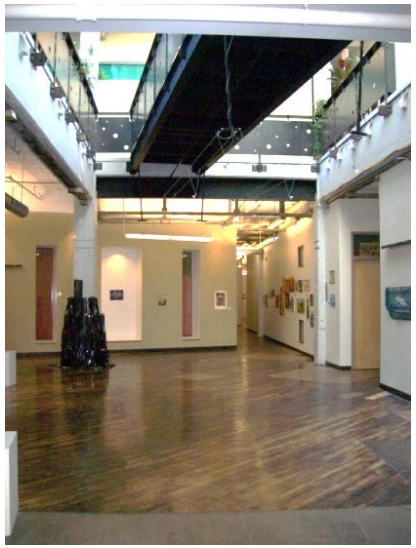
- An industrial facility from 1911 until 1995.
- Since SEND purchased the property in 1998 they have completed renovations, converting first and second floors into 36 live-work lofts for low-income artists, galleries, office space and a theater.
- Various environmental assessments as well as the removal of six petroleum product USTs between 1998 and 2006.
- Primary contaminants TCE and PCE
- TCE concentrations in groundwater beneath building Dec. 2005, depths typically between 25-30 ft (bls):
    - 10.2 µg/L directly upgradient (north) of Zone A
    - 24.1 µg/L along the west edge of Zone A
    - < 5 µg/L in four wells in Zone C and along the east edge of the building
    - Between 34 and 200 µg/L in a group of ten wells located downgradient (south) from Zone C.

Building Background – Wheeler Arts Building

- 100,000 sq ft
- Mix of slab-on-grade and basement construction, build in stages
- Contains more than 40 separate heating, ventilation and air conditioning (HVAC) zones and at least three major areas with different building envelopes.
- The Wheeler Arts Building has three main basement zones for this analysis:
    - A Northern, essentially unoccupied basement (17,250 sq ft) with two overlying occupied stories
    - B Central, essentially unoccupied basement (9,180 sq ft) with two overlying occupied stories
    - C Southern, slab-on-grade single story, used primarily for storage (7,790 sq ft).

Wheeler Building Exterior

Wheeler Renovated First Floor Common Area

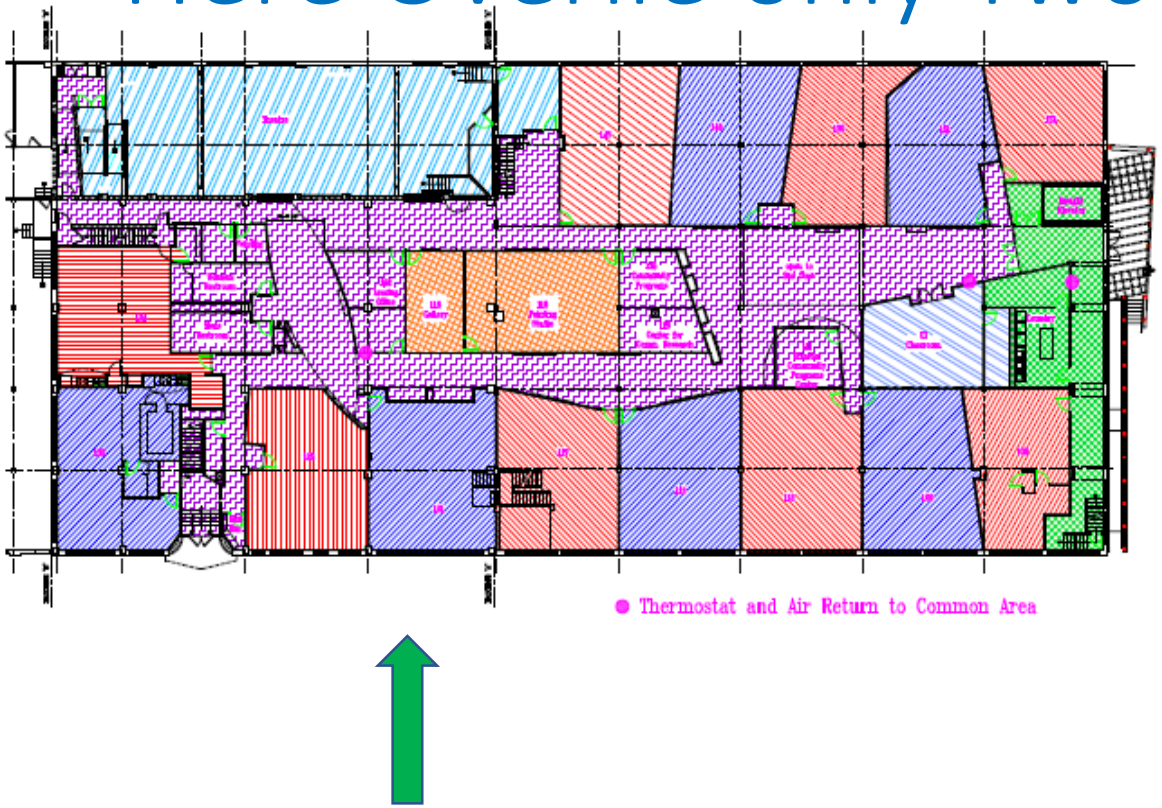


Hollow Tile Construction in Wheeler Basement Ceiling Provides Complex Flow Paths

Send Office Building Exterior

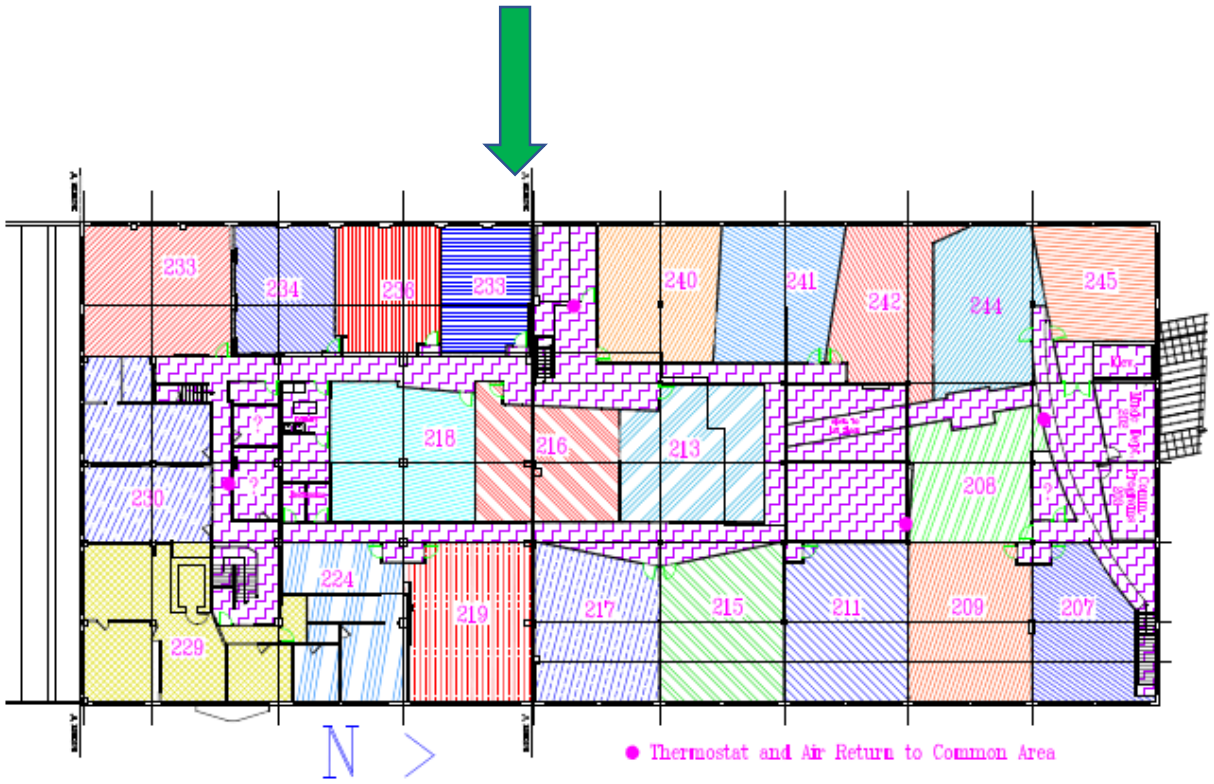
Gaps in Wheeler Basement Ceiling

Complex HVAC Zones – Upper Floors Shown Here Overlie only Two Basement Zones



19 First Floor HVAC Zones

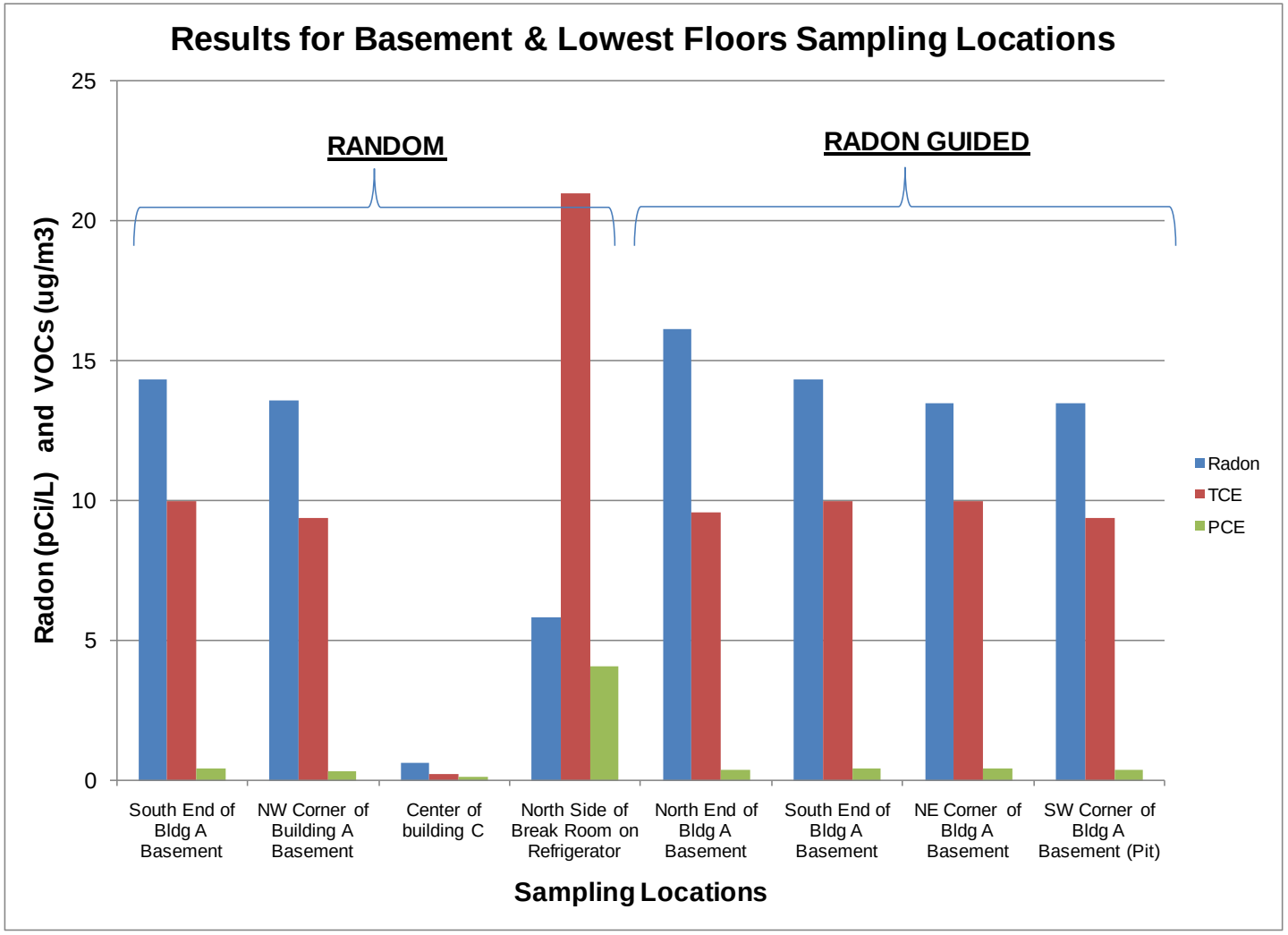
25 Second Floor HVAC Zones



Randomized Control Experiment on Radon Guidance of VI Sampling – Indianapolis

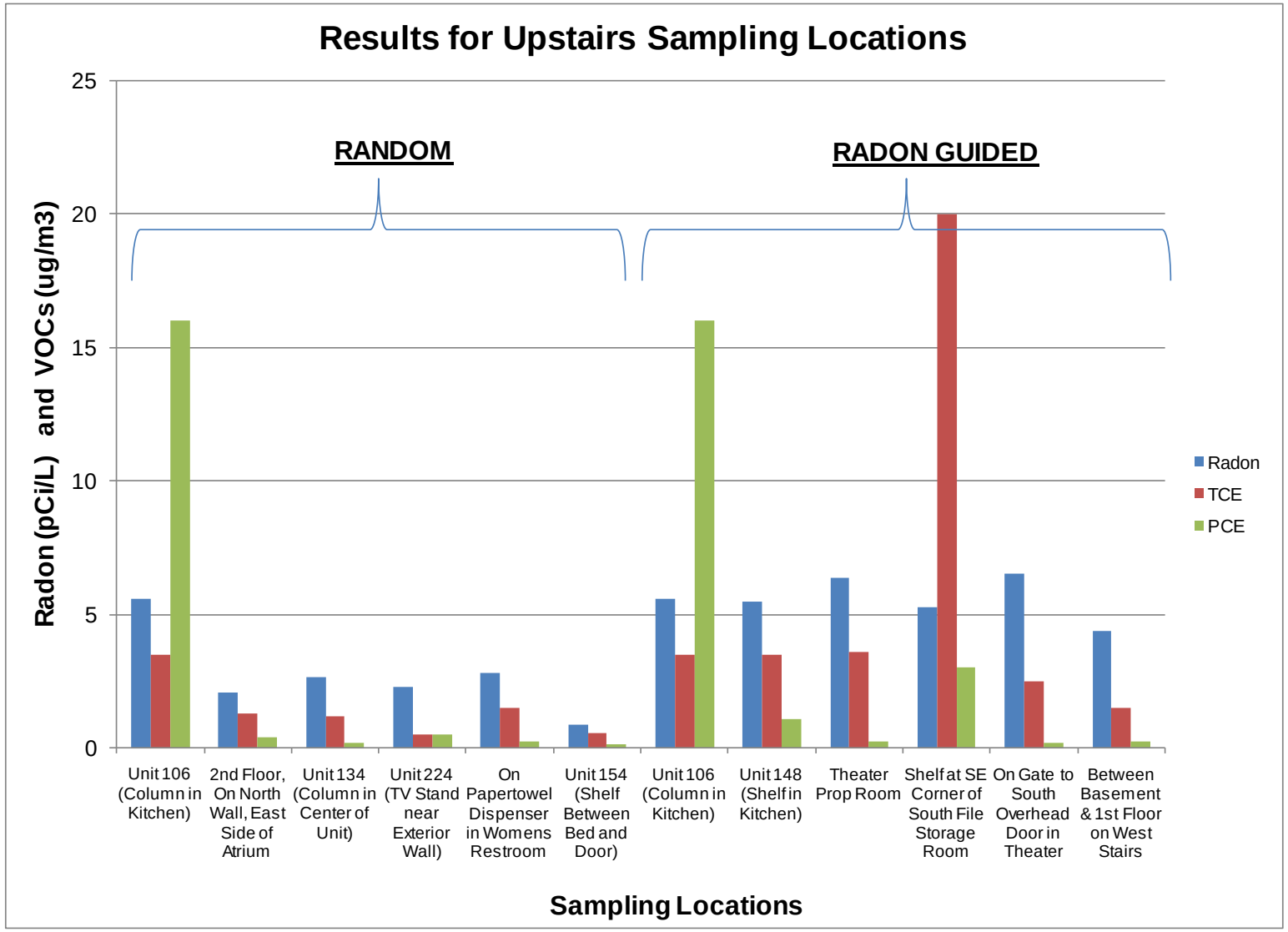
- Hypothesis: screening level radon measurements can help select locations for indoor VOC sampling
- Radon measurements taken from ~50 locations using low cost Electret Radon
- Sample locations were stratified into “basement and lowest floors” and “first (above basement) and second floors”
- Locations selected for VOC sampling using the highest Radon locations in the screening round vs. a random set of locations
  - Basement & lowest floor
  - First floor (above basement) and 2nd floor

Randomized Experiment: Basement and Lowest Floor Results in Indoor Air



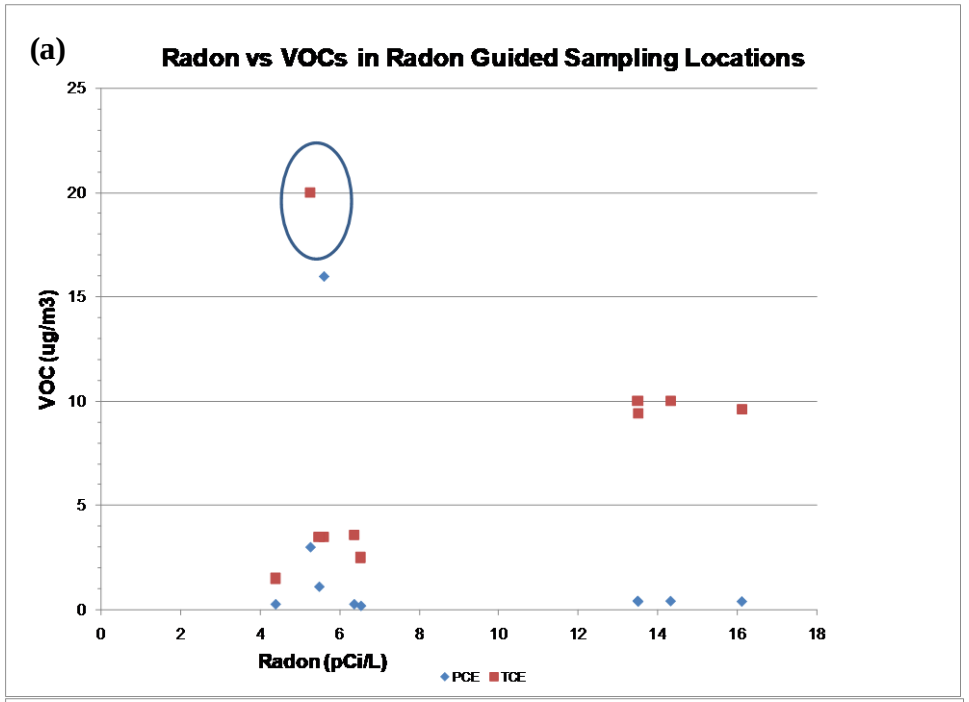
Key Point: Although not statistically significant in these open basements, elevated radon locations had consistently high TCE.

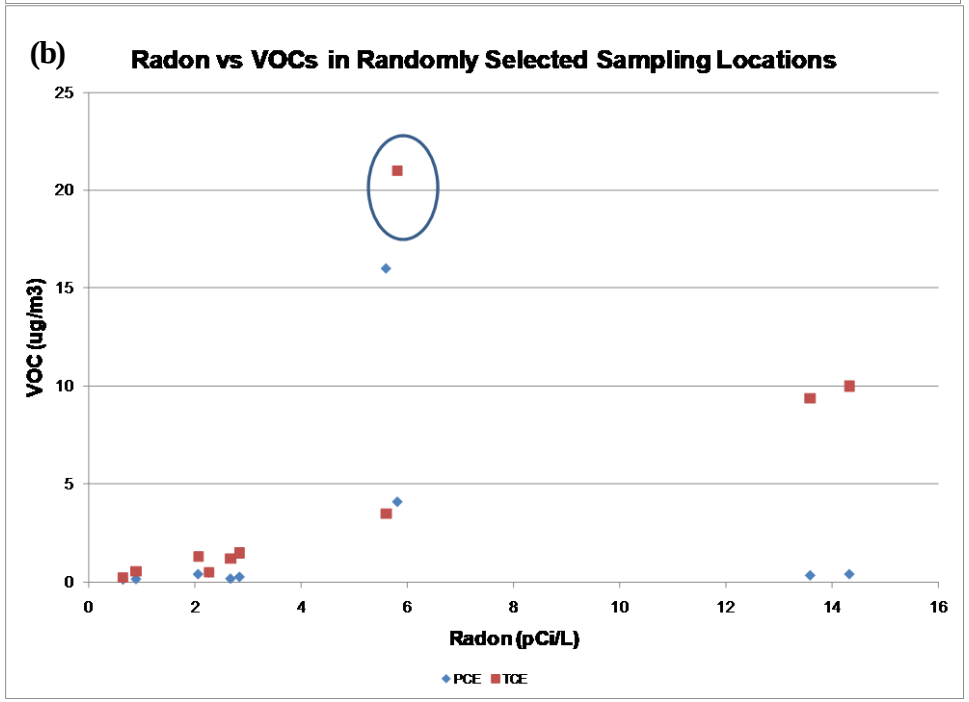
Randomized Experiment: Upstairs Results: Indoor Air



Key Point: Elevated radon concentrations were statistically more likely to have elevated VOC concentrations. This suggests that radon helped trace soil gas through from the basements to the upper floors.

Correlation Between Radon And VOCs In Indoor Air With Apparent Outliers Circled





Case 3: Spatial analysis of Indianapolis Duplex Indoor Air

- 7 primary sample locations: four in basement, two on first floor, one exterior
- Sides of duplex share common wall but no designed openings
- 422 Basement to first floor stairwell door typically shut, 420 typically open. No door between first and second floors.
- Extensive radon and VOC time series available – week long passive samples
- Indoor sample locations in basement highlighted in yellow.

Figure 3-8. Front view of duplex under winter conditions showing designation of sides and HVAC setup.

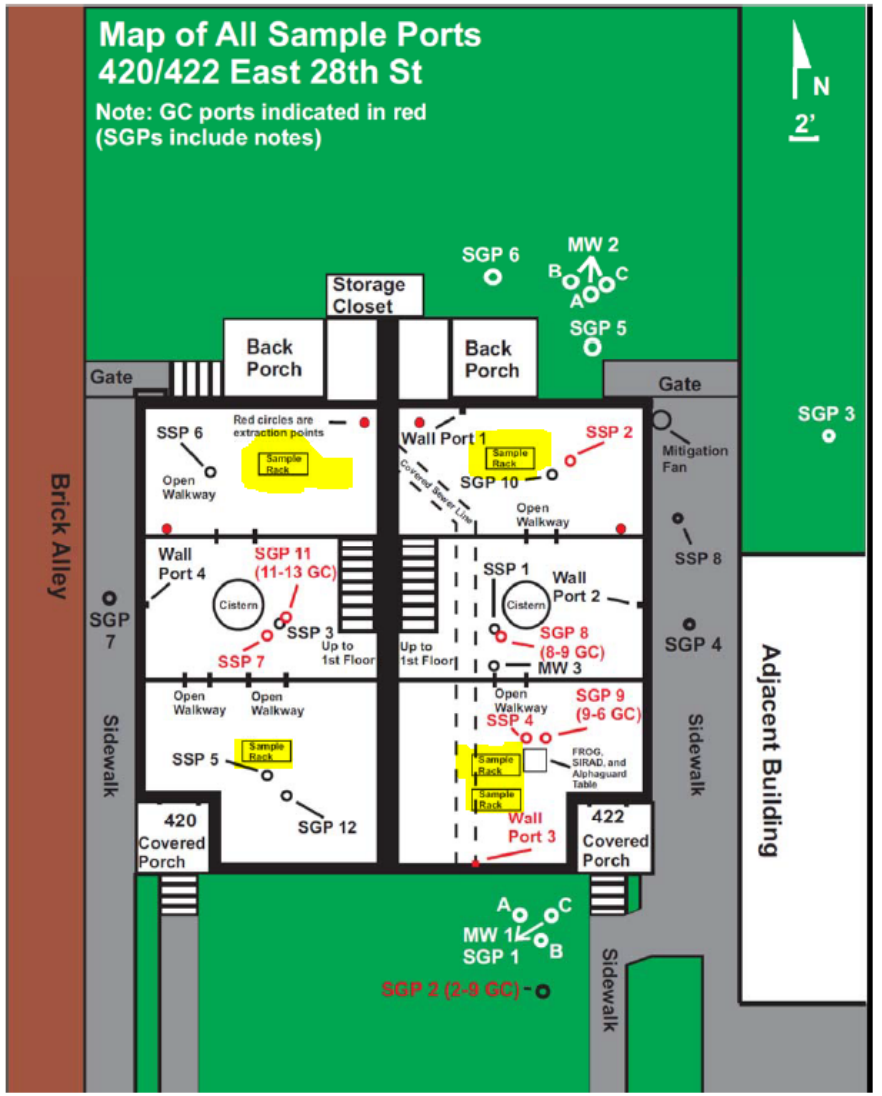
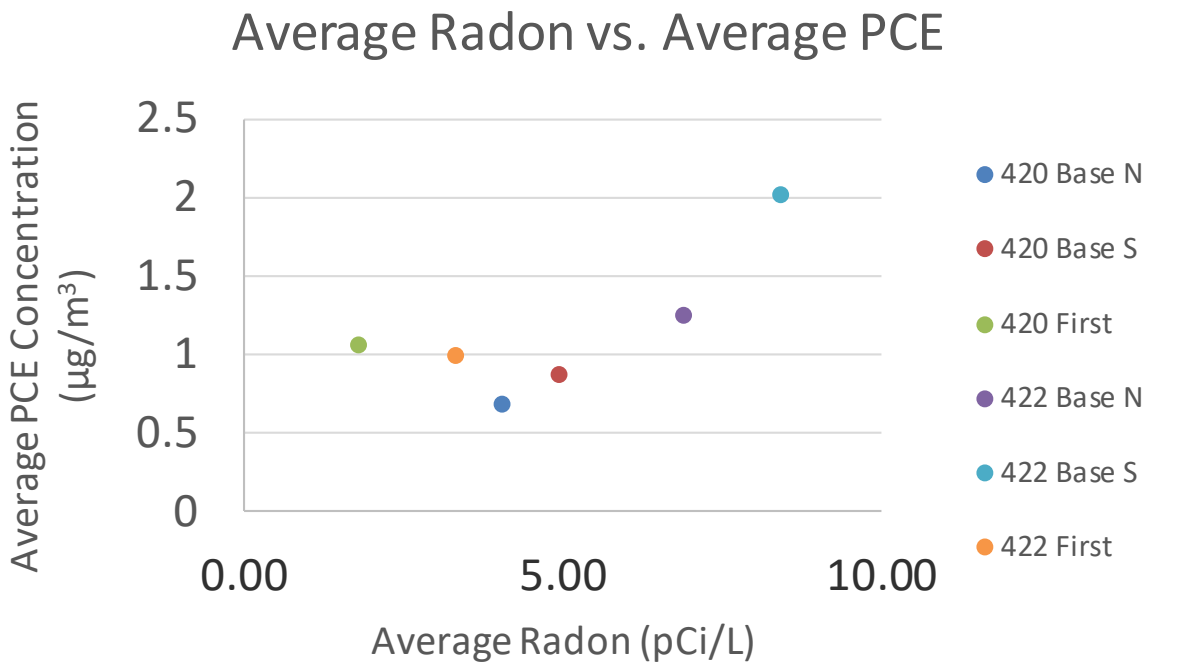
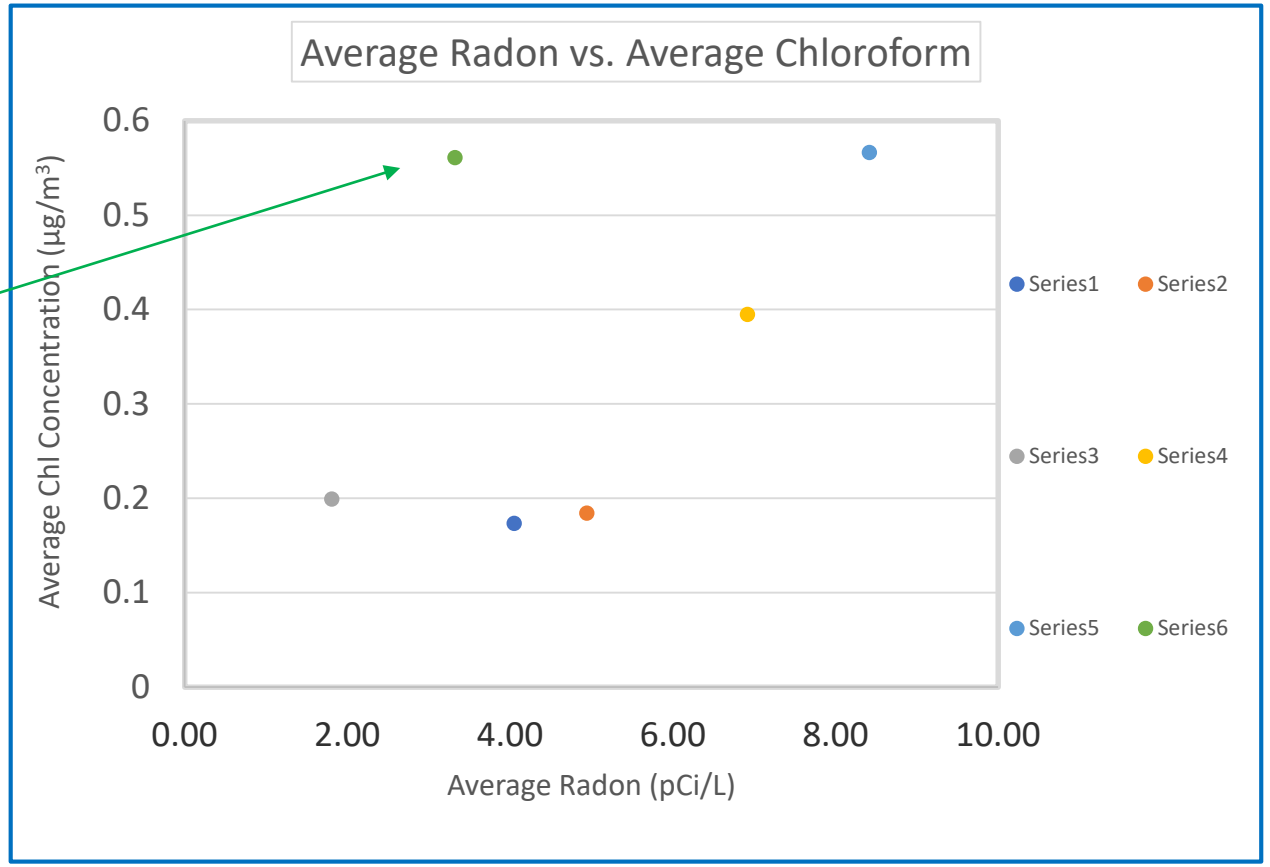


Figure 5-5. Interior and exterior sampling port locations.

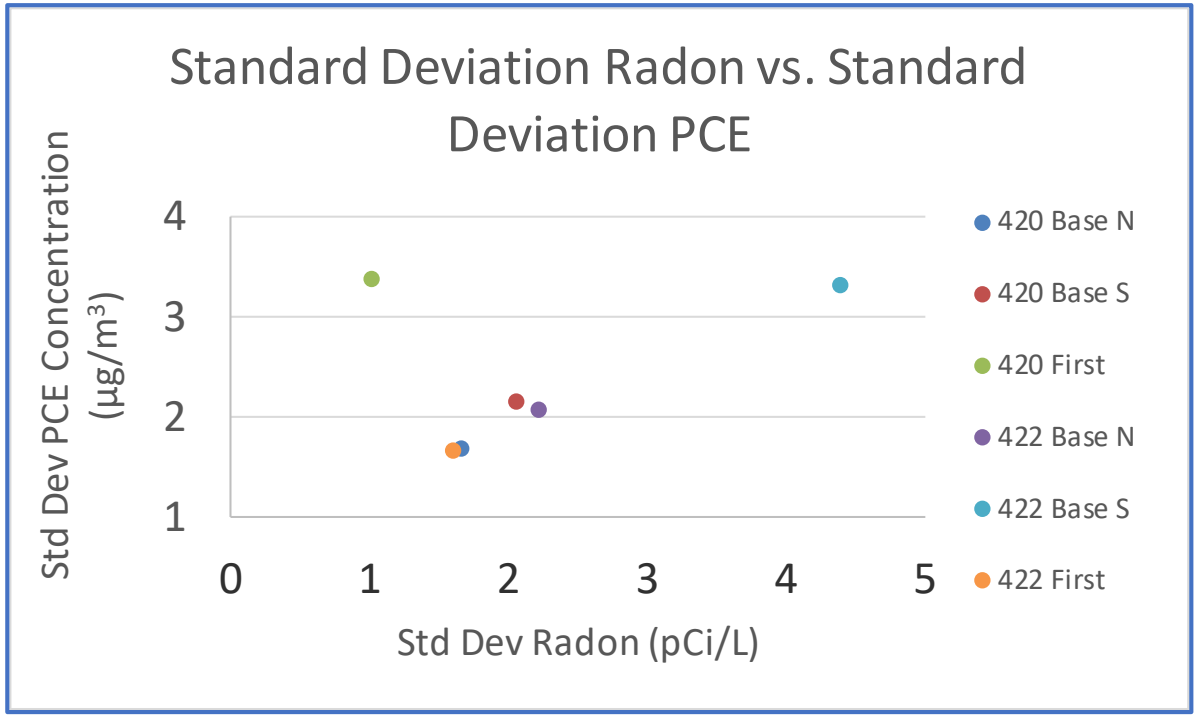
Spatial Analysis of Indianapolis Duplex Indoor Air Data – Annual Average Concentrations



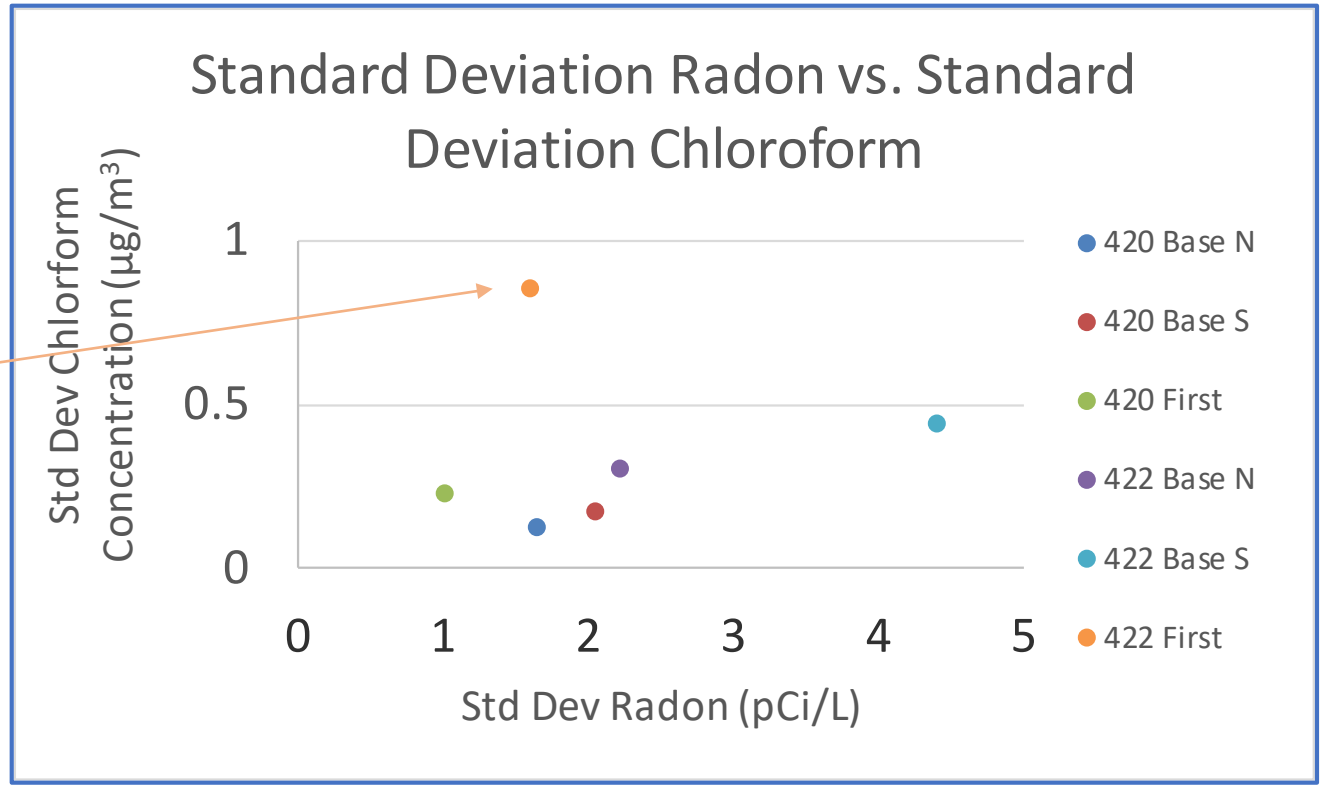
Apparent rough correlation between radon and VOCs with the primary exception being a location on the first floor where a preferential pathway (floor drain) was identified



Spatial Analysis of Indianapolis Duplex Indoor Air Data – Comparative Standard Deviations over Year



Point influenced by first floor preferential pathway that was closed off after several months of data collection



Comparative Analysis of Attenuation Factors: Sorted by Heating and Mitigation Status

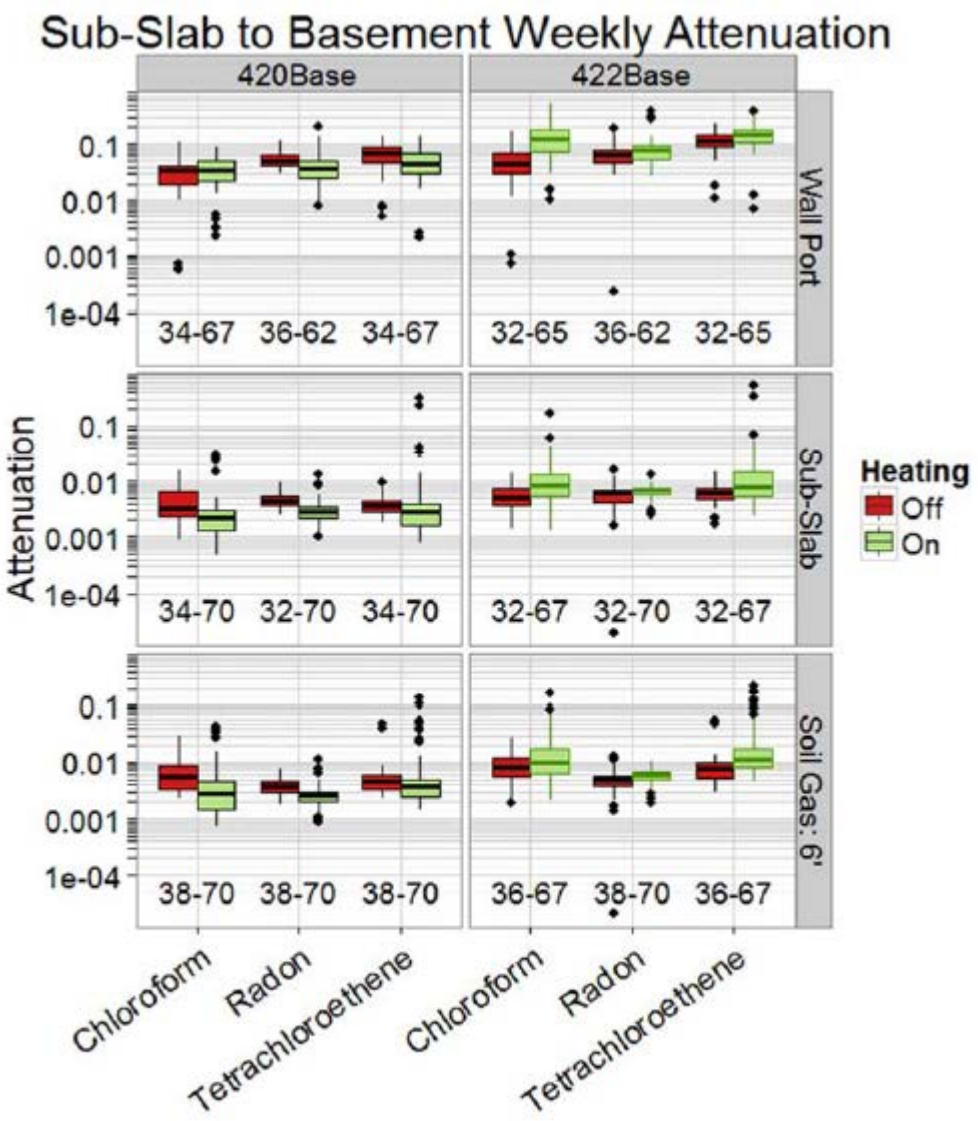


Figure 8-15. Attenuation of PCE, chloroform, and radon juxtaposed.

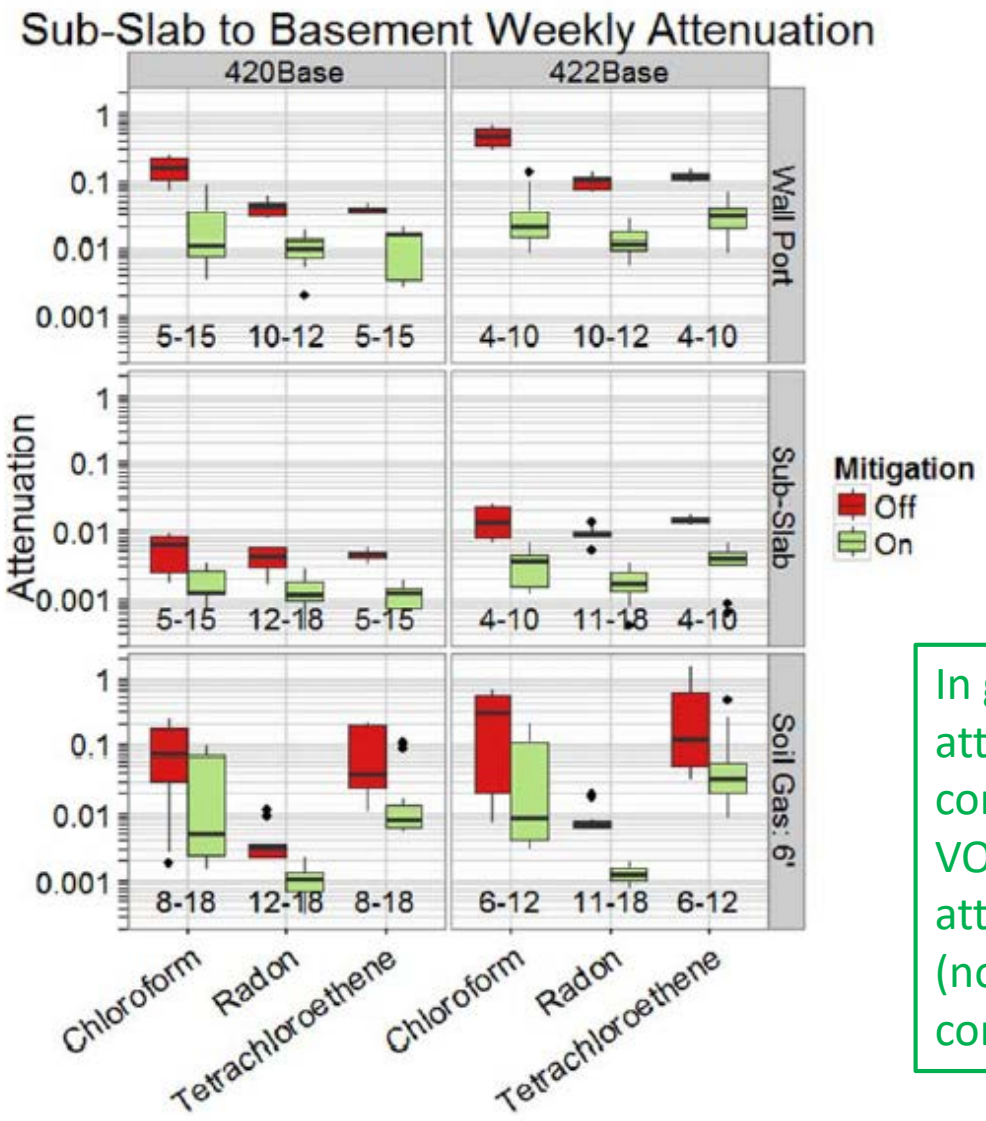


Figure 8-30. Attenuation of PCE, chloroform, and radon juxtaposed.

In general radon attenuation factor correlates with VOCs in attenuation factor (normalized indoor concentration)

Case 4: Site / Study Description (From Wisbeck 2006)

- Superfund Site in Pennsylvania
- Historically used to manufacture refrigerators
- Building was constructed between the early 1900s and 1960
  - Maze inside
  - Large bay doors
  - Ventilation fans
  - Subsurface construction was unknown
- Soil sources located adjacent to and potentially underneath the building
- Building is no longer owned by the responsible party
  - Don’t have control over current operations

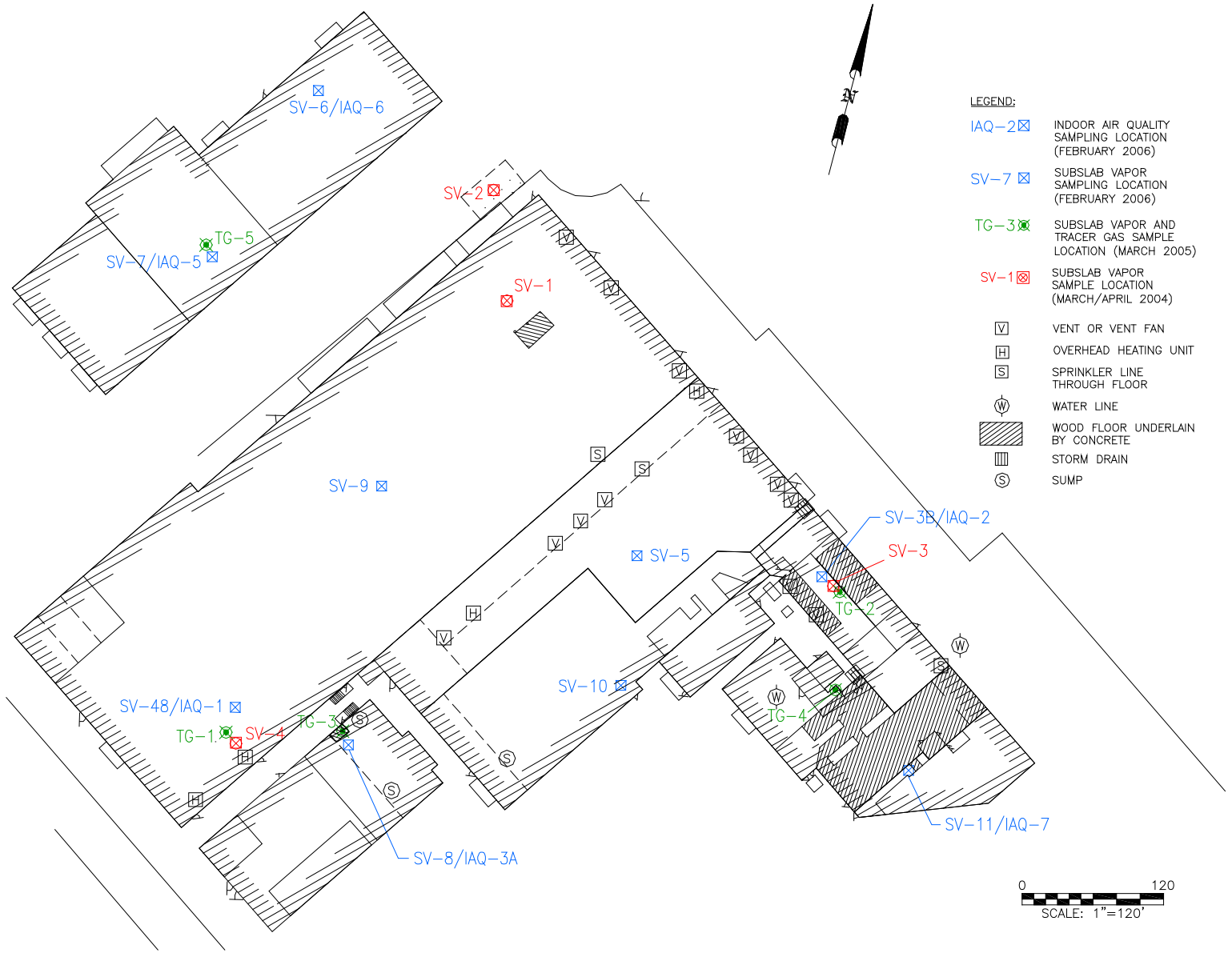
Subsurface Radon Sampling Equipment

- Radon In Soil Gas
  - Subsurface probe
  - Desiccant tube
  - RAD-7 with printer

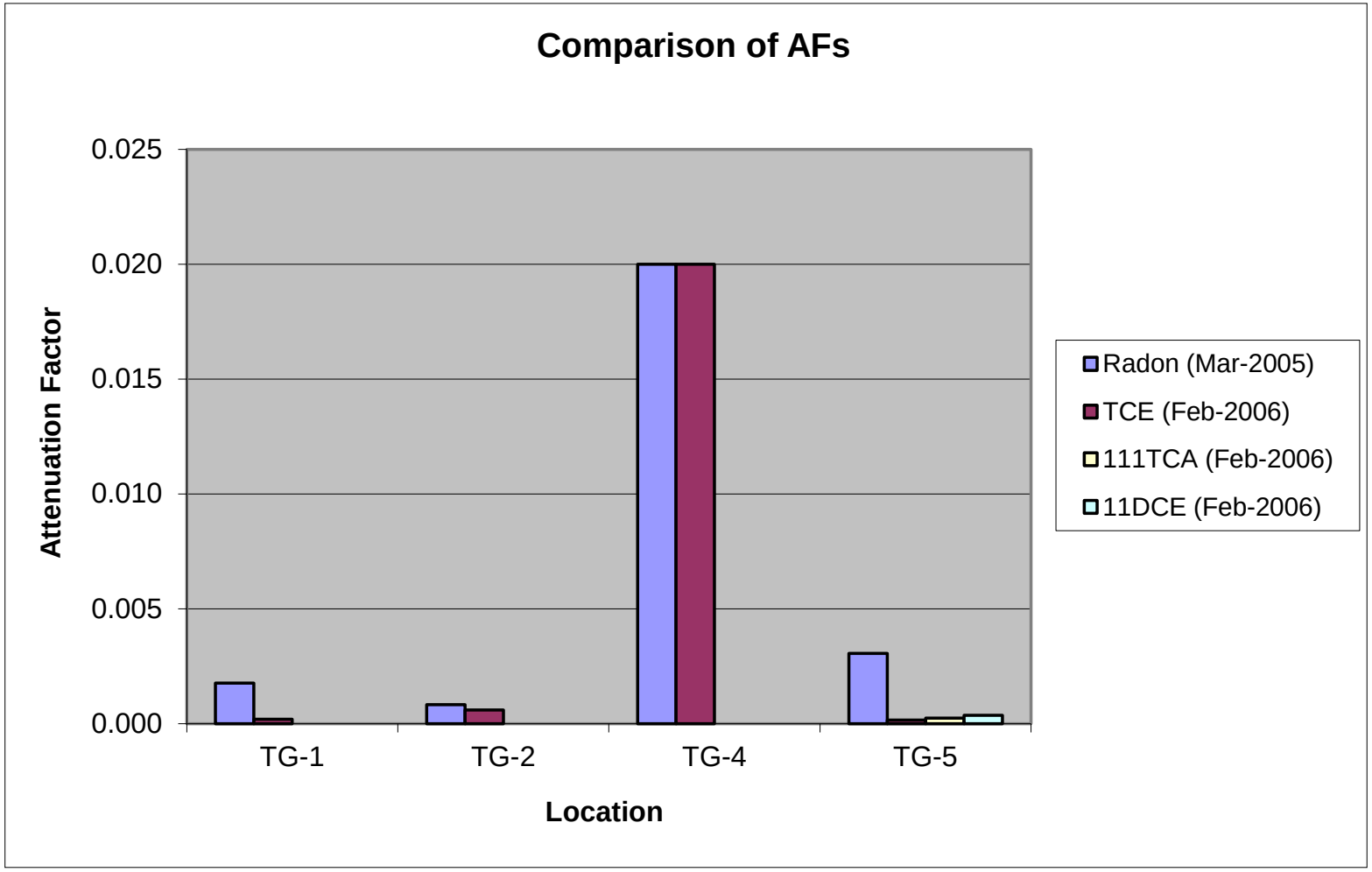
Measured Radon in Indoor Air Using Three Different Techniques

- RAD-7
- Charcoal Canisters
- Lucas Cell

Sampling Round 3 from Wisbeck



Comparison of TCE to Radon Attenuation Factors in Wisbeck



Key point: Radon attenuation factor (normalized indoor air concentration) predicts TCE well at highest AF location

Case 5: Raymark, CT

- Data reanalyzed from “Assessment of Vapor Intrusion in Homes Near the Raymark Superfund Site Using Basement and Sub-Slab Air Samples” EPA/600/R-05/147 March 2006
- Ground water beneath these homes is contaminated with 1,1,1-trichloroethane, 1,1-dichloroethylene, trichloroethylene, cis-1,1-dichloroethylene, and 1,1-dichloroethane
- Data from one monitoring round in March 2013 sufficient for reanalysis available from 9 structures of which 8 were residential.

Some Building Conditions Were Unusual

- Structures G and M - field stone basement wall
- Structures H and J – poured concrete basement wall, cracked slab
- Structure K – slab in basement less then 1” thick, poured concrete, cracks and holes
- Structure P – commercial building with slab 1.6 meters bgs, basement walls of field stone and mortar

Geologic Cross-section

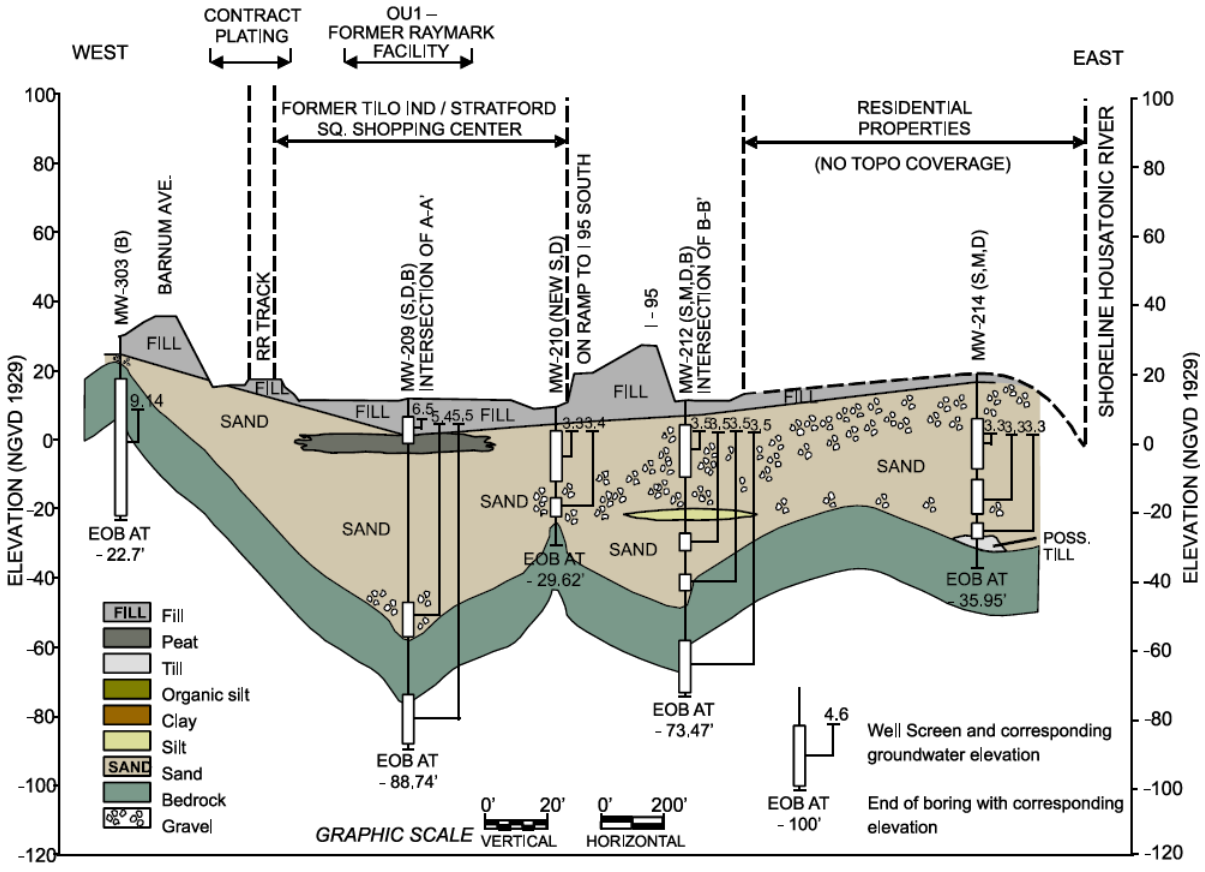
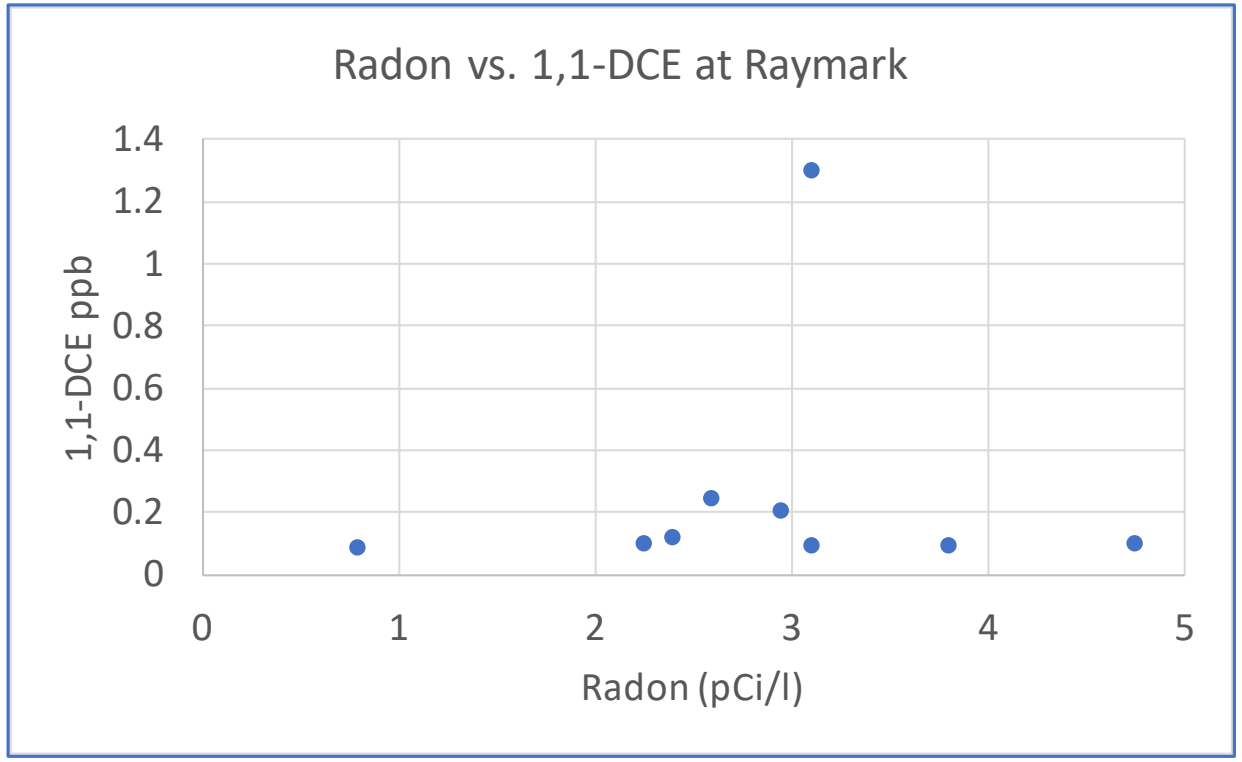
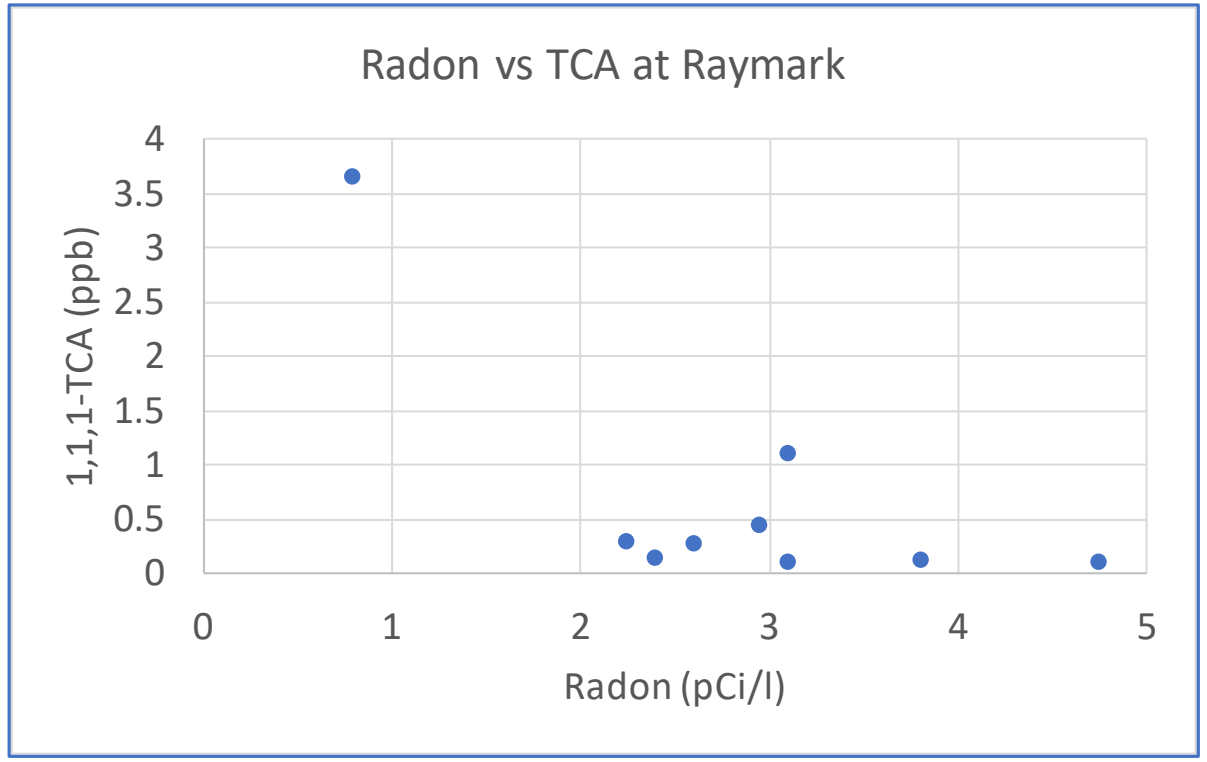


Figure 3. Geologic cross-section G – G' (modified from Tetra Tech NUS, Inc., 2000).

Raymark Data Reanalysis: Indoor Air





- 1,1, DCE detectable in 4 of 9 structures
- TCA detectable in 8 of 9 structures
- Radon detectable in all 9 structures
- No apparent correlation;

Original Reports Assessment of Radon vs. Indicator VOCs Based on Attenuation Factors

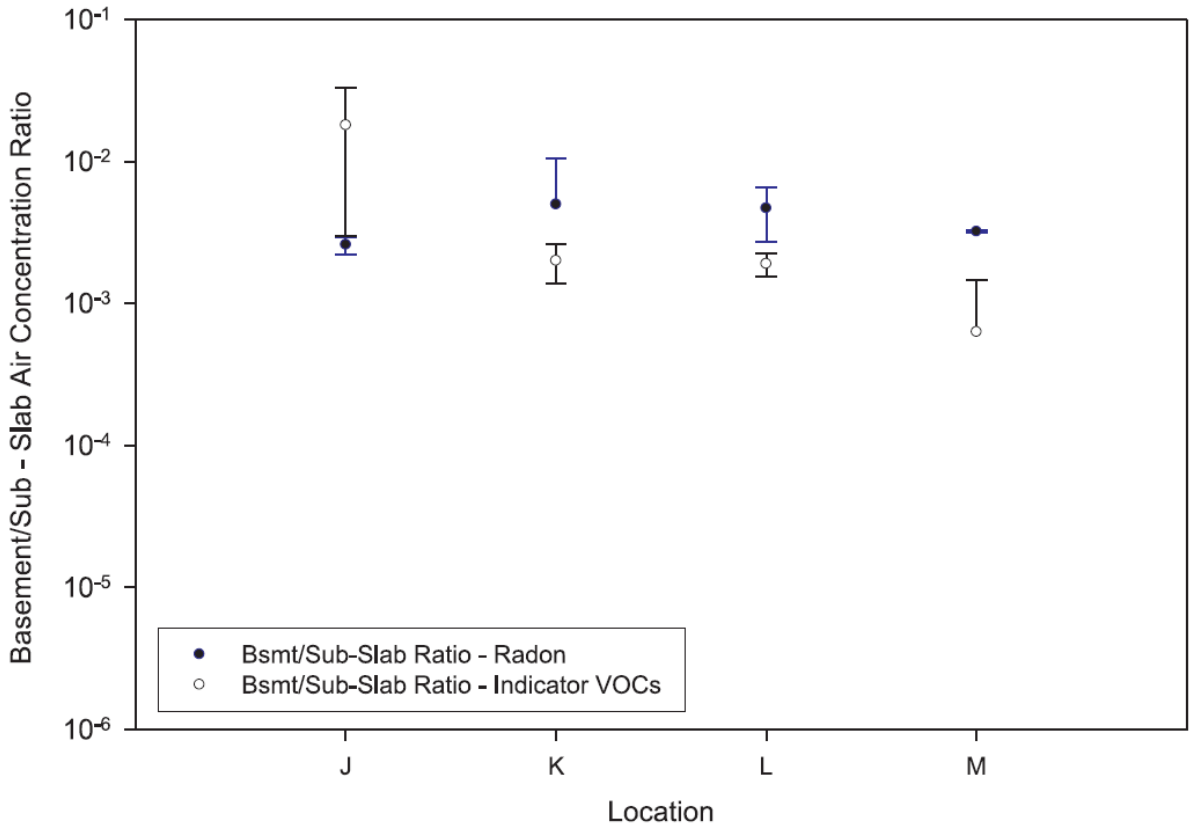


Figure 54. Comparison of basement/sub-slab air concentration ratios for radon and indicator VOCs associated with vapor intrusion. Samples for VOCs collected in one-liter Tedlar bags with on-site GC analysis.

Original authors consider 1,1-dichloroethylene and 1,1- dichloroethane to be relatively unique indicators of the breakdown of 1,1,1-TCA and cis-1,2-DCE as indicator of TCE breakdown. These were considered to be rare in indoor sources.

Original reports conclusion based on attenuation factors from four houses: “for this investigation, the use of indicator VOCs was preferable over the use of radon as an indicator compound to assess vapor intrusion”

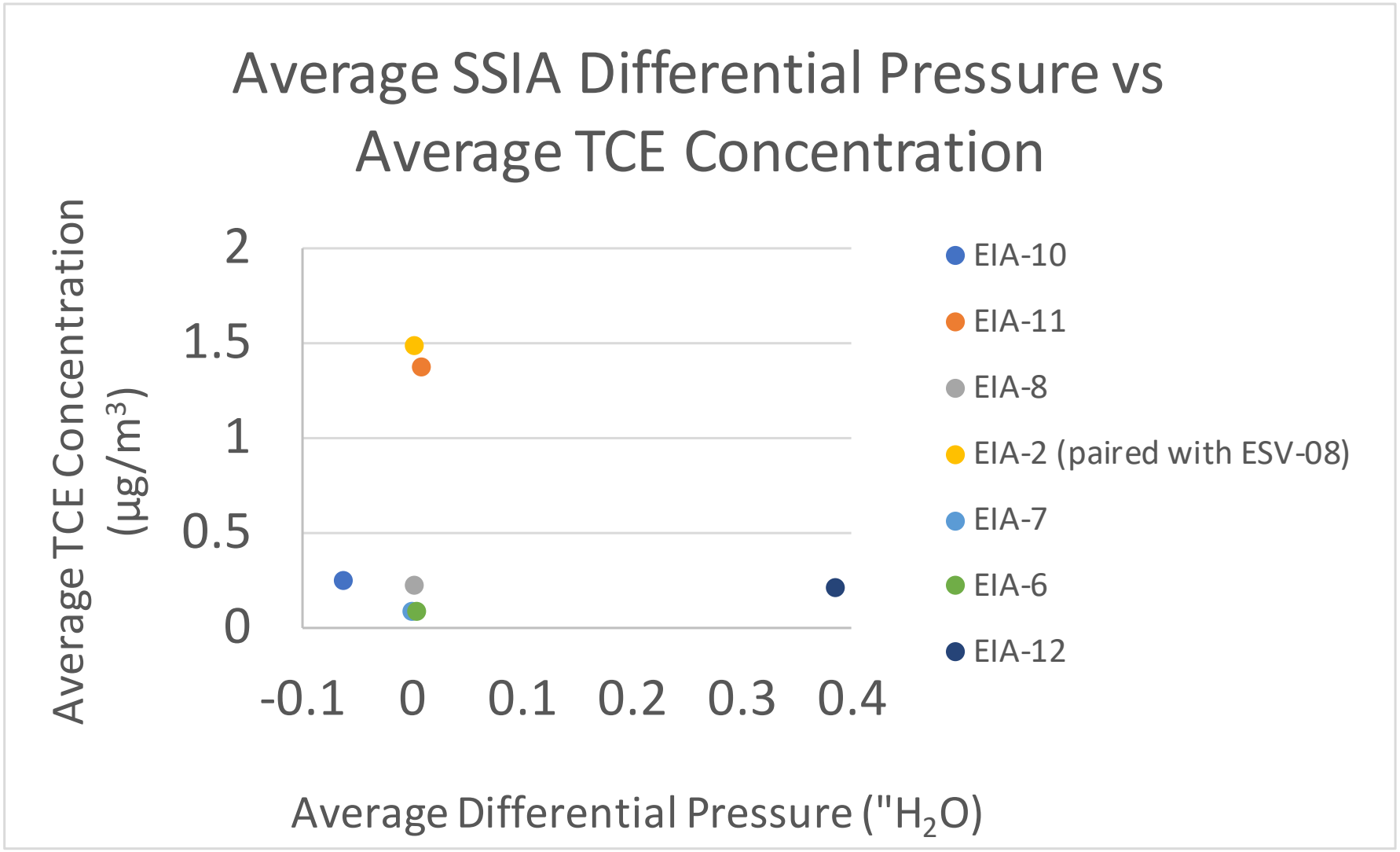
Conclusions re Radon Based Spatial Screening

- Some evidence of correlation between VOC and radon concentrations in indoor air apparent in four of five cases reviewed
- Given cost advantages (radon is inexpensive to monitor relative to VOCs) and conceptual agreement, this radon application is worthy of further testing.
- Potential limitations associated with radon
  - Radon concentrations in soil gas can be weaker then VOCs very near VOC release points (soil sources)
  - Low level radon in indoor air in some cases (relative to outdoor air) can limit method sensitivity
  - May not be a good indicator for some special cases such as those dominated by diffusion across the slab

Can ΔP or ΔT Be Used to Prioritize Spatially?

- EPA 2015 section 6.2.2 states “EPA generally recommends a “worst first” approach to prioritize….Buildings that are continuously occupied may pose a more immediate concern than buildings that are not currently occupied…Nonresidential buildings with bay-style doors that are routinely open may be better ventilated than other types of nonresidential buildings…. Interviews and building surveys during development of the investigation work plan …..also can provide useful information for prioritizing buildings... Sections 6.3 and 6.4 provide additional examples of survey information that can support planning……”
- Section 6.3.3 then refers to subslab to indoor pressure differential
- Presumably occupied spaces will generally have the larger winter time temperature differentials.
- Presumably spaces that have high air exchange rates will tend to have lower winter temperatures
- Little testing to date of the predictive value of these concepts.

Virginia Site A: Spatial



More negative differential pressure = more driving force into building