EPA Vapor Intrusion Workshop

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

Indianapolis Duplex Case Study

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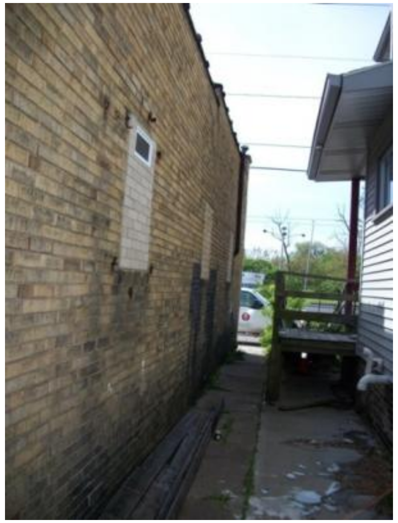
EPA Indianapolis Duplex – Classified in Menu of CSM Scenario Categories

Type & Depth to VOC source	Building type & size (ft2)	Foundation	Sub-foundation horizontal permeable	Preferential pipe pathway	Bldg-Climate zone (Temp)	Press./ Wind speed & direction	Intrusion primarily Advect. vs Diffusive
Shallow Soil	Modern sub-urban SFR Mod. 2k	Slab-on-Grade	Continuous horizontal/ permeable	High	1-3	Low	**Advective**
Deep Soil	**Legacy Urban Multi-Family**	Split level – SoG & basmt	**Discontinuous - impermeable**	**Mod.**	4	**Mod.**	Diffusive
Shallow GW	Non-Res. >10k ft2	**Full basement**		Low	**5**	High steady direct	50-50
'Deep' GW	Non-Res. >100k	Crawlspace-dirt floor		None	6-8	High varying direction	

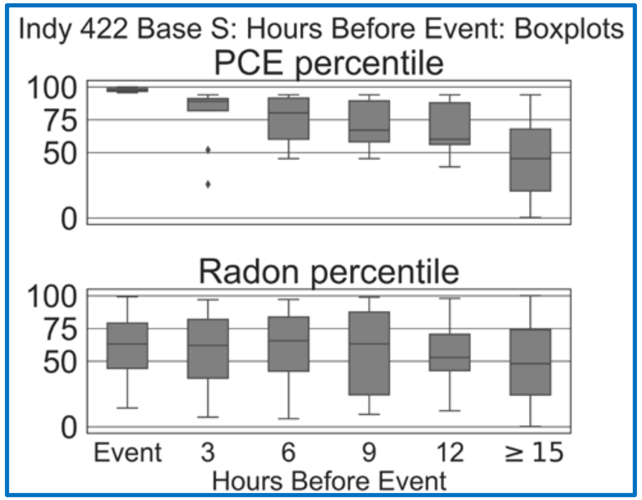
Building Tested

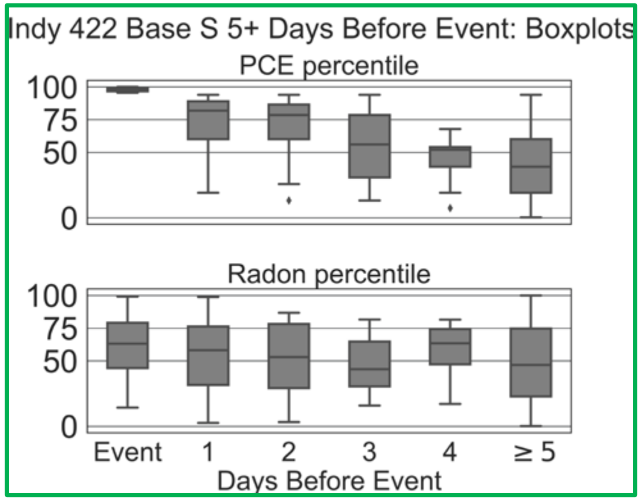
- Study duplex on 1915 Sanborn Map
- Basement +2 overlying floors
- Unoccupied, unfurnished
- Heated and unheated sides
- Top 7-8 ft: topsoil, cinders (fill); sandy silty clay loam (till).
- 8-25 ft: sand, gravel, cobbles (very coarse outwash).
- Depth to water (10.5 to 18.5 ft) rapidly fluctuates with nearby creek

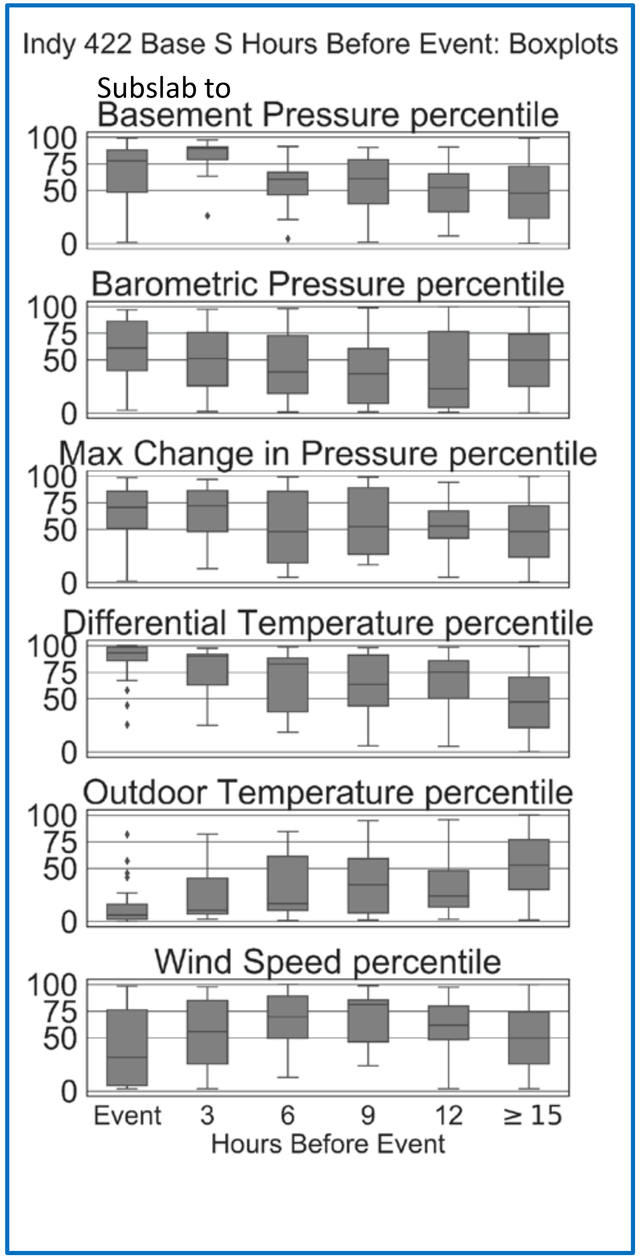
Cracks in basement concrete floor and brick walls

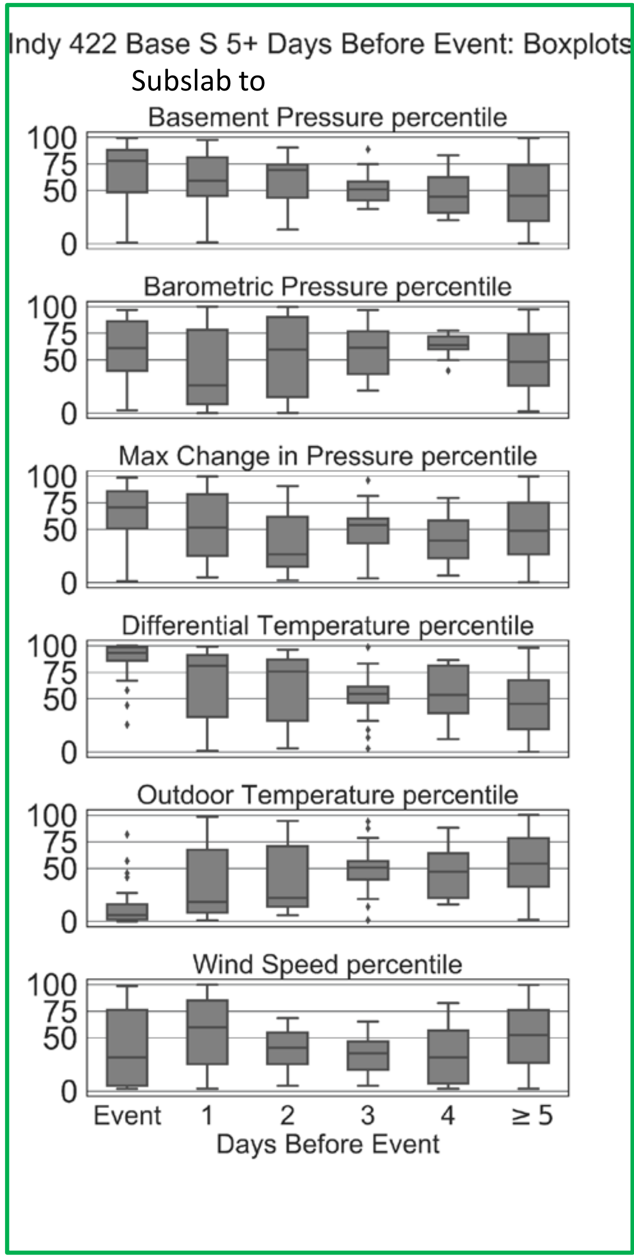


Indicators Preceding >95% PCE Indoor Air Observations: EPA Indianapolis Duplex Basement (Heated side)



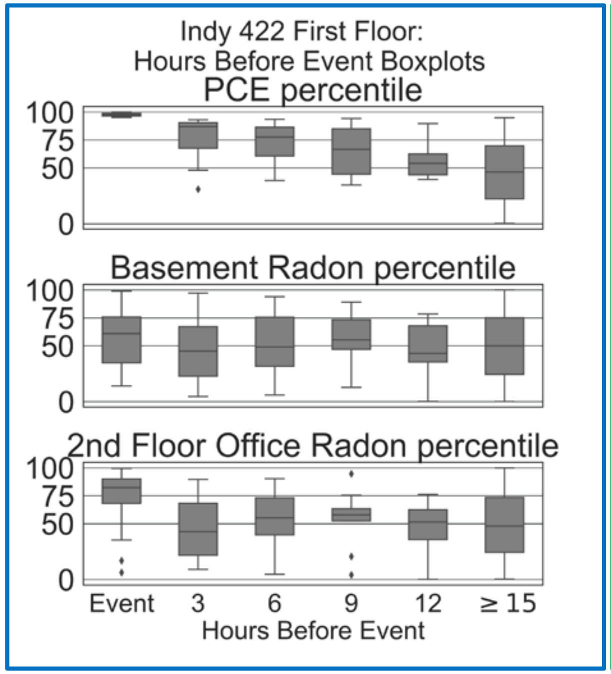


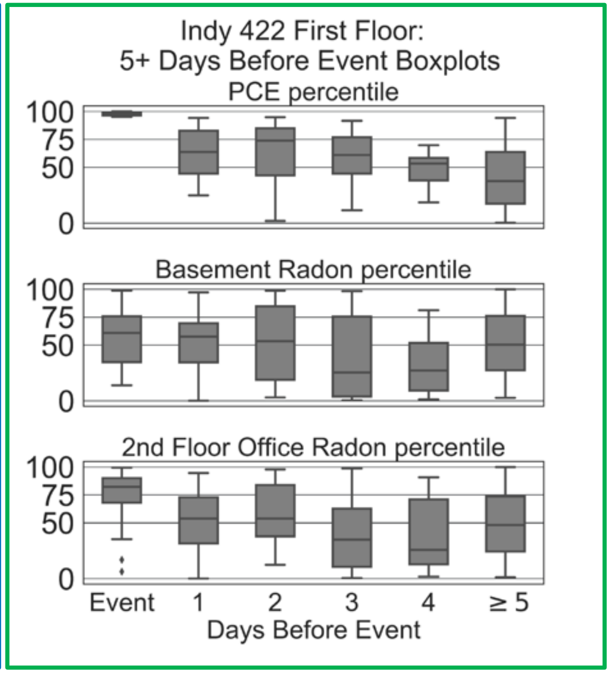


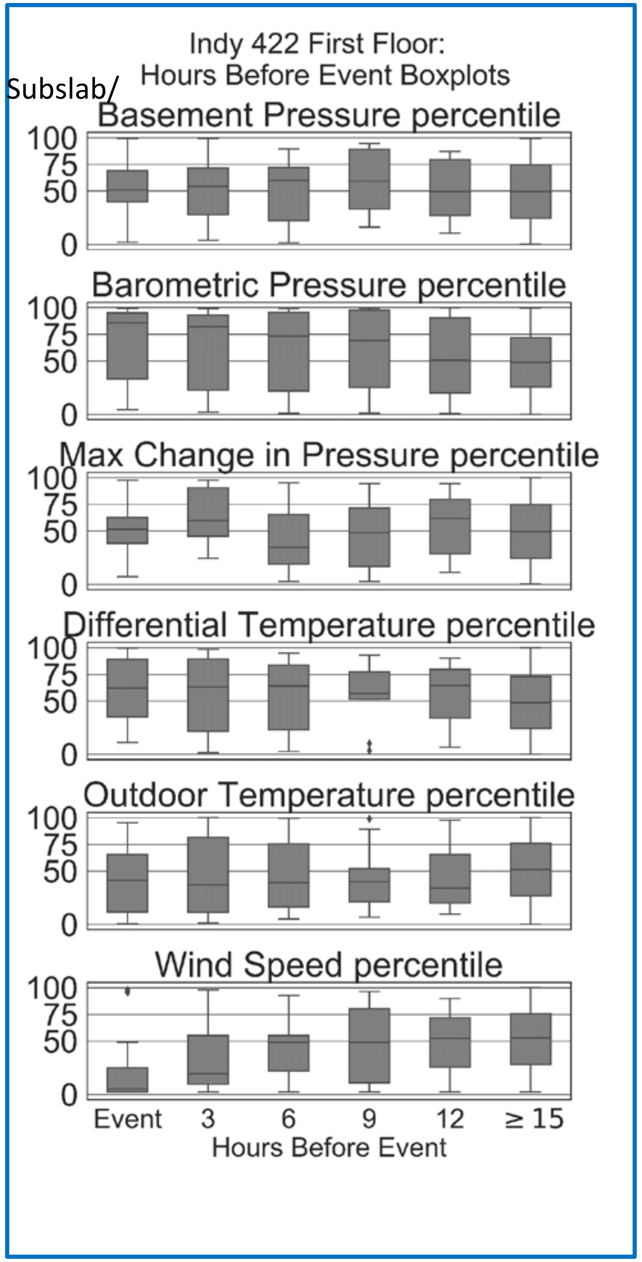


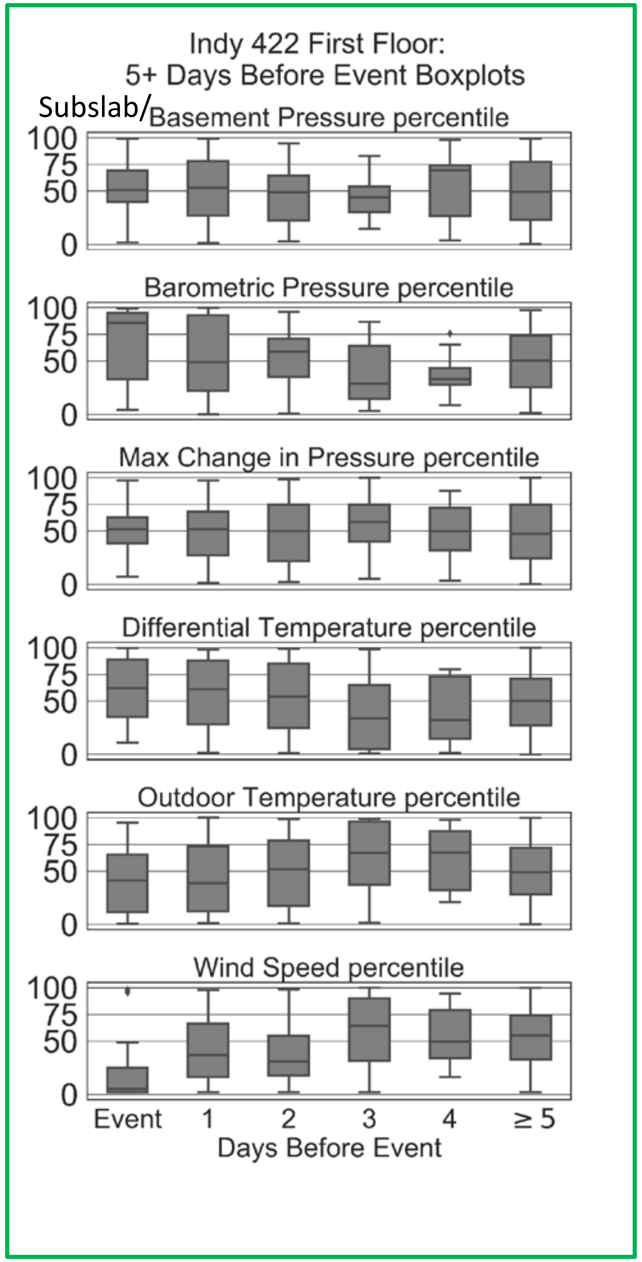
- Box and whisker summarizes 26 events
- Radon not an ideal tracer here
- Subslab to Basement ΔP a good indicator especially a few hours before the event
- Large changes in barometric pressure a few hours before can also be an indicator
- Decreasing exterior temperatures a good indicator, even days before
- Increasing differential temperature also useful
- Events seem to be associated with lower than normal winds

Indicators Preceding >95% PCE Indoor Air Observations: EPA Indianapolis Duplex First Floor (Heated side)





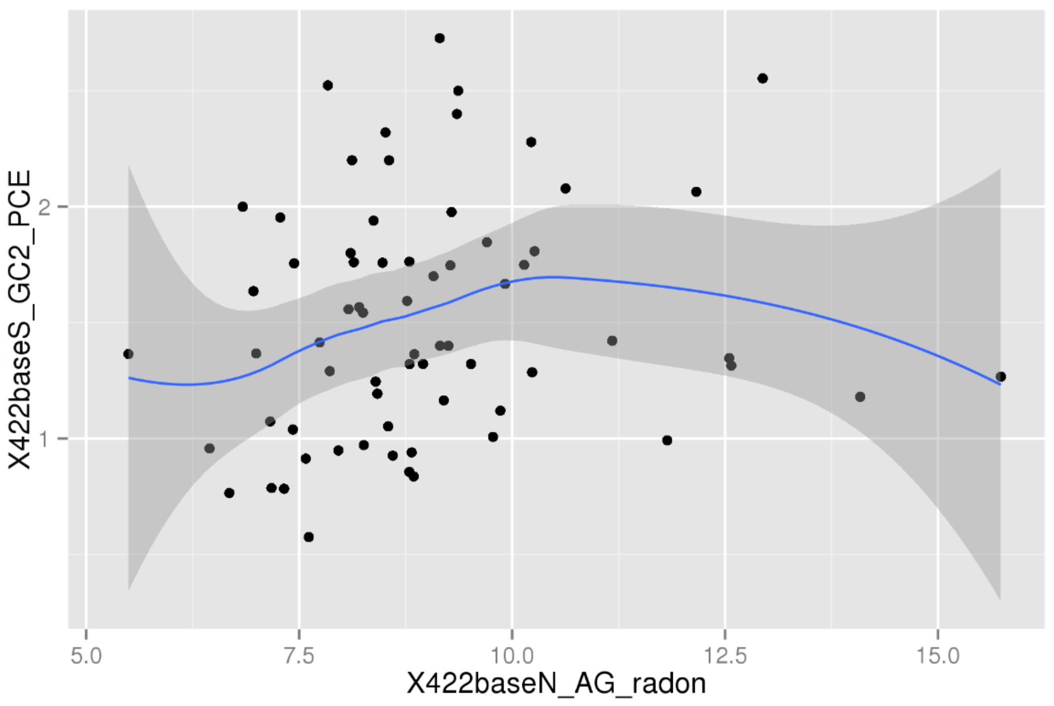




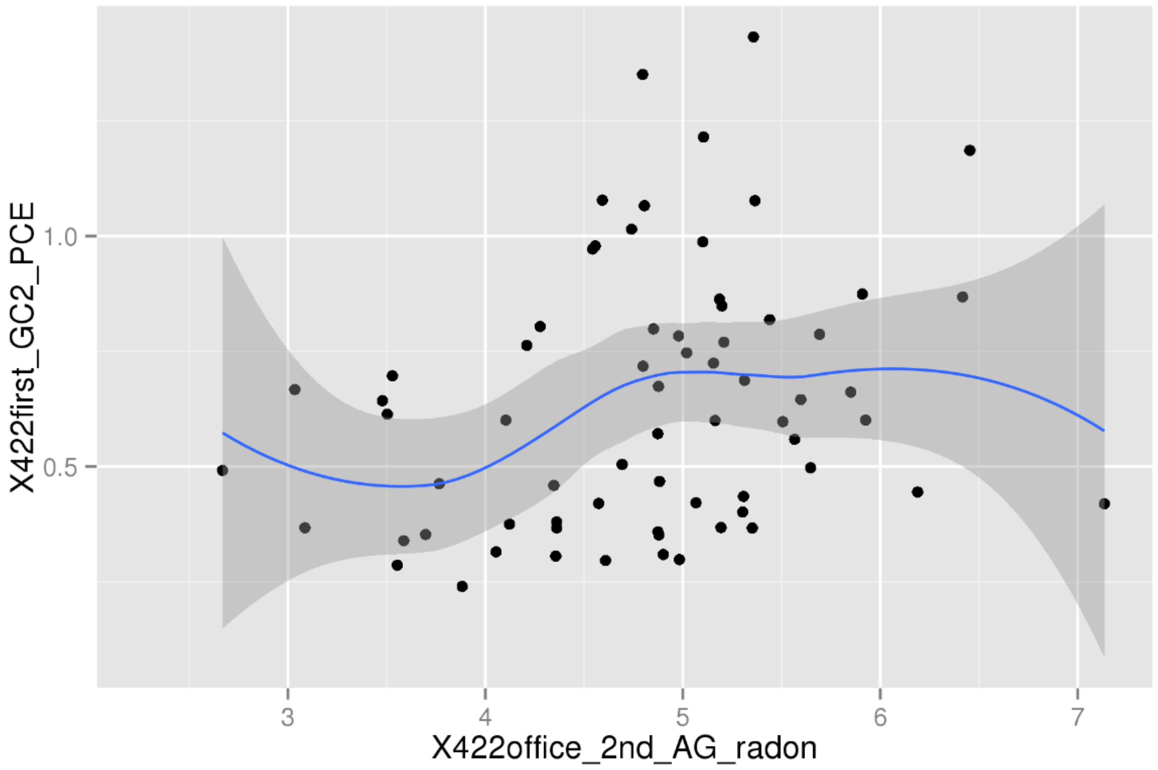
- 2nd Floor radon right at the event good indicator – soil gas moving upstairs!
- Subslab to basement ΔP not useful
- Increasing barometric pressure somewhat helpful
- Peak PCE associated with decreasing temperatures in the days before and decreasing wind speeds especially in the hours before the event.
- Trend consistent with high stack effect, and low AER

Back to Analysis of Full Range of Data – Radon vs. PCE – Heated Side

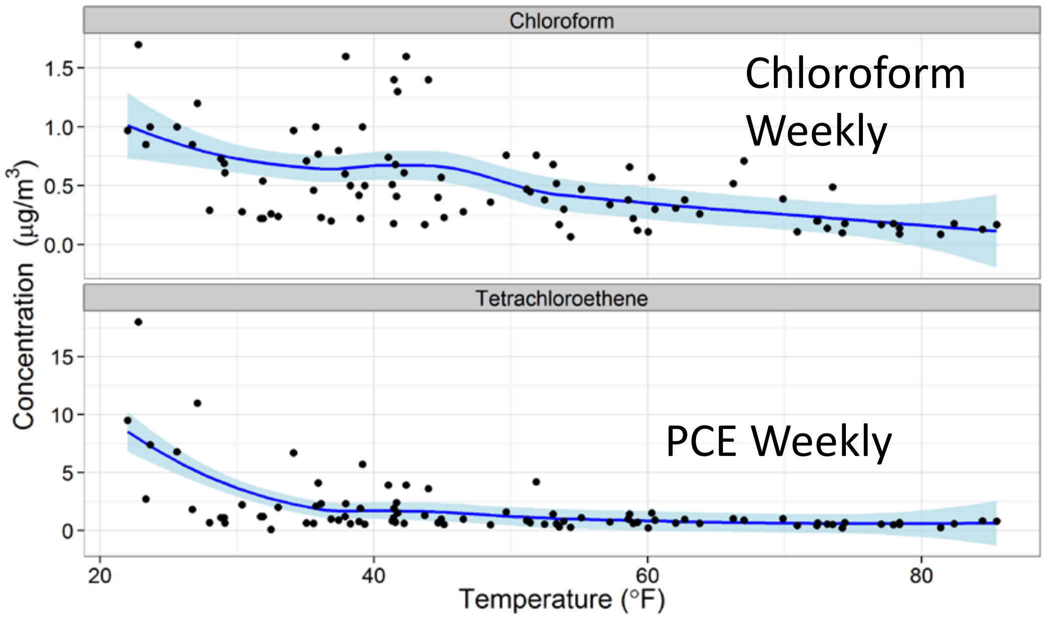
- Daily average PCE data from GC as a function of daily average of instrumental radon in heated basement. (Dec 2011- Feb 2012)

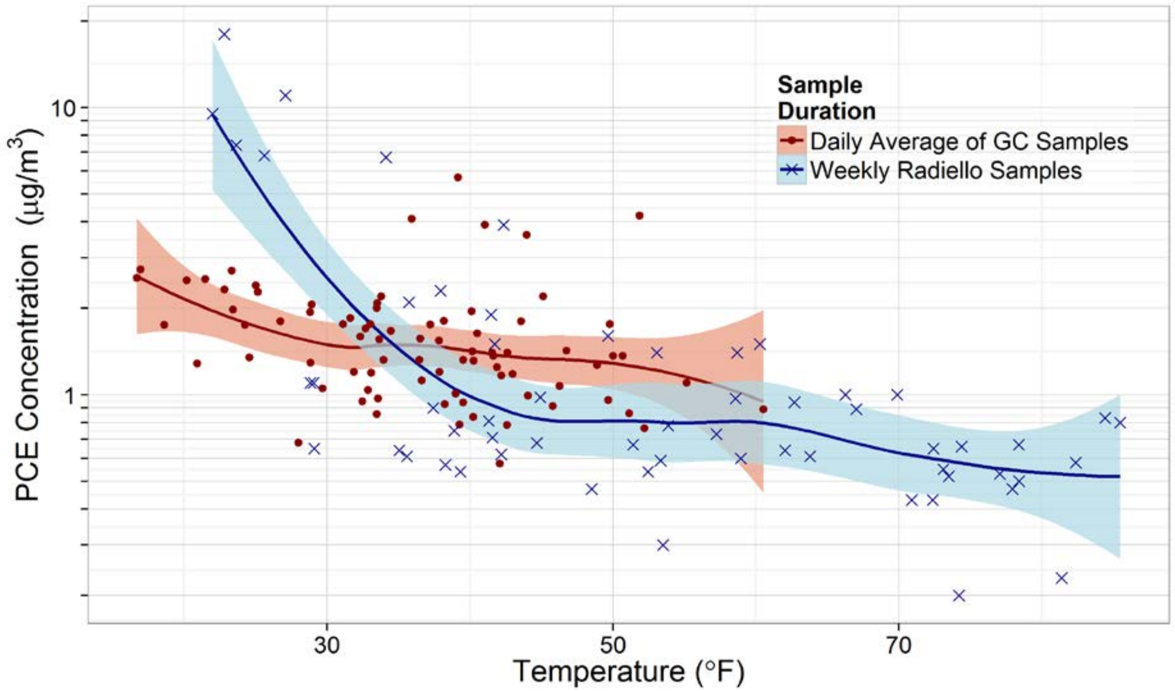


- Daily average PCE data from GC as a function of daily average of instrumental radon in upper stories (Dec 2011- Feb 2012)



Full Range of Data: Effect of Outside Temperature on VOCs in Indoor Air is Consistent Across Compounds and Data Sets





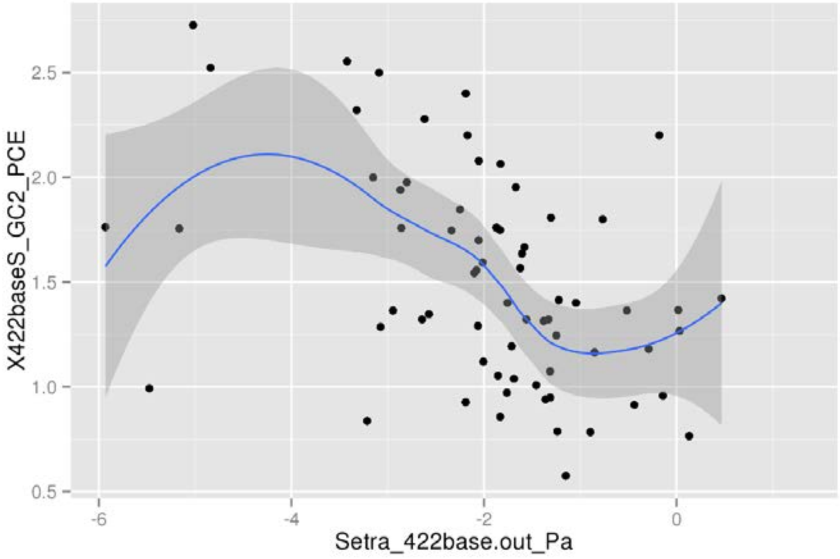
Comparing Two Data Sets

PCE Daily Resolution – Field GC Data, Dec 2011 – Feb 2012

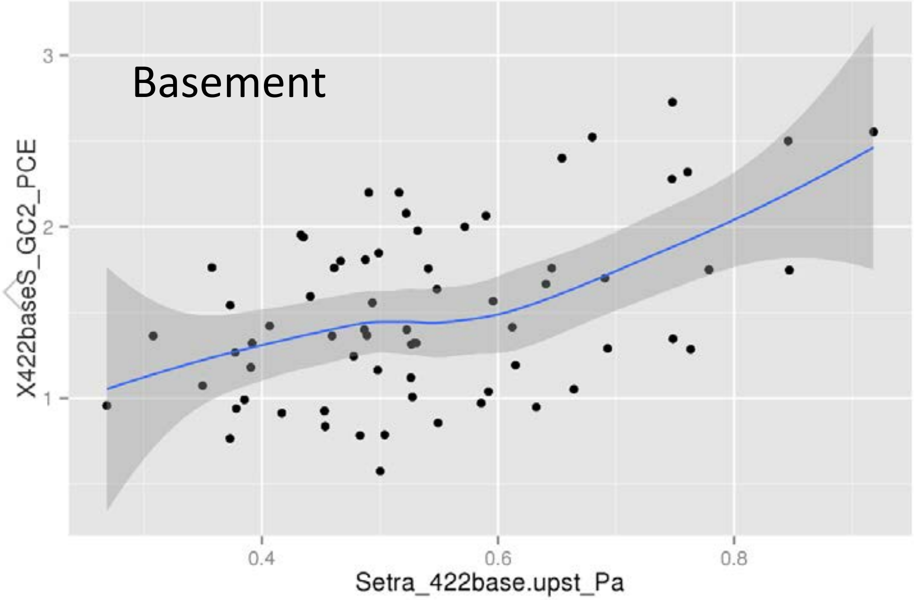
PCE Weekly Time Resolution – Passive Sampler Data, Jan 2011 – April 2013

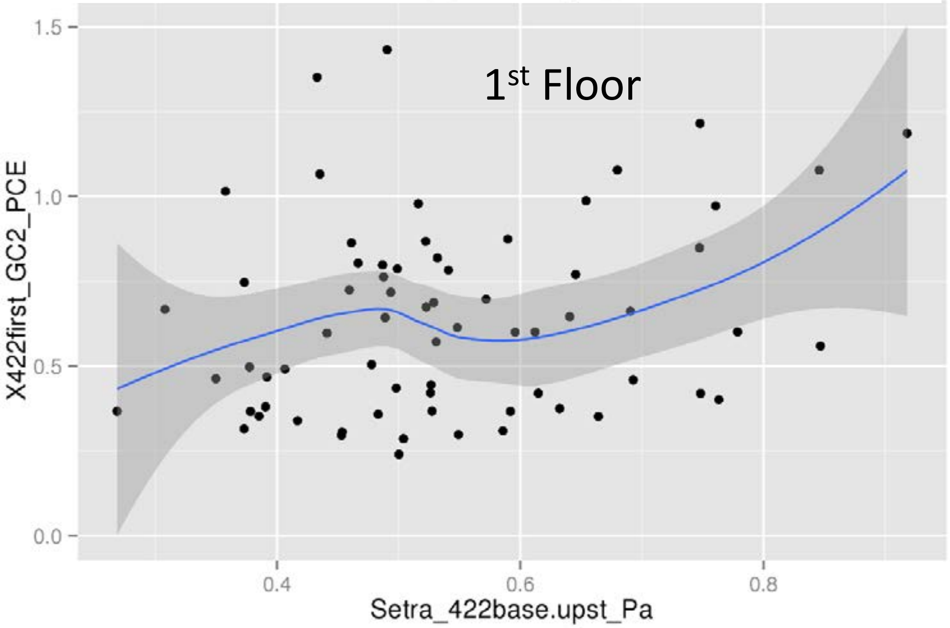
Analysis of Full Range of Data: ΔP Dec 2011- Feb 2012

- Daily average PCE data from GC as a function of daily average of ΔP from Basement to Exterior (these negative values indicate basement is depressurized)



Key Point: Elevated PCE indoors associated with basement depressurized vs. outdoor air; and with second floor depressurized vs. basement.





Daily average PCE data from GC as a function of daily average of ΔP from basement to upper stories (positive values indicate flow up through structure)

Example Time Series Results Interpretation

<u>Using on-line GC Data for basement PCE Dec 2012 – March 2013, mitigation off, Exterior Temperature in F, the following equation was significant at the 99% confidence level:</u>

$C_t - C_{(t-1)} = 0.748 + -0.078 * T_t + 0.057 * T_{(t-1)}$

C= Concentration T = Exterior temperature t= time

Note red and green coefficients similar but opposite in sign.

Example A: falling temp: 20 F today; 40 F yesterday, on average PCE concentration increased 1.5 μg/m^3.

Example B: rising temp: 20 F today, 10 F yesterday, on average PCE concentration decreased 0.2 μg/m^3

Key Time Series Conclusions

- The ***change*** in the differential temperature and thus stack effect strength was more important than the absolute value of the differential temperature. Indoor air concentrations of VOCs are expected to be high when the weather is getting colder, but would not necessarily be expected to be as high during a period of sustained cold weather. Not all winter sampling times are equivalent.
- The most consistent relationship for barometric pressure is that an elevated (greater than 30 inches) and/or rising barometric pressure is associated with increasing vapor intrusion.
- No statistically significant effect of rain was seen.
- ***Increasing*** radon as a predictor was found to be statistically significant at the 99 confidence level and to predict 40-60% of the variability in indoor air VOC concentrations.

Key Time Series Conclusions

- The proportion of the VOC variability that could be predicted from any one meteorological or pressure variable was <30%.
- Observations for VOCs are consistent with those previously made in the radon literature:

"This paper identified about thirteen factors that can affect radon variation in the soil and house environment. The thirteen factors being 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. One can see the complexity of understanding and studying radon variability in homes." - Lewis and Houle 1985 "A Living Radon Reference Manual"

Where Can I Get More Information?

- *Fluctuation of Indoor Radon and VOC Concentrations Due to Seasonal Variations*, 2012; EPA/600/R-12/673 https://cfpub.epa.gov/si/si_public_record_report.cfm?Lab=NERL&dirEntryId=247212
- *Assessment of Mitigation Systems on Vapor Intrusion: Temporal Trends, Attenuation Factors, and Contaminant Migration Routes under Mitigated and Non-mitigated Conditions.* U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-14/397, 2015. https://cfpub.epa.gov/si/si_public_record_report.cfm?Lab=NERL&dirEntryId=308904
- *Simple, Efficient, and Rapid Methods to Determine the Potential for Vapor Intrusion into the Home: Temporal Trends, Vapor Intrusion Forecasting, Sampling Strategies, and Contaminant Migration Routes*. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-15/070, 2015. https://cfpub.epa.gov/si/si_public_record_report.cfm?Lab=NERL&dirEntryId=309644
- *Indianapolis Research Duplex Total Database* https://catalog.data.gov/dataset/indianapolis-research-duplex-total-database
- Lutes, C. C., Truesdale, R. S., Cosky, B. W., Zimmerman, J. H., & Schumacher, B. A. (2015). Comparing Vapor Intrusion Mitigation System Performance for VOCs and Radon. *Remediation Journal*, *25*(4), 7-26.
- McHugh, T., Beckley, L., Sullivan, T., Lutes, C., Truesdale, R., Uppencamp, R., ... & Schumacher, B. (2017). Evidence of a sewer vapor transport pathway at the USEPA vapor intrusion research duplex. *Science of the Total Environment*, *598*, 772-779.
- Zimmerman, J. H., Lutes, C., Cosky, B., Schumacher, B., Salkie, D., & Truesdale, R. (2017). Temporary vs. permanent sub-slab ports: A comparative performance study. *Soil and Sediment Contamination: An International Journal*, (just-accepted), 00-00. http://www.tandfonline.com/doi/full/10.1080/15320383.2017.1298565
- Numerous conference presentations on this and other projects at: https://iavi.rti.org/WorkshopsAndConferences.cfm