Vapor Intrusion (VI) Guidance and Fact Sheets for Indicators, Tracers, and Surrogates (ITS)

Reasonable Maximum Exposure (RME) Considerations when Estimating VI Risk

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EPA Vapor Intrusion Workshop, San Diego CA , March 17th, 2020

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EPA Guidance and Fact Sheets on ITS

- EPA (2015) VI Guidance
  - Buildings with radon greater in indoor air than ambient (outdoor) air are likely susceptible to soil gas intrusion…
  - Pressure differences during sampling can support insights about driving forces
  - EPA recommends documenting wind direction, precipitation information, temperature, barometric pressure

- EPA ITS Fact Sheets (https://iavi.rti.org/workshops.html)
  - *Monitoring Radon as a VI Tracer or Surrogate*
  - *Measuring Pressure (Differential and Barometric) as a VI Indicator*
  - *Measuring Temperature as an Indicator for VI*

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Monitoring Radon as a Vapor Intrusion (VI) Tracer or Surrogate

What is Radon and Why Measure it at a Volatile Organic Compound (VOC) Contaminated Site?

- Radon is colorless, odorless, naturally occurring gas that is a common component of soil gas.
- Radon has few indoor sources, and thus is a relatively unique tracer of soil gas intrusion into buildings, following the same pathway to indoor air as soil gas and with very similar mechanisms as VOCs in soil gas.
- Radon exposure poses very substantial carcinogenic hazards in and of itself, so reducing radon is a valuable side benefit of mitigating the VI pathway (for more information, see https://www.epa.gov/radon/health-risk-radon).
- Radon is measured in picocuries per liter (pCi/L) or becquerels per cubic meter (Bq/m³): 1 pC…
- EPA recommends mitigation of residences with radon levels greater than 4 pCi/L and consid… at levels between 2 and 4 pCi/L.

Where to Measure Radon?

- Radon can be monitored with these methods in crawlspace, ambient, entry pathway, and ind…
- Select indoor locations to represent the zones in which exposure likely occurs, such as breat… occupied basements and first floors.
- Ambient radon in outdoor air can be an important comparison because outdoor radon can si… to indoor levels. Estimates of ambient air radon in the United States averages 0.4 to 0.7 pCi… concentrations ranging from less than 0.01 to 1.5 pCi/L. Radon in ambient air is higher at nig… over land then over oceans. Radon seasonality in outdoor air depends on wind direction and…
- Monitoring of crawlspaces and air in preferential pathways (for example wall cavities) can pr… times and places of soil gas entry. Radon surveys can be used to identify entry points such a…
- Radon is likely to be detectable in soil gas almost everywhere in the United States, but conce… enough to be clearly observable after attenuation into indoor air are most likely in medium to… (Zones 1 and 2 in https://www.epa.gov/sites/production/files/2015-07/documents/zonemapco…
- Very roughly, high risk radon zones are likely to have soil gas radon greater than 1,350 pCi/L… radon zones range from 270 to 1,350 pCi/L (Lewis and Houle, 2009).

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Measuring Pressure (Differential and Barometric) as a Vapor Intrusion (VI) Indicator

What Pressures?

- Differential pressure (ΔP)—Difference in pressure between two points in space (indoor/outdoor or indoor/subslab).
- Change in barometric pressure (ΔBP)—Pressure in the atmosphere (indoor and outdoor), change in BP over time is most important (Figure 1).
- Normal changes in BP can be quite large and create pressure differentials across the building envelope if all else is equal (Figure 2). A regular diurnal variation of up to 300 pascals (Pa) is common and weather fronts can cause BP to change by 1,000 Pa over several days.
- Falling BP leads to vapors flowing out of the ground as pressures seek to equalize, but with a time delay.
- Wind loads and stack effects are also important causes of BP variations.

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Measuring Temperature as an Indicator for Vapor Intrusion (VI) Studies

What Temperatures?

Measure or estimate indoor temperature (T_i), outdoor temperature (T_o), and differential temperature (ΔT) using the formula $\Delta T = T_i - T_o$. For example, if inside = 75°F, outside = 30°F, then ΔT = 45°F.

Where to Measure Indoor Temperature?

In the main living space—definitely. Ideally also in the basement/crawlspace and attic.

Where to Measure Outdoor Temperature?

At a location near the house sheltered from direct sun or use your local weather station.

When to Measure Temperature?

At least hourly is a good start—temperature has a diurnal and seasonal cycle. It typically does not change more than a few degrees per hour.

- In comparison studies temperature should be measured at least as frequently as your volatile organic compound (VOC) or radon data are. So, for studies using 24-hour Summa canisters, the average temperature for the day is the bare minimum.

With What?

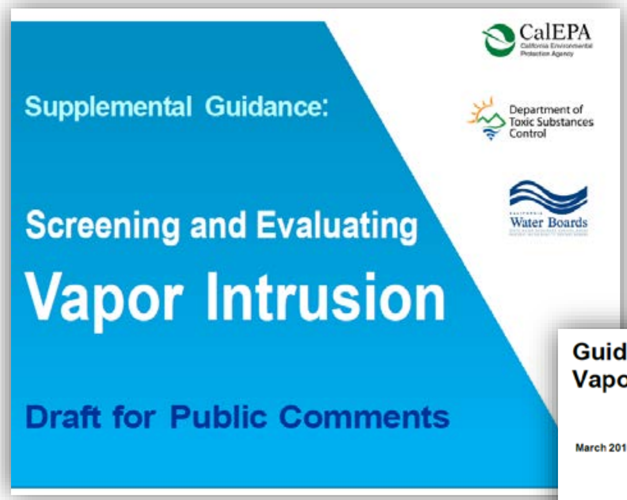
- Inexpensive digital temperature loggers are widely available and cost less than $100 per location (e.g., https://www.microdaq.com and www.onsetcomp.com). Some pressure instruments give temperature as well.

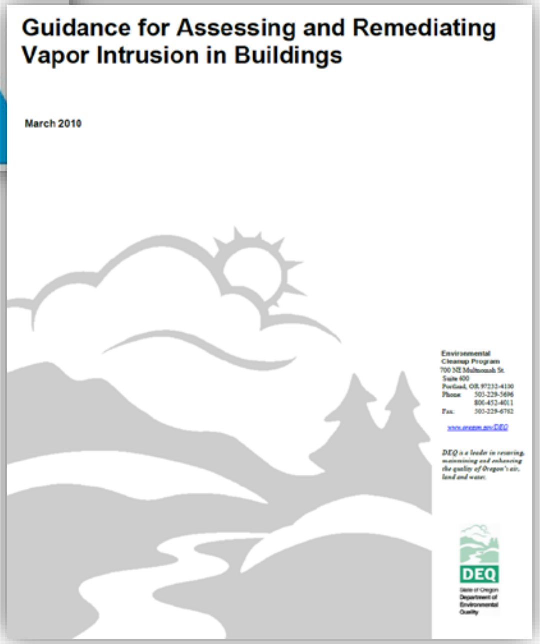
Power interruptions and daylight savings time. When selecting temperature-monitoring equipment for long-term projects, determine ahead of time how those devices will react to power outages and time changes due to daylight savings time. These events can affect the accuracy of date/time stamps, especially when comparing data streams coming from multiple independent devices.

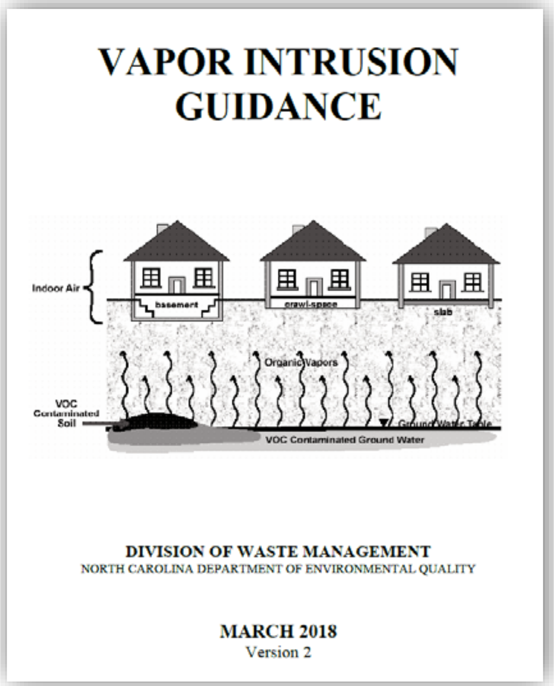
- Historical outside temperature data for thousands of locations are cataloged either for specific period or normal values (https://www.ncdc.noaa.gov/cdo-web/, https://www.wunderground.com/history/, https://www.ncdc.noaa.gov/cdo-web/datatools/selectlocation.

Examples of State VI Guidance -- ITS

- CalEPA (2020) Draft Supplemental VI Guidance
  - Naturally-occurring radon or other tracers may be used for evaluating subsurface VI
- North Carolina (2018) VI Guidance
  - Radon can be monitored in indoor air and compared to outdoor levels
  - Sub-slab and indoor air radon may be used to estimate sub-slab to indoor air attenuation factors”
  - VI can be evaluated using … pressure data to demonstrate the driving force for soil gas entry … or evaluation of tracers
- Oregon (2010) VI Guidance
  - Subsurface and indoor radon can provide another line of evidence for evaluating VI potential
  - Changes in pressure can move gases … wind can enhance VI rates … collect barometric pressure and wind-speed during indoor sampling







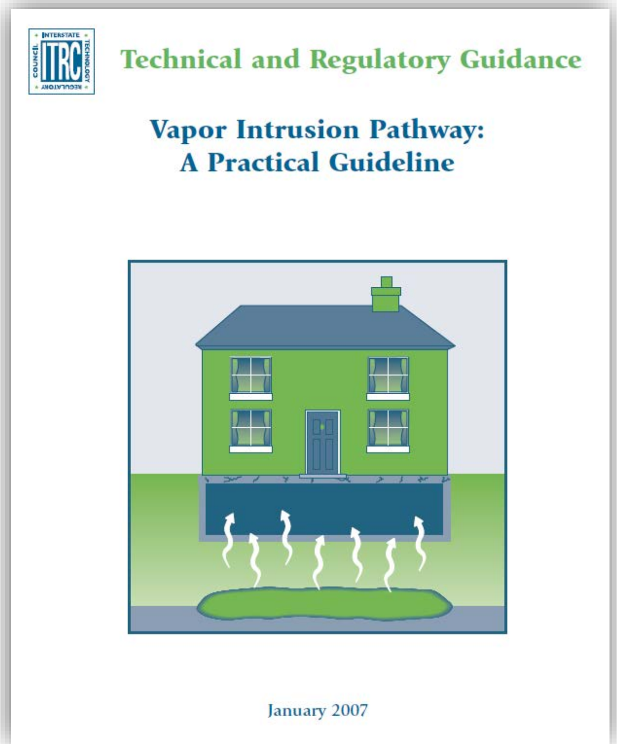
ATSDR and ITRC VI Guidance -- ITS

- ATSDR (2012) Evaluating VI Pathways
  - Compare indoor and outdoor air levels of low-cost tracers or indicators of soil gas intrusion, such as radon
  - Barometric pressure drops can increase VI
- ATSDR Home Alterations and VI Fact Sheet (in progress)
  - Radon sampling can help determine the need for more in-depth chemical VI investigation
- ITRC (2007) VI Guidance
  - Radon is a commonly used tracer for VI
  - Measurement of pressure gradient can assist in interpreting measured indoor concentrations
  - Collection of meteorological data can help assess VI

Evaluating Vapor Intrusion Pathways

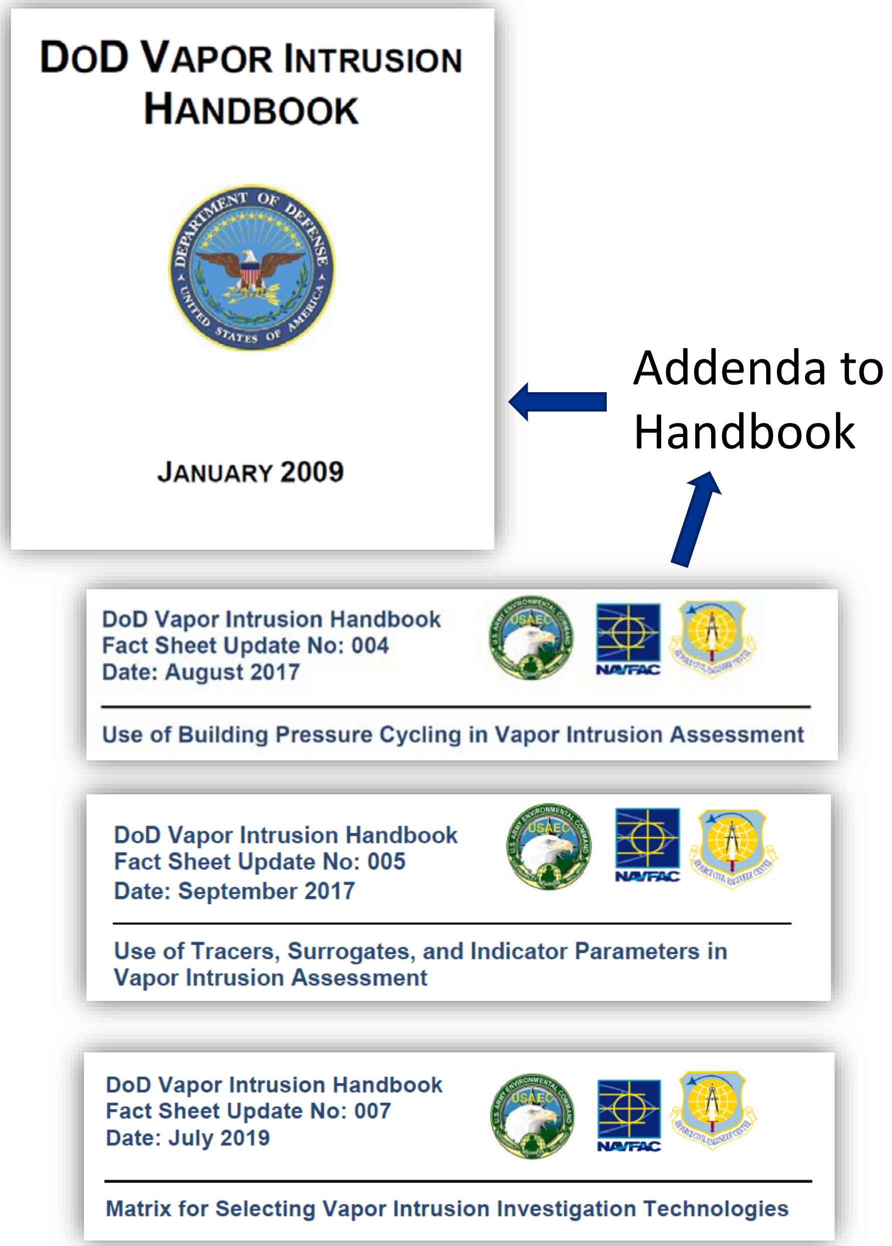
Guidance for ATSDR's Division of Community Health Investigations

October 31, 2016



Department of Defense (DoD) -- Indicators and Tracers

- DoD (2009) VI Handbook
  - Radon data may help filter out data not associated with VI
  - Pressure can help assess need for further investigation
  - Temperature, barometric pressure and precipitation can influence vapor flux
- DoD (2017) Fact Sheet 004: Use of Building Pressure Cycling in Vapor Intrusion Assessment
  - Pressure fluctuations induce varying amounts of VI
  - Controlling building pressure can reduce spatial/temporal variability of indoor air concentrations due to VI
- DoD (2017) Fact Sheet 005: Use of Tracers, Surrogates, and Indicator Parameters in VI Assessments
  - Tracers, surrogates, and indicators can be used for several purposes as part of a VI assessment
- DoD (2019) Fact Sheet 007: Matrix for Selecting Vapor Intrusion Investigation Technologies
  - Building pressure differentials, radon, temperature differentials, and tracers can be used to assess VI



DoD (2019) Matrix of VI Technologies Fact Sheet

DoD Vapor Intrusion Handbook
Fact Sheet Update No: 007
Date: July 2019

NAVFAC

Matrix for Selecting Vapor Intrusion Investigation Technologies

Table 1. Matrix of VI Investigation Technologies

			Soil Screening			Soil Vapor & Indoor Air Field Screening			
			1	2	3	4	5	6	7
VI Pathway Assessment	Investigation Objective	Sub-objectives	Discrete soil samples for VOC analysis with microwave extraction	Continuous coring or profiling (MIP, Dye LIF)	Soil Physical Properties (core logging, geotech analysis)	Handheld PID (VOCs)	Portable GC/PID (Tedlar bags)	Mobile GC/ECD (Tedlar bags, glass syringes, Teflon tubing)	Portable GC/MS (HAPSITE) & MS/MS (TAGA)
Are VOCs/SVOCs associated with the subsurface vapor source(s) also present in the indoor environment?	Characterize indoor air exposure point concentrations	Characterize or address temporal variability	-	-	-	-	++	+++	++
		Characterize or address spatial variability	-	-	-	-	++	+++	+++

Example study question, DQO, and sub-DQO

Ranking Description:

- \- Not applicable or expected to perform poorly
- \+ Provides some information when combined with other higher ranked technologies
- ++ Useful technology for the stated objective
- +++ Provides most definitive results or represents state of the art technology

DoD (2019) Matrix of VI Technologies Fact Sheet (cont'd)

VI Indicator and Tracer Technologies (useful technologies to help achieve objectives)

Table 1 (cont'd)

			Soil Vapor & Indoor Air Sampling				rensic Tools					
			8	9	10	11	12	13	14	15	16	17
									Indicators, Surrogates & Tracers			
VI Pathway Assessment	Investigation Objective	Sub-objectives	Evacuated Canister with analysis by EPA Method TO-15	Active Sorbent Sampler with analysis by EPA Method TO-17	Passive Sorbent Sampler	Flux Chambers	Compound Ratio Analysis	Compound Specific Isotope Analysis	Building Pressure Differential Monitoring	Other R= Radon, TD = Temperature Differential; Tr= Introduced Tracers	Building Pressure Cycling	High Volume Soil Gas Sampling
Are VOCs/SVOCs associated with the subsurface vapor source(s) also present in the indoor environment?	Characterize indoor air exposure point concentrations	Characterize or address temporal variability	+++	+++	++	-	-	-	++	$++^{R,TD}$	+++	-
		Characterize or address spatial variability	+++	+++	+++	-	-	-	-	$++^{R,TR}$	++	-

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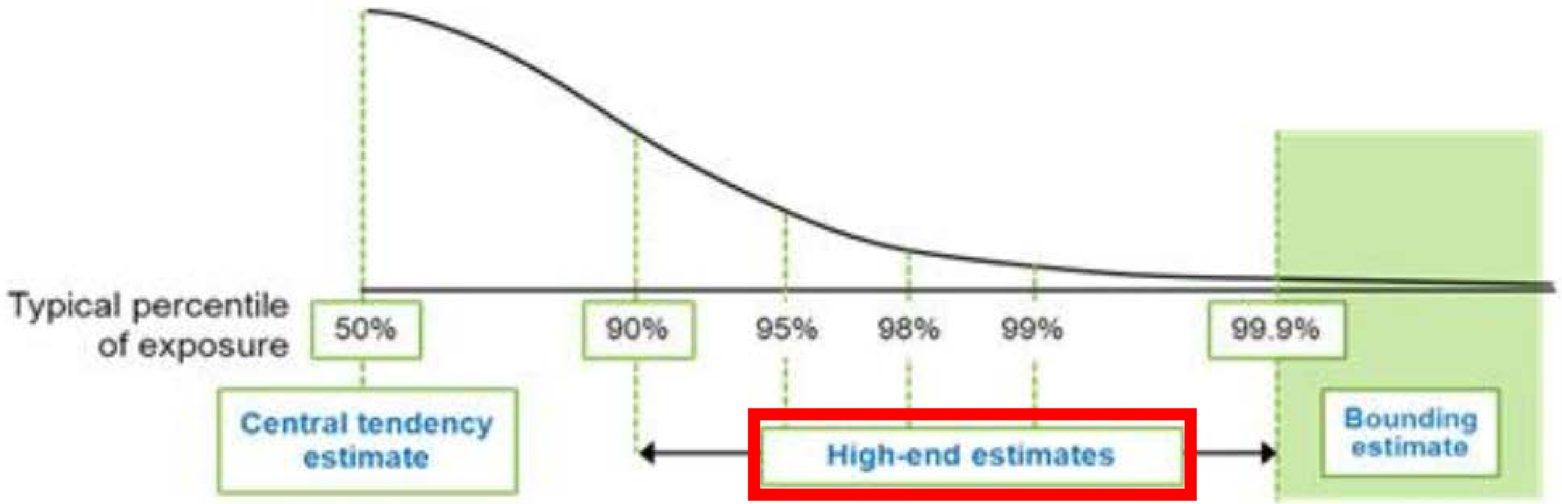
Reasonable Maximum Exposure (RME)
USEPA (1989) Risk Assessment Guidance for Superfund (RAGS)

RME = Highest exposure that is reasonably expected to occur

- Exposure depends on:
  - Chemical exposure concentration; and
  - Input parameters that describe the exposed population
- Values for inputs selected to give RME estimate
  - Combination of central tendency and high-end values



www.epa.gov/expobox/exposure-assessment-tools-tiers-and-types-deterministic-and-probabilistic-assessments

Estimating the Inhalation Exposure Concentration (EC)

USEPA (2009) RAGS Part F, Supplemental Guidance for Inhalation Risk Assessment

$$EC = (CA \times ET \times EF \times ED)/AT$$

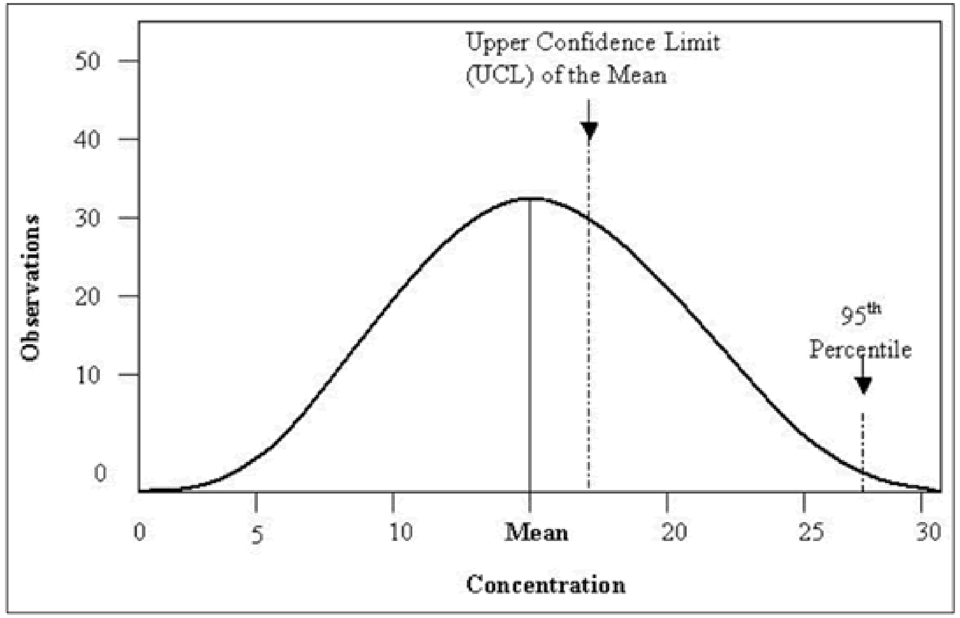
EC ($\mu g/m^3$) = exposure concentration;
CA ($\mu g/m^3$) = contaminant concentration in air;
ET (hours/day) = exposure time;
EF (days/year) = exposure frequency;
ED (years) = exposure duration; and
AT (ED in years x 365 days/year x 24 hours/day) = averaging time

$$\text{Cancer Risk} = EC \times \text{Toxicity Value}$$

$$\text{Noncancer Hazard} = \frac{EC}{\text{Toxicity Value}}$$

Risk Management (USEPA, 1991)
- Cancer: 1E-06 to 1E-04
- Non-cancer hazard: 1

- RME needs to account for:
  - Uncertainty in chemical concentration (CA); and
  - Variability in exposure parameters (ET, EF, and ED)
- Chemical concentration:
  - Use estimate of arithmetic average (e.g., 95UCL)
  - Account for time and space (exposure area)
  - 95UCL can be > max with limited data or extreme variability

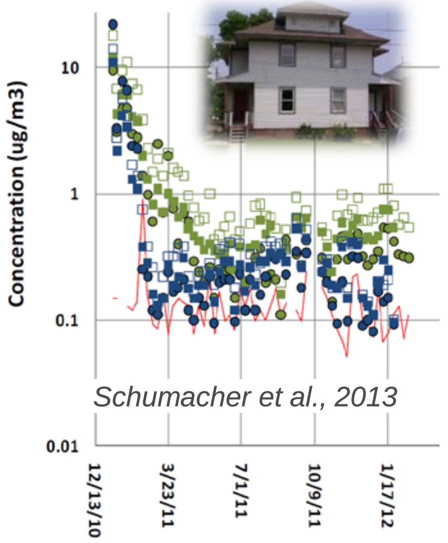


USEPA (1992) Supplemental Guidance to RAGS: Calculating the Concentration Term

Considerations when Estimating Indoor Air Concentrations

EC = (CA x ET x EF x ED)/AT

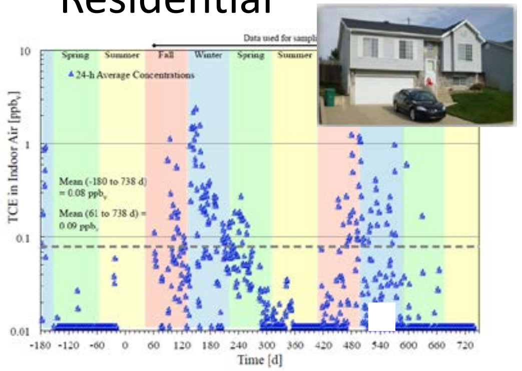
Residential



Schumacher et al., 2013

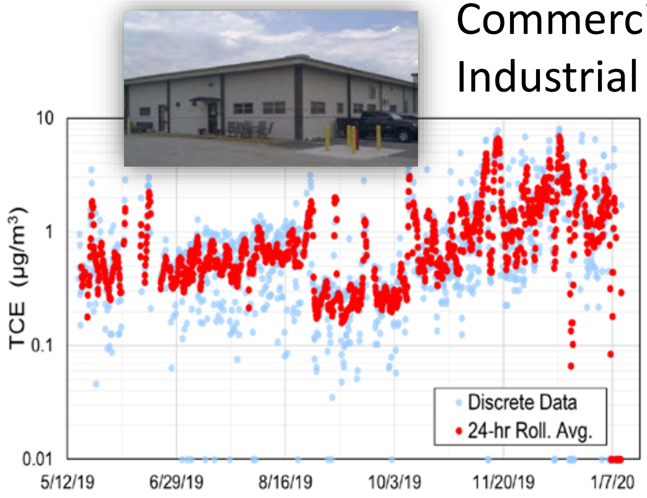
- Can 95UCL on mean be calculated with sufficient confidence?
- How to account for uncertainty/variability in time and space?
  - Timing, type, number, location/zone, frequency, and duration of samples?
- Should maximum or 95th/90th percentile indoor concentrations be used if unable to calculate 95UCLs?
- How can indicators/tracers/surrogates (ITS) increase confidence?

Residential



Johnson et al., 2015

Commercial/
Industrial



Thank you!

Questions?

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