Putting Spatial and Temporal Variation Together

DoD Virginia Site A – Climate Zone 4

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Study Questions

- What tools can be used to define sampling zones?

- Can the zones with the highest potential for VI be identified?

- Analyzing spatial and temporal variations together:

  - Can sampling points be selected based on source, receptor, and visual preferential pathways?

  - Can concentration and ΔP data be used to understand air mixing in "building within a building" scenario?

  - Do sample locations with high radon variability in indoor air also have high VOC variability?

  - Does the degree of spatial and temporal variability in the radon attenuation factor at various locations provide useful information about susceptibility of those locations to VOC vapor intrusion?

Defining Terms Regarding Zones

- Commercial structures can have many HVAC and sampling zones:

  - HVAC zones (thermal zones) - spaces controlled with one thermostat typically served by one air handling unit

  - Sample zones - enclosures within a building where indoor air samples have been collected

- Sample zones should have limited air mixing with other sample zones and complete mixing within the zone.

  - Within a single zone, in the absence of indoor sources, variability across space is generally lower than variability with time
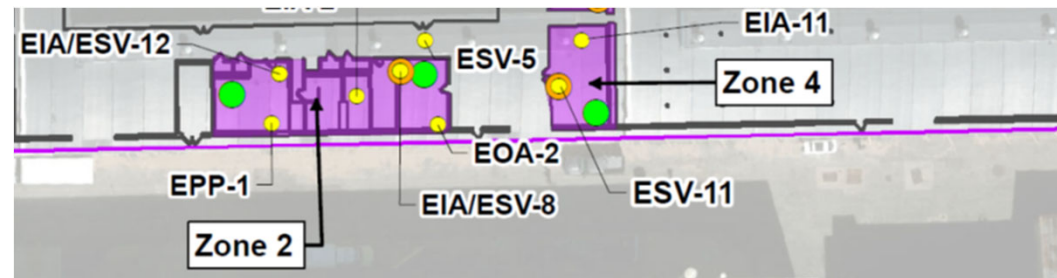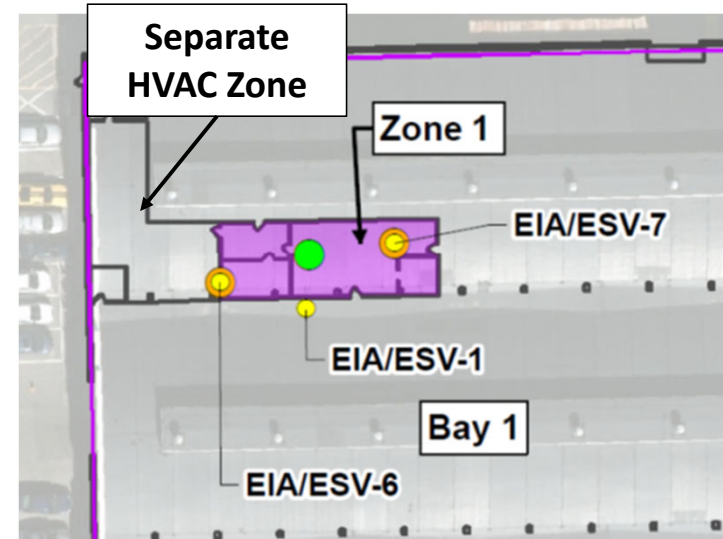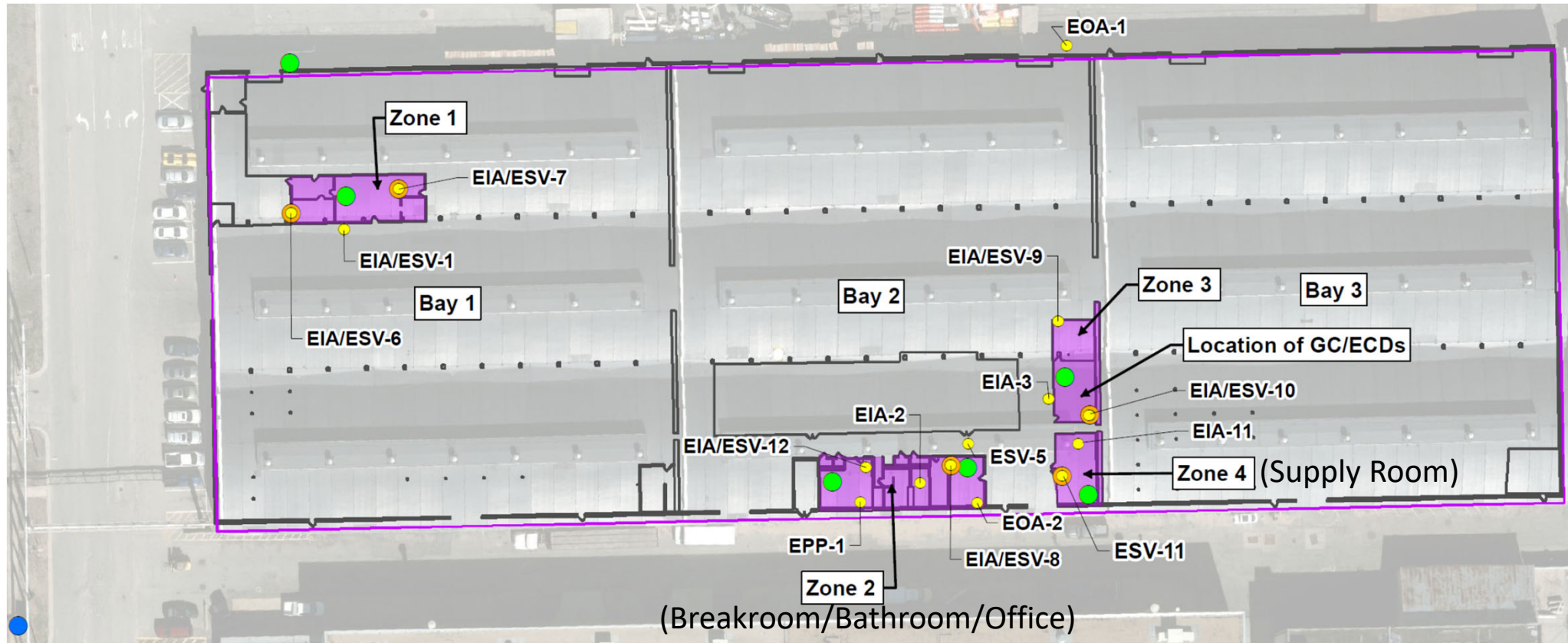
Simulations of How Contaminants Mix Indoors
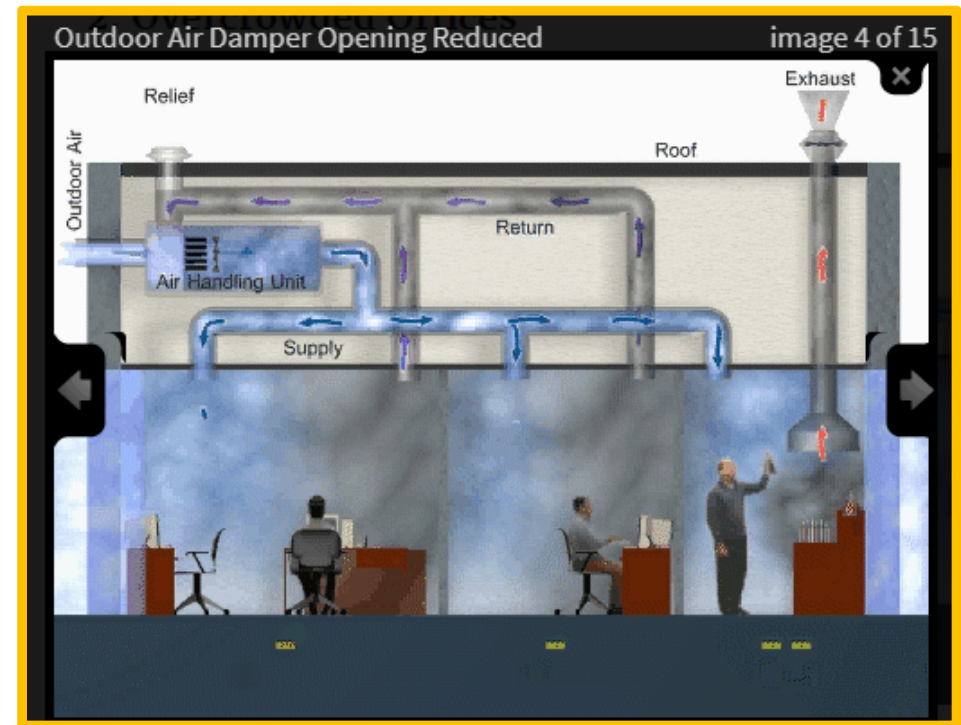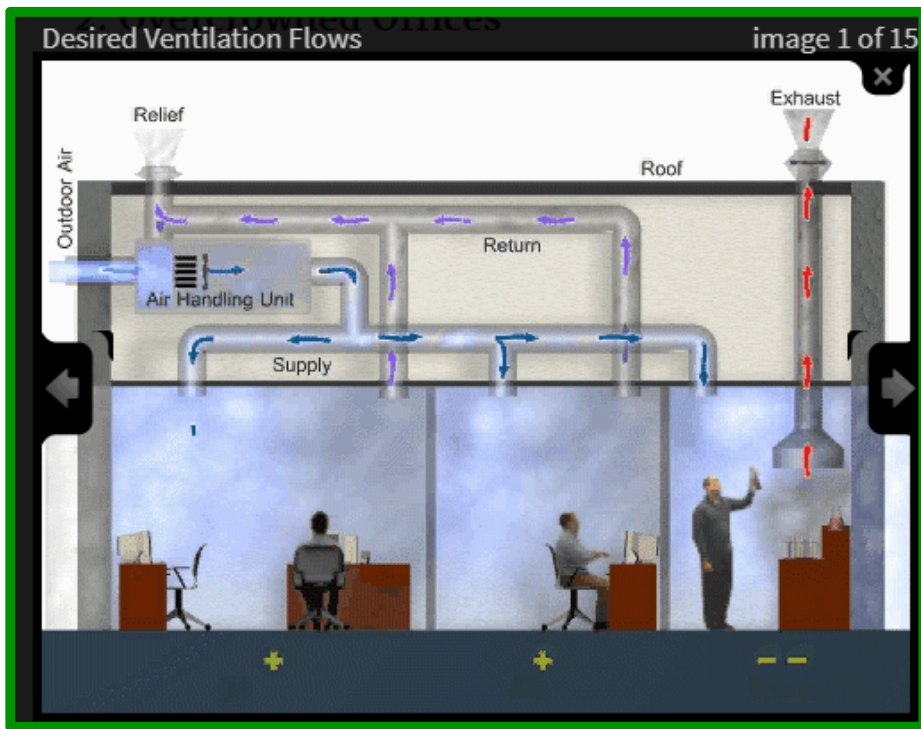
From US EPA Animation Series Visual Reference Modules for the Indoor Air Quality Building Education and Assessment Model; https://19january2017snapshot.epa.gov/indoor-air-quality-iaq/animation-series-visual-reference-modules-indoor-air-quality-building_.html

VA Site A – Building Characteristics

- ~120,000 ft^2 building constructed of brick with a poured concrete slab and is divided into three large bays

- Heat provided by steam-fired unit heaters with overhead fans in the warehouse/storage bays.

- No centralized cooling system within the warehouse space. During Summer, bay doors are kept open and portable fans provide airflow.

- Various wood-framed office areas constructed separately within the bays with separate ceilings and HVAC units.

  - Separate spaces considered "buildings within a larger building"

# Zones Within Larger Building, Sampling Locations, and Types of Data

# Zone 2 - Office 211, Breakroom, and Restroom

- Compartments
  - Regularly occupied office
  - Breakroom and restrooms
  - Supply room and janitor closet
- 4-Ton split-HVAC system
  - Direct expansion air source heat pump unit
  - Ducted to outside with damper closed, but filter enclosure open to warehouse
  - Supply/return vents in office/breakroom/restrooms; exhaust fans in restrooms always on
  - Thermostat in office "on" unless occupants turn it off
- Baseline air exchange rate (AER) tracer test
  - Office 211: 2.7 - 3.0 ACH
  - Breakroom: 2.3 - 3.0 ACH
  - Men's restroom: 3.1 ACH

Utility Sampling Location
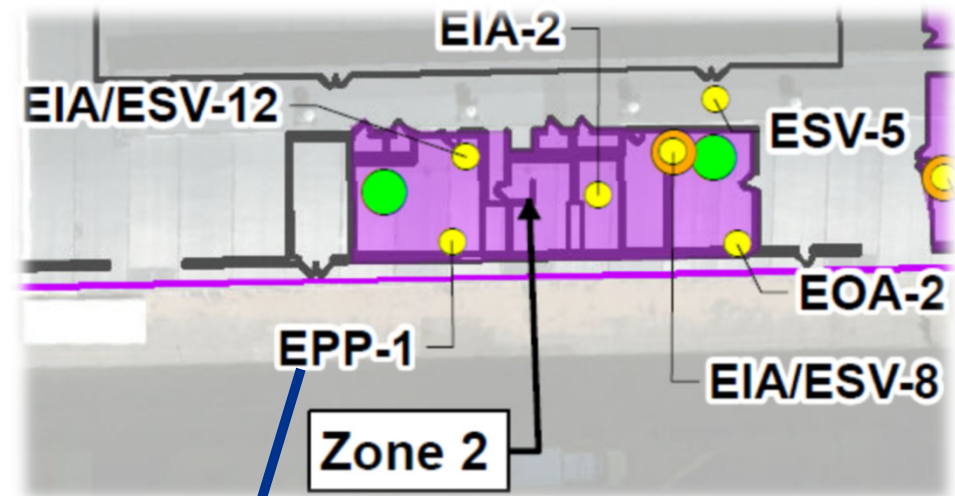
- ○ GC/ECD cVOC Sampling Locations
- ○ Differential Pressure & Temp Locations
- ○ Indoor Radon Sampling Locations
- ○ Outdoor Weather Station

Zone 4 – Supply Room

- Compartment
  - Single storage room (510 ft^2)
  - Frequently entered, but not occupied full-time
- Air Handling
  - Wall-mounted ductless unit with wireless thermostat (always operating)
  - No connection to outdoor air
  - Return vent, but no supply vent
  - Passive wall vent between storage room and warehouse, blocked with cardboard/duct tape
- Baseline AER tracer test
  - 0.21 ACH

Zone 4

ESV-11

EXIT
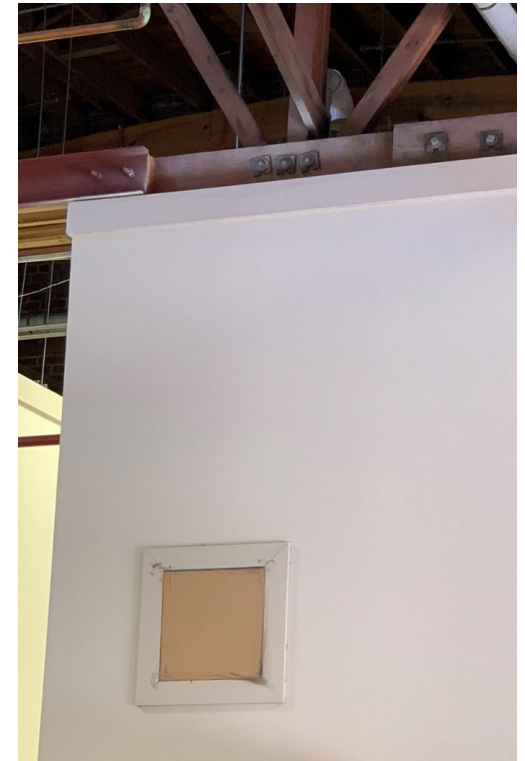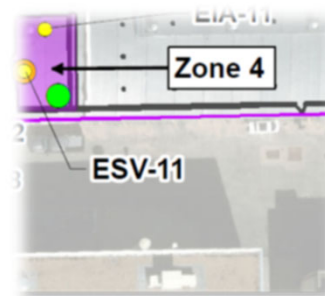
Identifying Sampling Zones

- HVAC/Sampling Zones initially identified through a visual- and interview-based survey process

- Follow-up detailed HVAC Inspection

- Tracer Testing (SF_6 decay) to determine baseline AER

NAVFAC
Naval Facilities Engineering Command

Industrial Building Survey (With HVAC)

Inspection Info
Select an Installation
Date
Time
Preparer(s)
Other Preparer name
Select a Building for Inspection
Other Building Name
Building/Facility Name (if different than listed in iNFADS above)

Contact Info
Primary Building POC Contact Name
Primary Building POC Phone Number
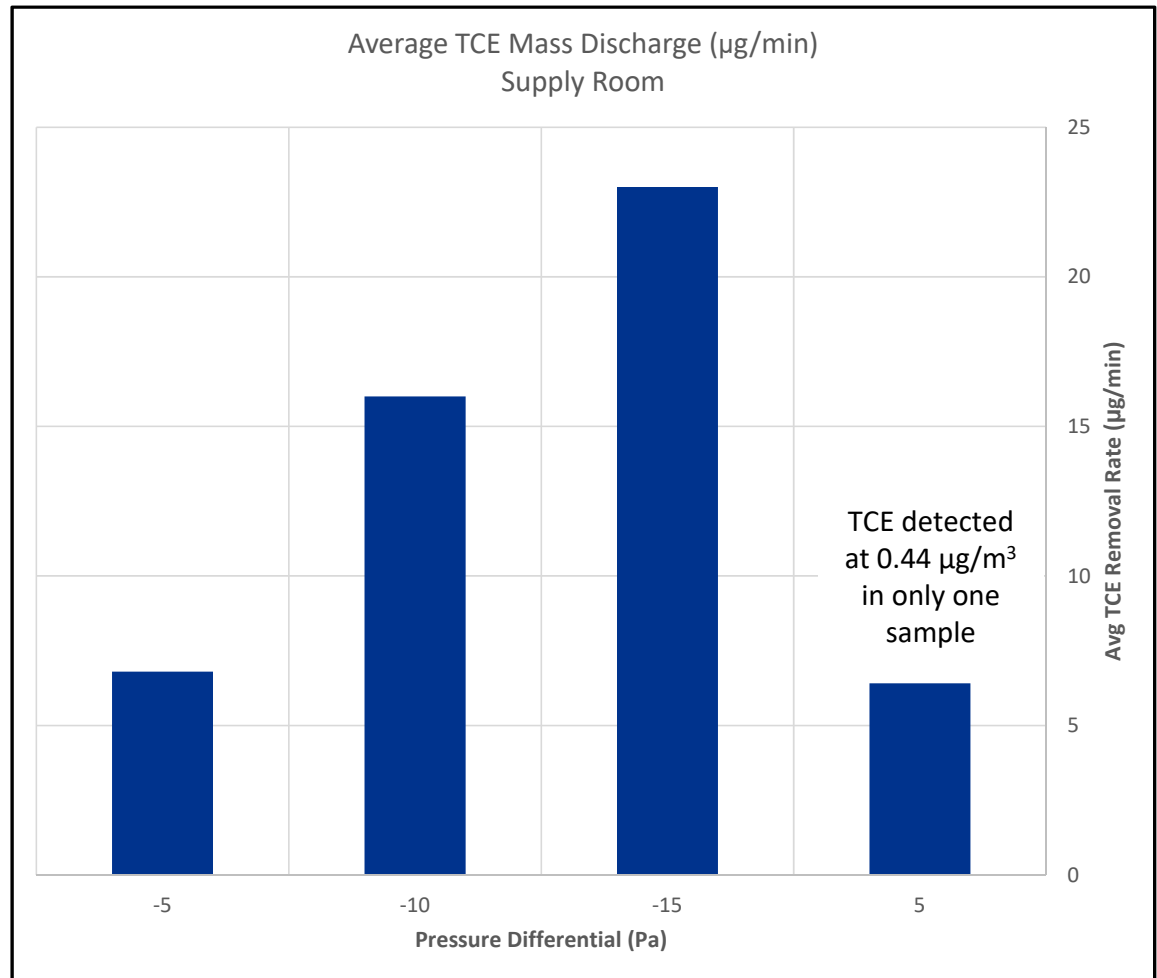Primary Building POC email address
Building POC Notes

Space Tested	Test Date (2019)	Room Volume (Cubic Feet)	Ventilation		Notes
			ACH	CFM	
Zone 1	3/27	9,450	0.80	126	—
Zone 2 Office	3/27	4,186	2.99	208	Outside air damper open
Zone 2 —Breakroom	3/27	4,078	2.96	202	Outside air damper open
Zone 2—Men's Restroom	3/28	1,569	3.08	81	Outside air damper open, door opened 14 times
Zone 2— Breakroom	3/28	4,078	2.34	159	Outside air damper closed
Zone 2 — Office	3/28	4,186	2.71	189	Outside air damper closed, door opened 6 times
Zone 2—Men's Restroom	3/28	1,569	3.06	80	Outside air damper closed, door opened 10 times
Zone 3	3/27	5,720	0.90	86	—
Zone 4	3/27	5,870	0.21	21	—

Identifying Sampling Zones - HAPSITE Survey and Pressure Testing
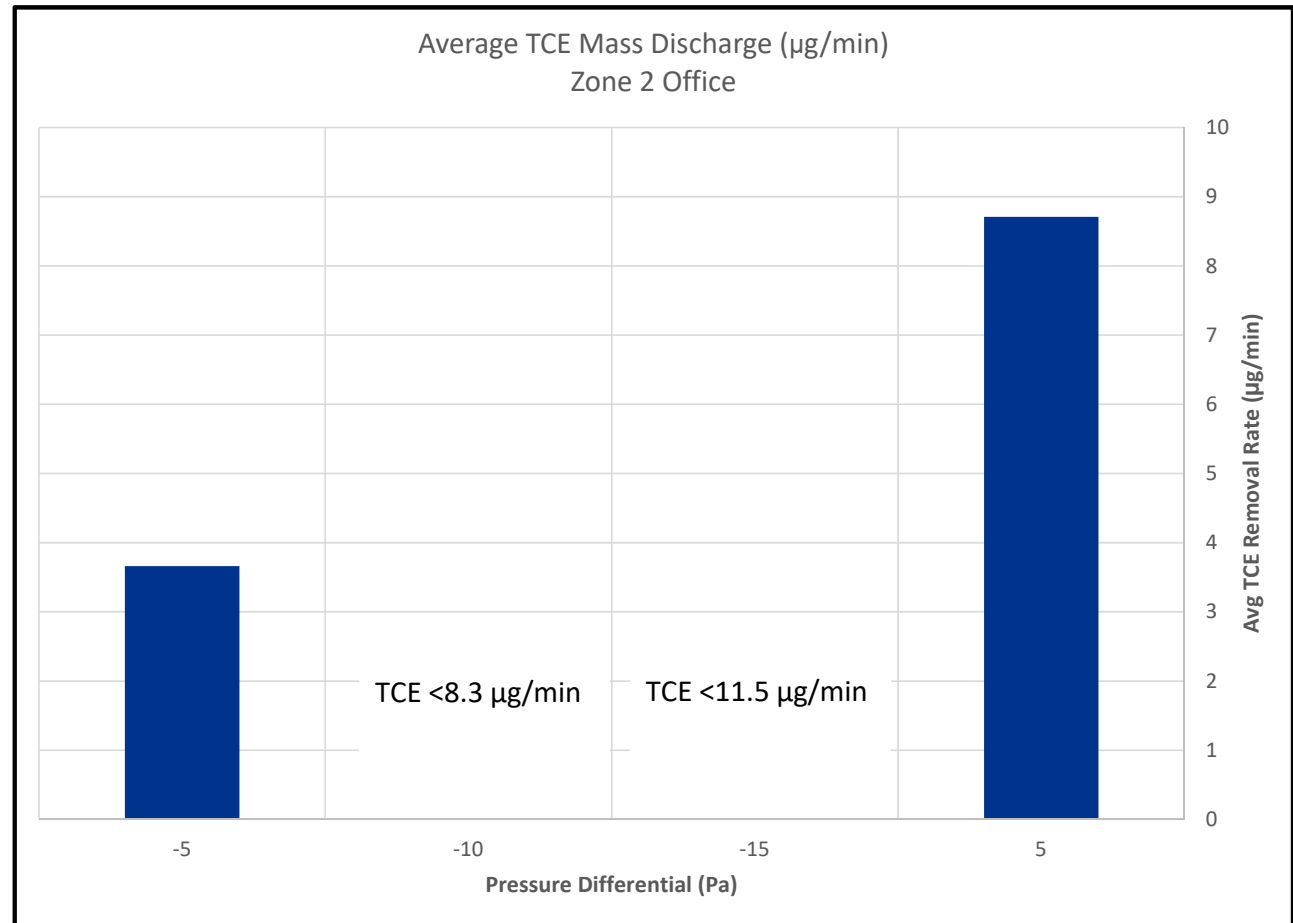
- ## Supply Room BPC Results

  - Result indicate VI is occurring

    - Increasing Mass Discharge under increasingly negative conditions

    - Decrease in Mass Discharge under positive conditions

Average TCE Mass Discharge (μg/min)
Supply Room

TCE detected at 0.44 μg/m³ in only one sample

Avg TCE Removal Rate (μg/min)

Pressure Differential (Pa)

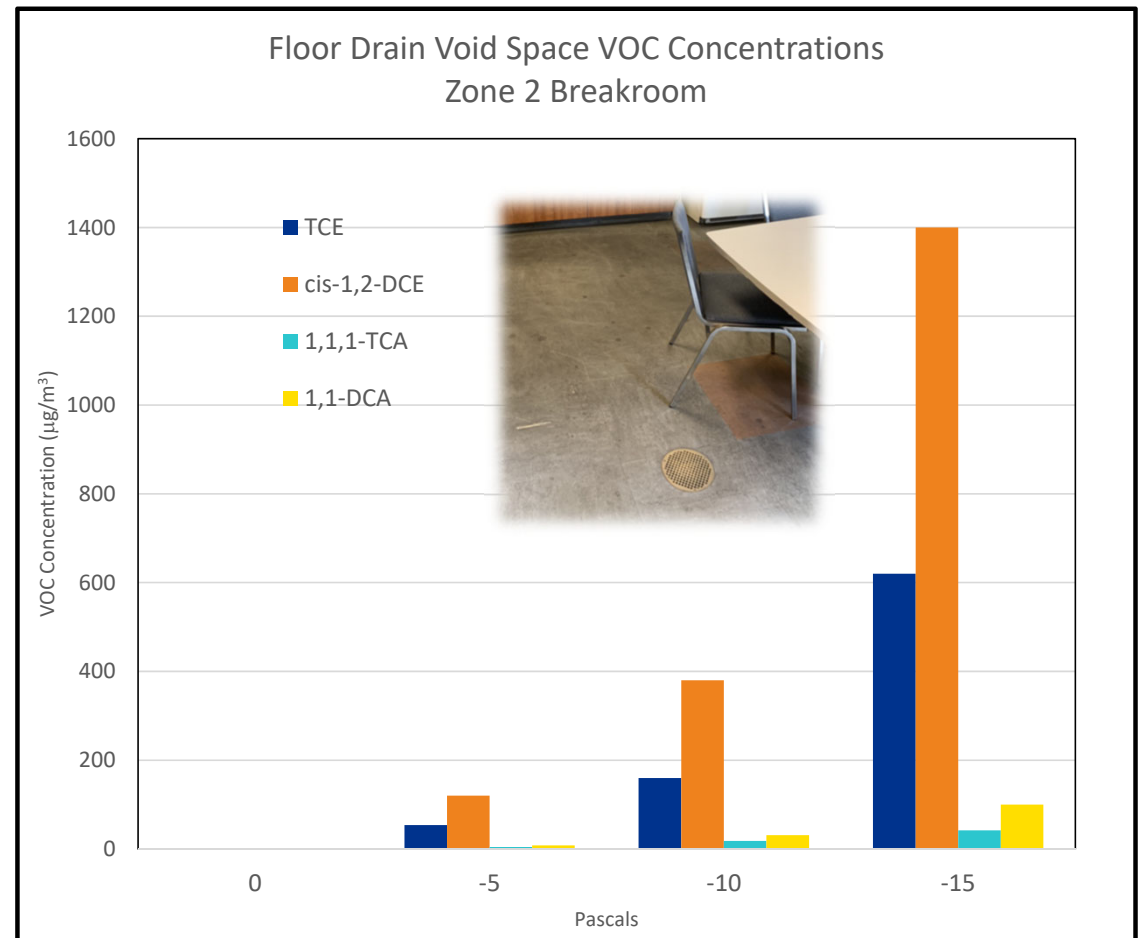# Identifying Sampling Zone - HAPSITE Survey and Pressure Testing

- Zone 2 BPC Results
  - Tests conducted in breakroom and office
    - TCE not detected in breathing space during any of the tests in the breakroom – mass discharge not calculate**d**
    - TCE Mass Discharge in Office does not follow traditional VI trend
      - Dilution due to leaky space resulted in no detects above reporting limits during -10 and -15 Pa tests
      - Results inconclusive – traditionally would be indicative of indoor source

Average TCE Mass Discharge (µg/min)
Zone 2 Office

TCE <8.3 µg/min   TCE <11.5 µg/min

Pressure Differential (Pa)
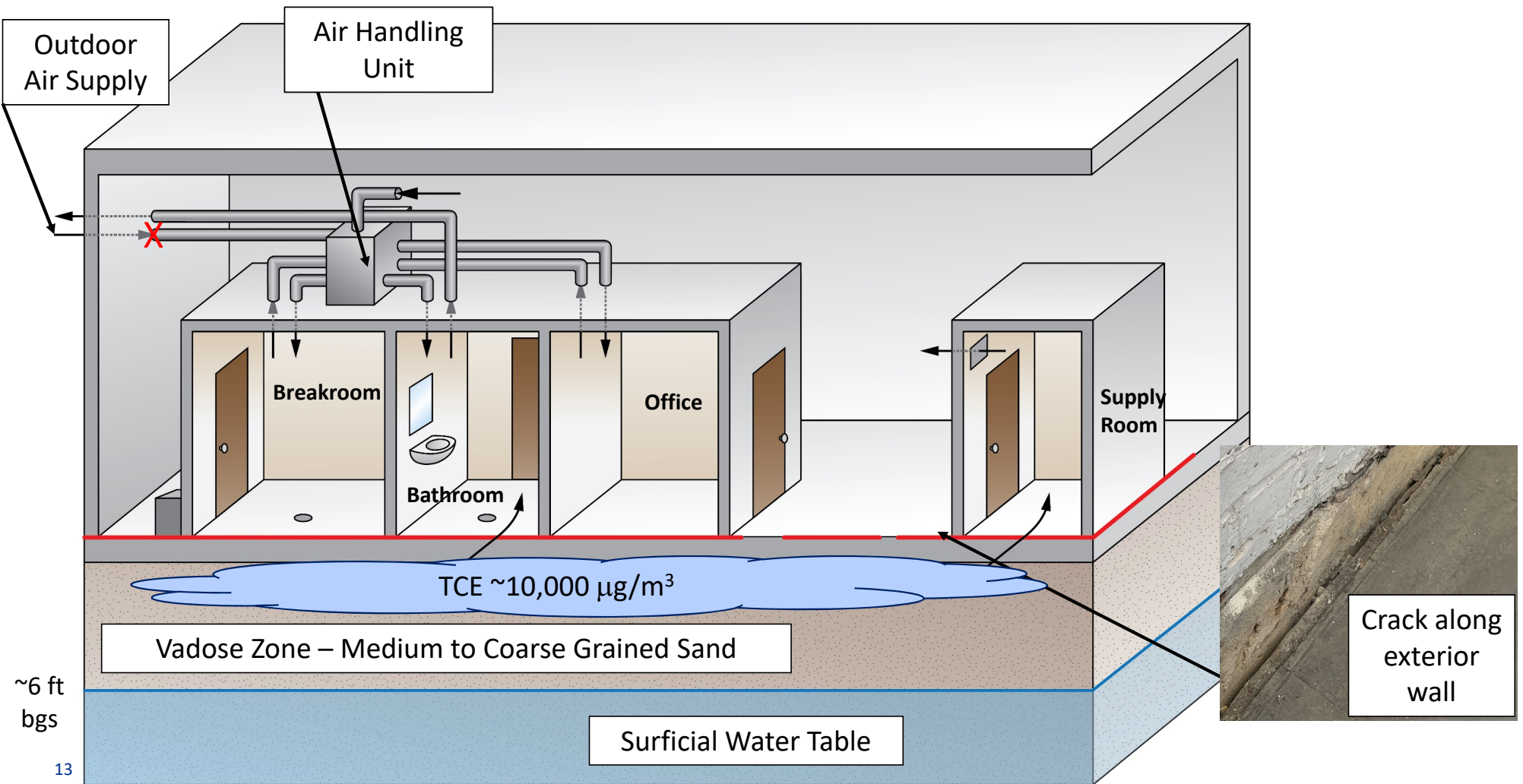
Avg TCE Removal Rate (µg/min)

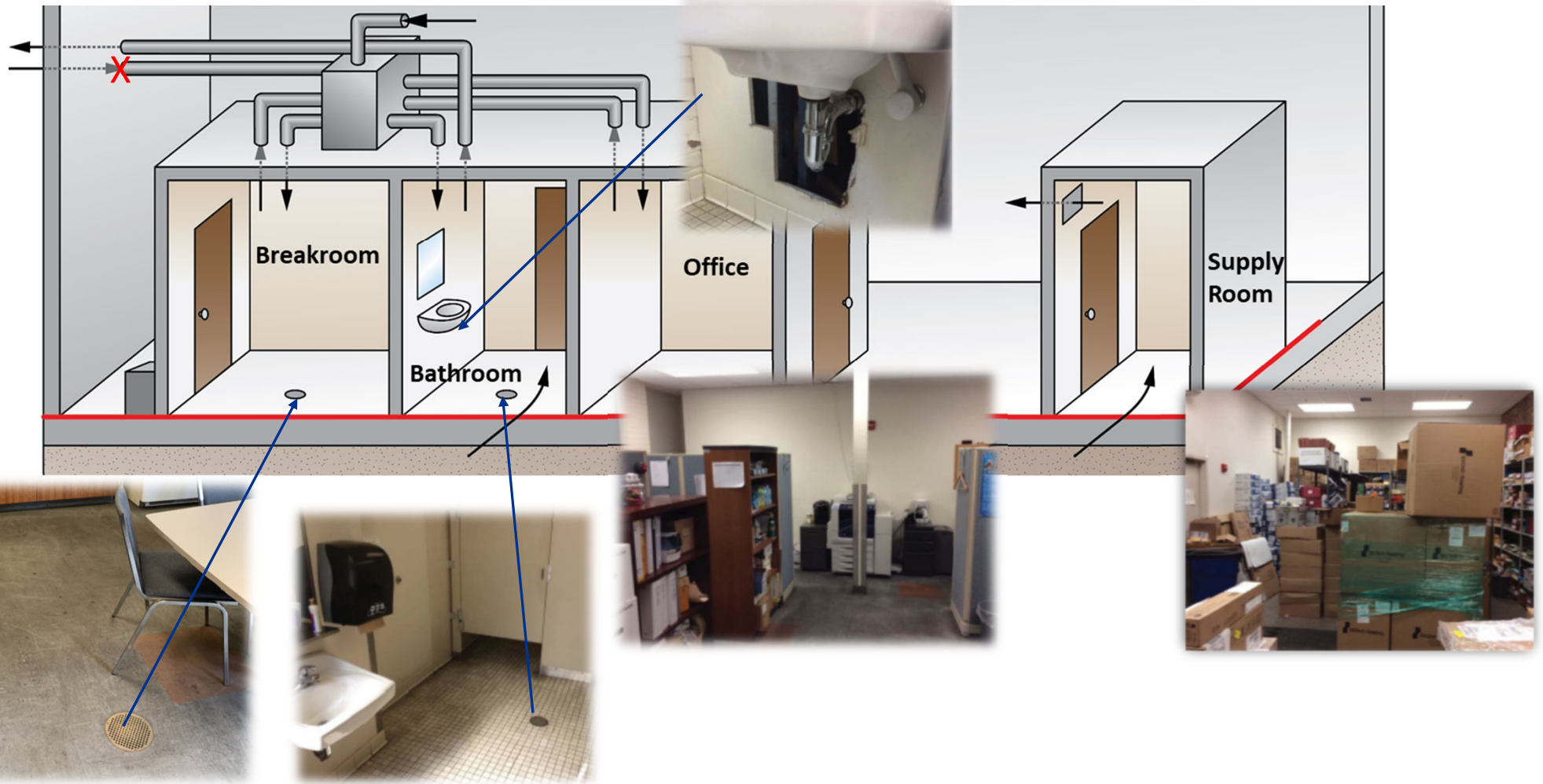# Identifying Sampling Zones - HAPSITE Survey and Pressure Testing

- Zone 2 BPC Results
  - Potential preferential pathway identified during building survey (floor drain)
  - Samples collected with HAPSITE indicate increasing trend in void space during negative pressure tests
- Due to confirmed pathway and similar features in bathroom, indoor air sampling location in bathroom selected
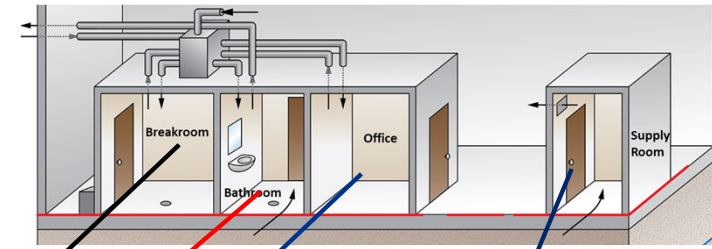

Floor Drain Void Space VOC Concentrations
Zone 2 Breakroom

Vapor Intrusion Conceptual Site Model

Outdoor Air Supply

Air Handling Unit

Breakroom

Bathroom

Office

Supply Room

Crack along exterior wall

TCE ~10,000 μg/m³

Vadose Zone – Medium to Coarse Grained Sand

~6 ft bgs

Surficial Water Table

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Vapor Intrusion Conceptual Site Model

Zone Behavior - TCE Concentrations

Zone 2 TCE Concentrations

IA-2 24-hr Roll. Avg   IA-8 24-hr Roll. Avg.
IA-12 24-hr Roll. Avg
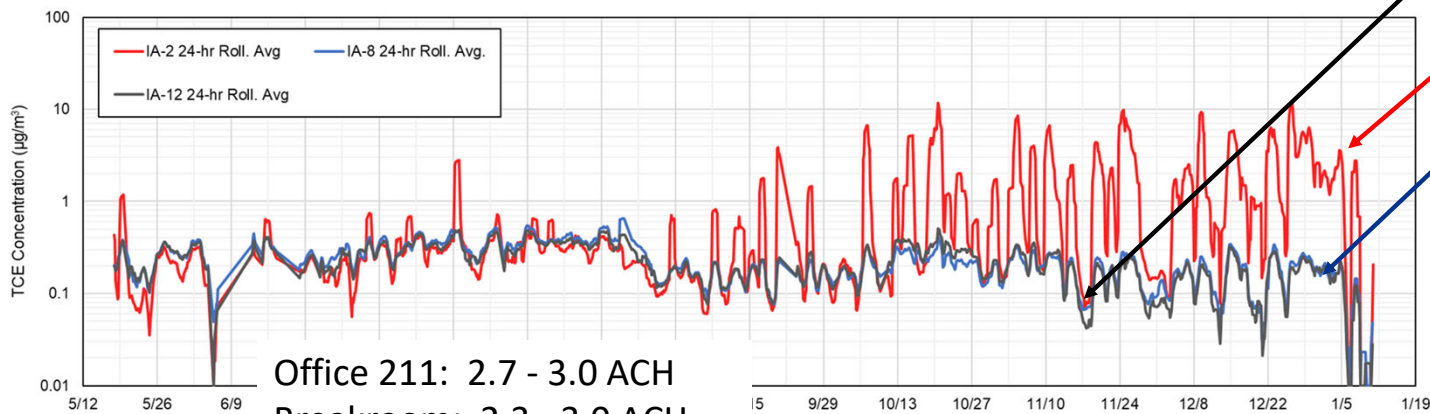
Office 211: 2.7 - 3.0 ACH
Breakroom: 2.3 - 3.0 ACH
Restroom: 3.1 ACH

Supply Room TCE Concentrations
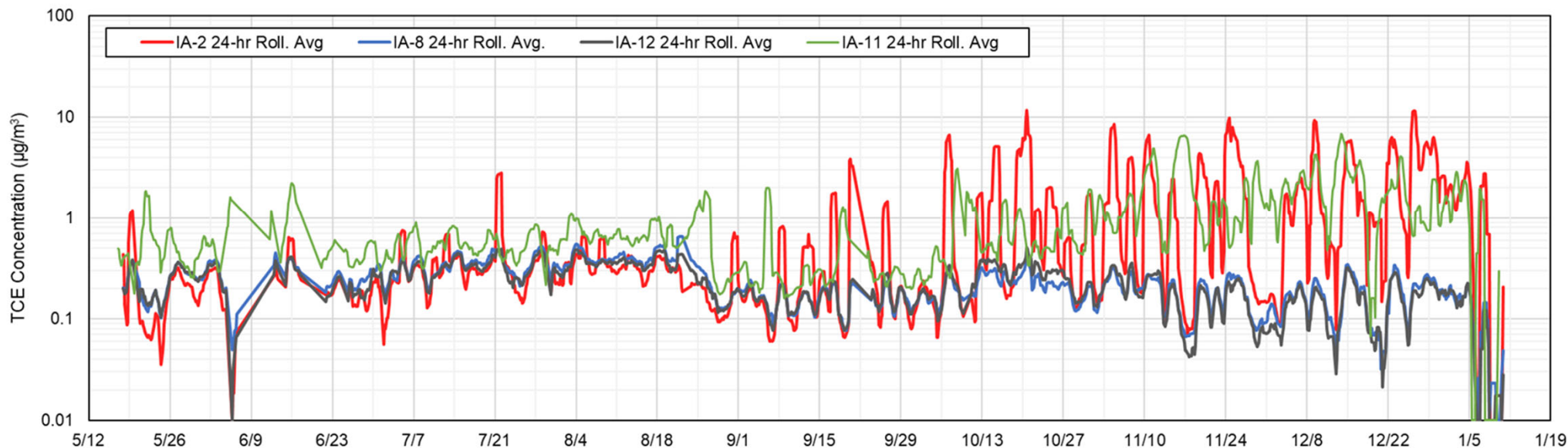
0.21 ACH

IA-11 24-hr Roll. Avg
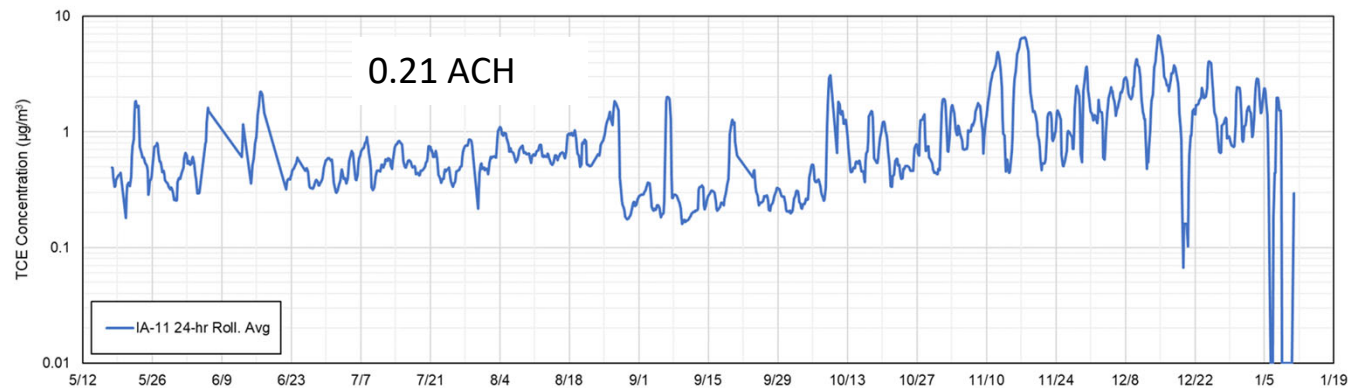
ACH = Air Changes per Hour

Do Zones 2 and 4 Exhibit Similar TCE Trends?

- Similar trend observed between all 3 sampling locations in Zone 2 (office, bathroom, breakroom) with differences in magnitude

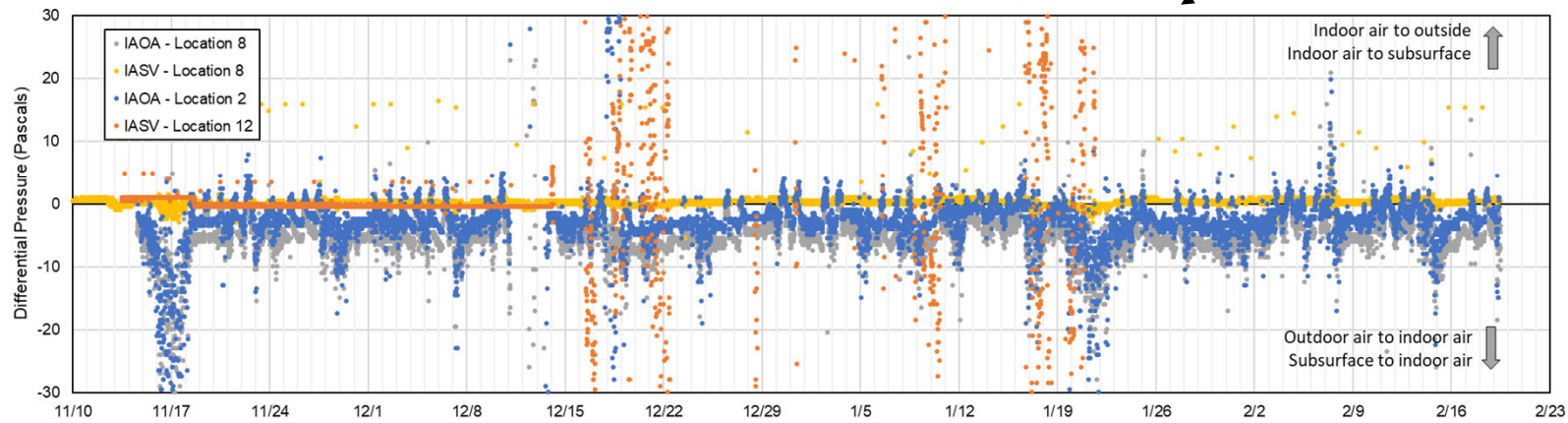- TCE trend in Zone 4 (Supply Room) does not follow same pattern as Zone 2

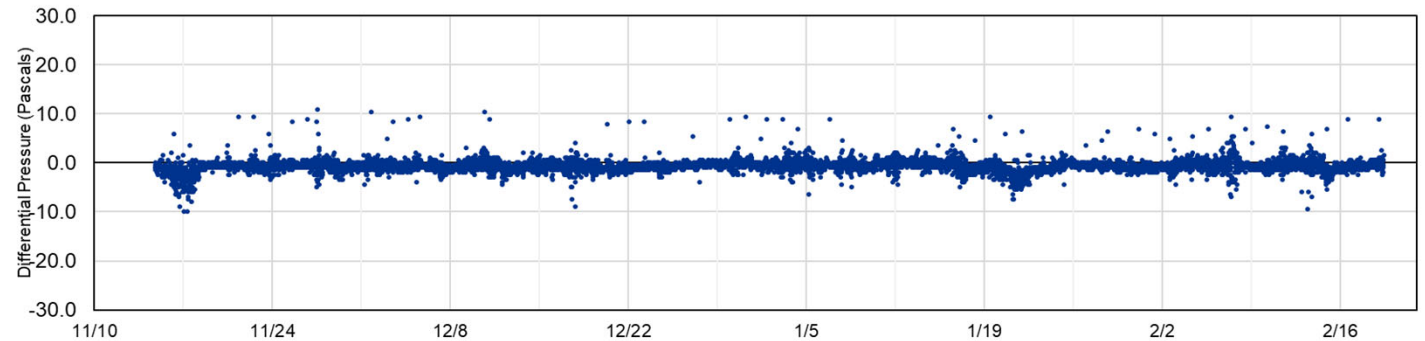Zone 2 (Locations 2, 8, and 12) and Zone 4 (Location 11) TCE Concentrations

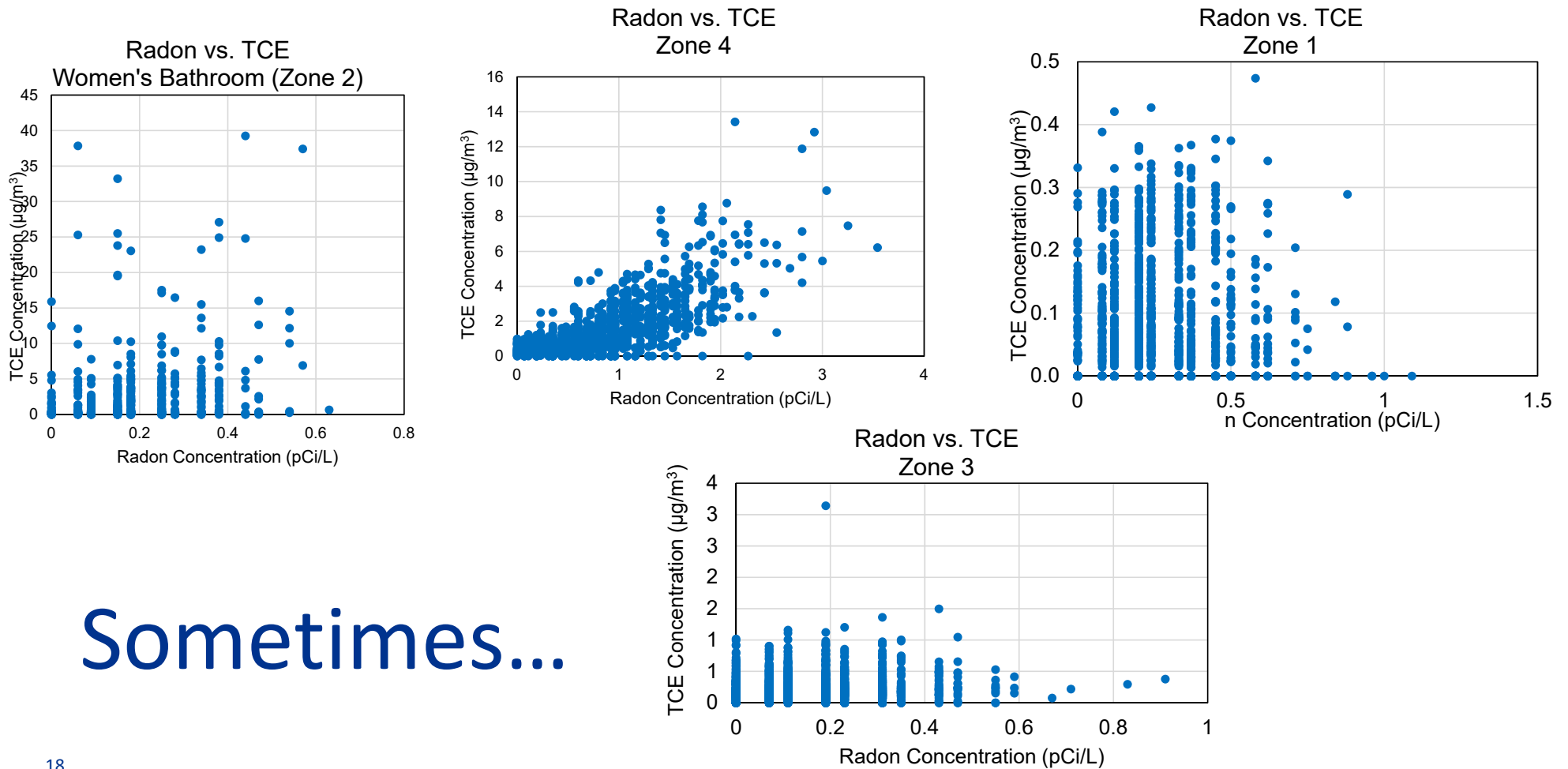# Zone Behavior - Differential Pressure
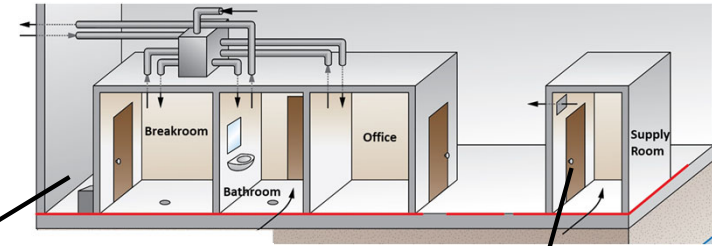
Zone 2 Differential Pressure
Office (8) Women's Bathroom (2) Breakroom (12)

Supply Room Differential Pressure (Location 11)

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Does Radon Indoor Air Concentration Predict TCE Indoor Air Concentration Across Sampling Locations?

Radon vs. TCE
Women's Bathroom (Zone 2)

Radon vs. TCE
Zone 4

Radon vs. TCE
Zone 1

Radon vs. TCE
Zone 3

Sometimes…

TCE Versus Radon in Supply Room and Women's Bathroom

Zone 4: TCE and Radon (IA-11)

Women's Bathroom: TCE and Radon (IA-2)

Radon Similar to Outdoor Air
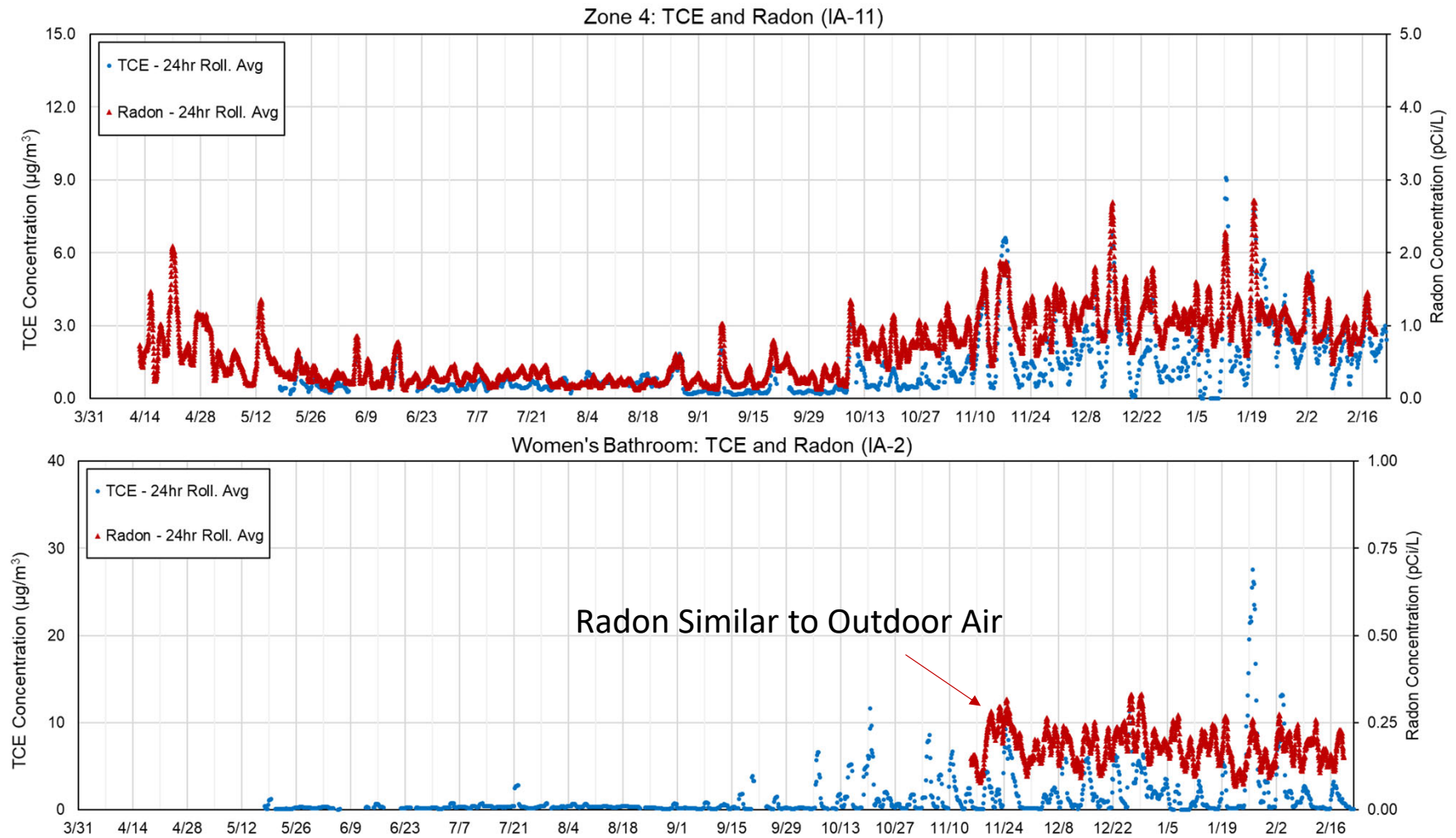
Does Radon Indoor Air Variability Predict TCE Indoor Air Variability Across Sampling Locations?

- ## Not at VA Site A…

  - Recall that radon in the women's bathroom is reflective of outdoor air

Radon Relative Deviation vs. TCE Relative Std Deviation

Breakroom/Office

Supply Room

TCE Relative Standard Deviation (y-axis): 0, 50, 100, 150, 200, 250, 300

Radon Relative Standard Deviation (x-axis): 0, 20, 40, 60, 80, 100, 120
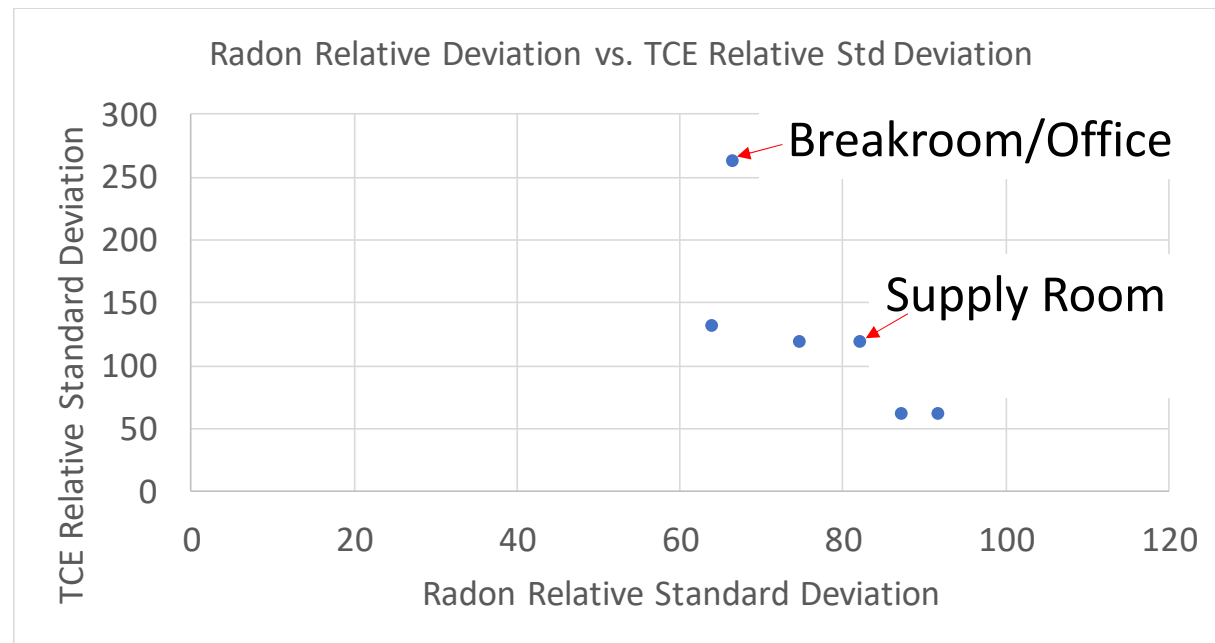
Radon Attenuation Factors – Clues to VI?

Virginia Site A Radon Attenuation Factors

Areas with highest VI occurring

Calculated Attenuation Factor

2.0E-03
1.5E-03
1.0E-03
5.0E-04

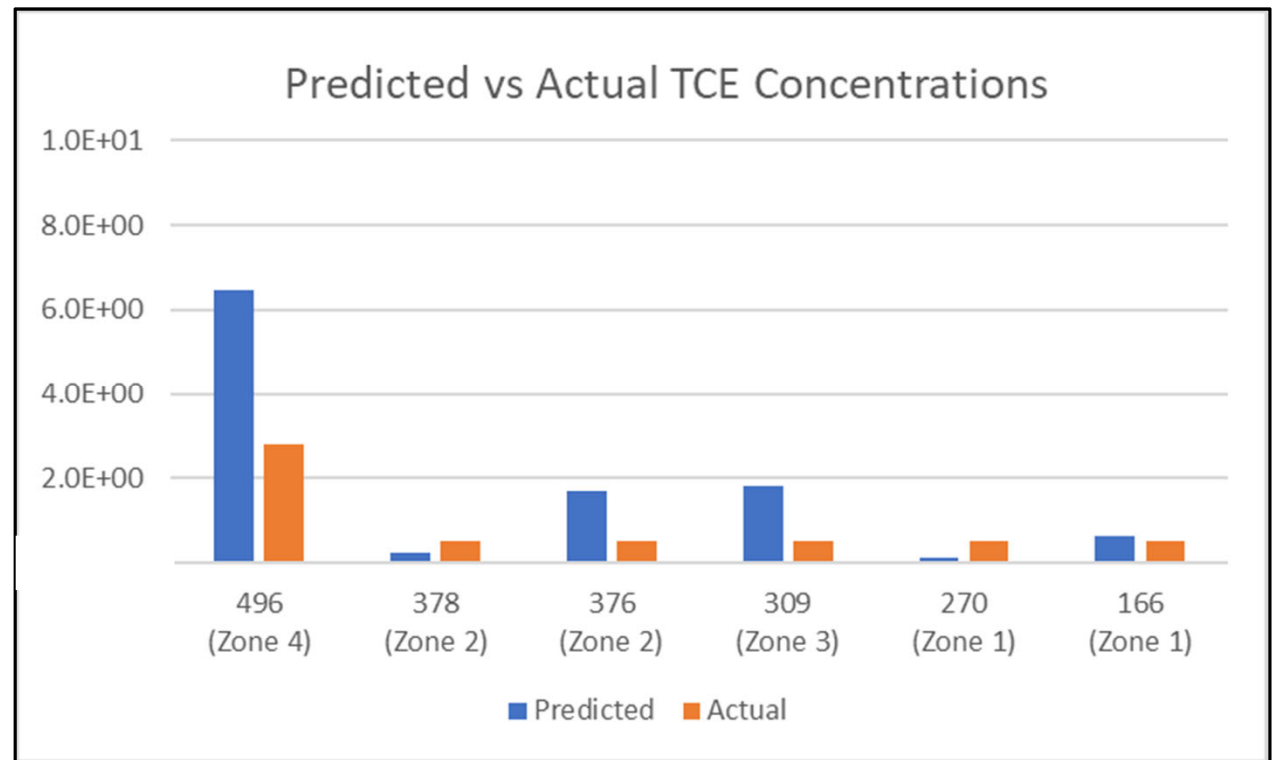| 496 (Zone 4) | 378 (Zone 2) | 376 (Zone 2) | 309 (Zone 3) | 270 (Zone 1) | 166 (Zone 1) |

Radon Subslab Concentration (pCi/L)
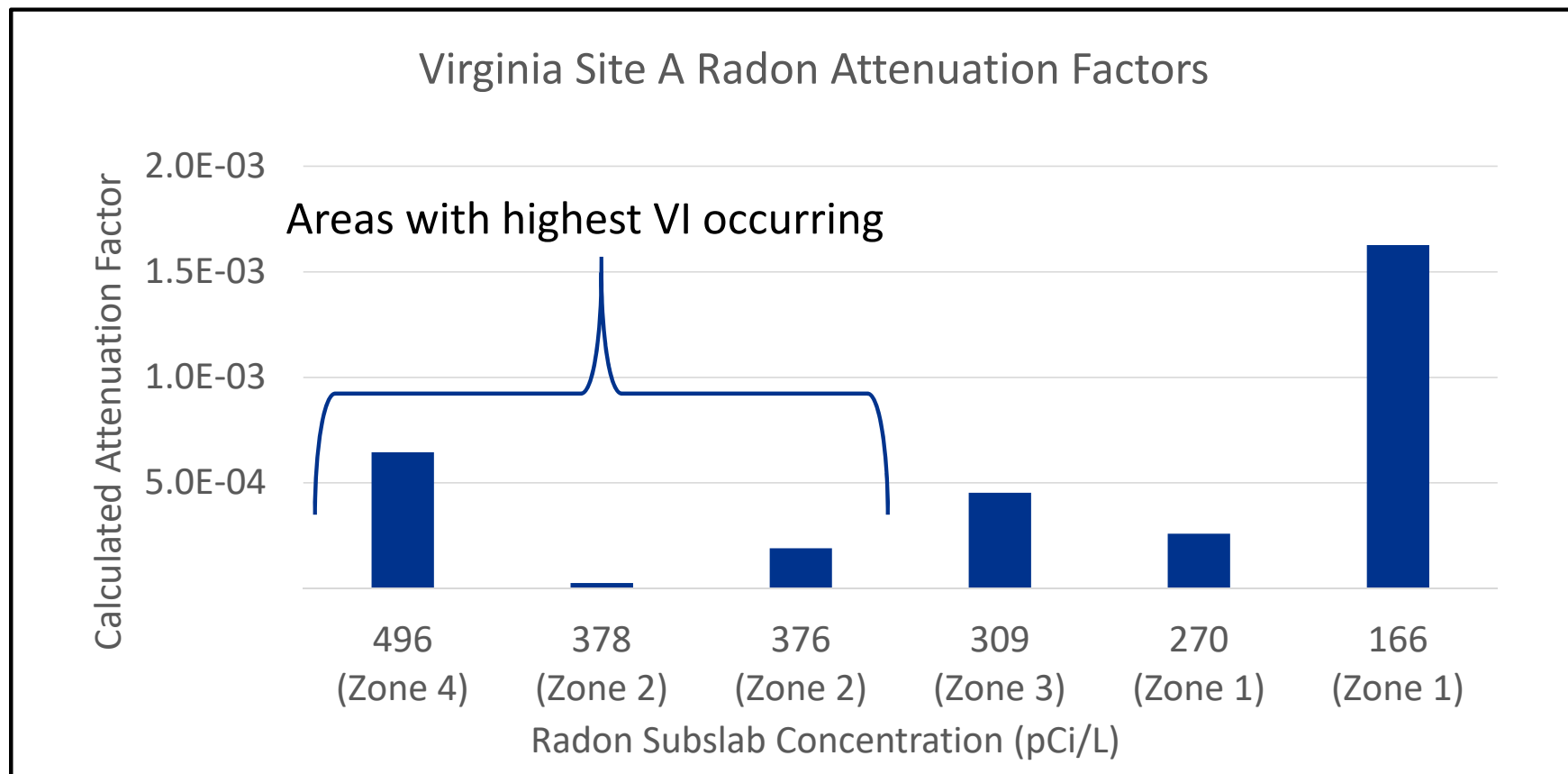
Predicted TCE Concentrations

- Calculated based on Radon AFs and observed subslab concentrations

- Highest VI predicted in Supply Room (Zone 4)
  - Radon was well correlated

Predicted vs Actual TCE Concentrations

Conclusions

- Detailed Building Surveys (including HVAC surveys), Tracer Testing, and Building Pressure Control are effective tools to identify sampling zones

- Different rooms within the same sampling zone indicate similar trends in VOC concentrations; however, some spaces within the zone are more susceptible to VI – real zones are not completely mixed

  - Important to identify potential preferential pathways when selecting sampling locations; place sample where highest probably of entry exists

- Different HVAC/Sampling Zones can show exhibit significantly different behavior even when source strength is similar

- Radon is more effective in predicting VI in HVAC/Sampling Zones with low AERs

  - May be more effective in zones with higher AERs when present in indoor air significantly higher than background (less subject to dilution)

- Radon AFs may be useful in prioritizing sampling zones in some cases

Acknowledgements

- Navy funding and oversight: Travis Lewis, Donna Caldwell and Jillian Wheeler

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- Data Analysis: Laurent Levy, Keri Hallberg, Victoria Boyd, Brian Cosky, Chris Lutes

Thank you!

Questions?

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