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.

How?

- Include a time and date stamp along with the measurement.
- Check and record temperature calibration periodically against another instrument, such as a NIST-traceable thermometer or an ordinary thermometer checked in ice water (0°C) and boiling water (100°C at sea level).

Why?

- Differential temperature of indoor to outdoor readings is a good indicator of the strength of the stack effect, and thus advective flow of soil gas into the building.
- The annual expected range of differential temperature for a building can be calculated merely by knowing how the thermostat is set, or if the HVAC is used, and looking up online climate data, which is available for most towns. Historical data can then be used to evaluate how close the sampling rounds are likely to have been to the maximum stack effect conditions.
- Weather forecasts for temperature are often accurate to ±5°F for five days ahead, far enough to be useful for sample scheduling.

- In temperate climates with distant sources of VOCs where advective flow is dominant, VI is generally higher in winter (Schuver, 2018). However, situations have been observed involving high concentrations of VOCs from sources directly beneath buildings where concentrations were higher under warm conditions (i.e., Barnes and McRae, 2017).
- VOC concentrations can increase sharply at the coldest temperatures experienced (Schuver, 2018).

Example Data Quality Goals for Indicator Measurements

Measurement	Accuracy	Precision	Range	Sensitivity	Resolution
Temperature	±2° F ±1° C	±2° F ±1° C	-30° F to 120° F -35° C to 50° C	2° F 1° C	0.5° F, 0.2° C

Where Can I Get More Detailed Information?

Barnes, D.L., and M.F. McRae. 2017. The predictable influence of soil temperature and barometric pressure changes on vapor intrusion. *Atmospheric Environment* 150: 15-23.

Keener, K. 2006. *Selection and Maintenance of Temperature Measurement Devices*, Purdue University Extension FS-25-W. https://www.extension.purdue.edu/extmedia/FS/FS-25-W.pdf.

Kurtz, J. 2018. *Outdoor Temperature and Differential Temperature as Indicators for Timing of VI Sampling to Capture the RME;* Presented at AEHS Workshop 2018 San Diego. https://iavi.rti.org/WorkshopsAndConferences.cfm?PageID=documentDetails&AttachID=1080.

Lstiburek, J.W. 2014. BSI-075: How buildings stack up. *ASHRAE Journal* 56(2): 42. https://www.buildingscience.com/documents/insights/bsi-075-how-do-buildings-stack-up

Racusin, J.D. 2017. *Essential Building Science: Understanding Energy and Moisture in High Performance House Design*, New Society Publishers, 2017, Gabriola Island, BC, Canada.

Schuver, H.J., C. Lutes, J. Kurtz, C. Holton, and R.S. Truesdale. 2018. Chlorinated vapor intrusion indicators, tracers, and surrogates (ITS): Supplemental measurements for minimizing the number of chemical indoor air samples—Part 1: Vapor intrusion driving forces and related environmental factors. *Remediation Journal* 28(3): 7-31.

US EPA (Environmental Protection Agency). 2003. *A Standardized EPA Protocol for Characterizing Indoor Air In Large Buildings.* https://www.epa.gov/indoor-air-quality-iaq/standardized-epa-protocol-characterizing-indoor-air-quality-large-office.

US EPA. 2015. *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*., EPA/600/R-15/070. Office of Research and Development, Washington, DC.

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