The HVAC Factor

Evaluating Radon Fluctuations in a Non-Residential Building via Continuous Monitoring

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Background

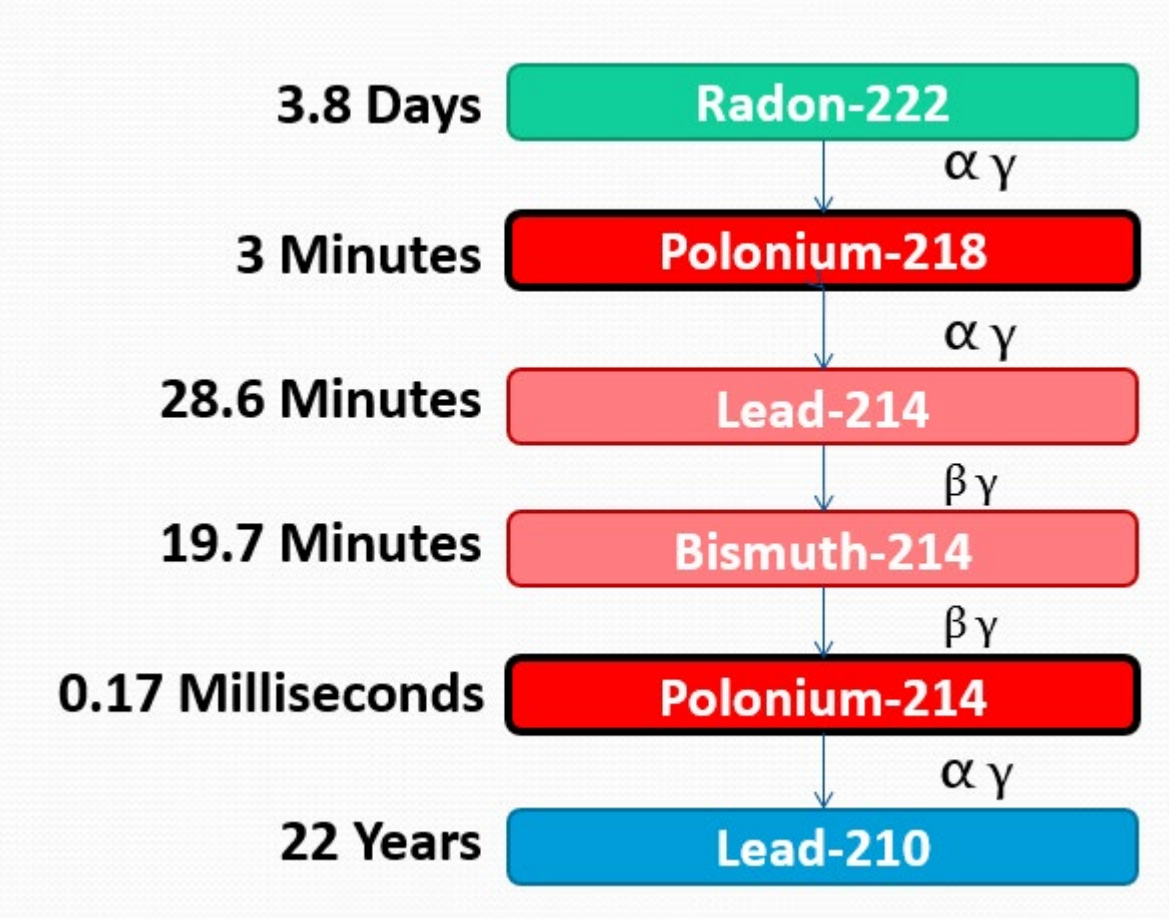
- Large non-residential buildings, such as those on military installations, have complex air handling systems that greatly affect pressure within the building, and therefore radon levels
- Unlike smaller homes where weather can drive radon entry, large buildings are dominated by robust HVAC systems that override the effects of external temperature and other environmental factors (EPA 1989, Leovic et al. 1990, EPA 1993)
- In many cases, these buildings can have 1 or 2 rooms or a section of rooms where radon is elevated due to imbalanced air distribution or pressure within these rooms
- Large air handling systems (when operating as designed) increase air circulation, causing better plate-out of radon decay products (RDPs) and leading to lower equilibrium factors (EF) compared to smaller residential dwellings with less robust air handlers (Kotrappa et al. 2003)

Government/Military Considerations

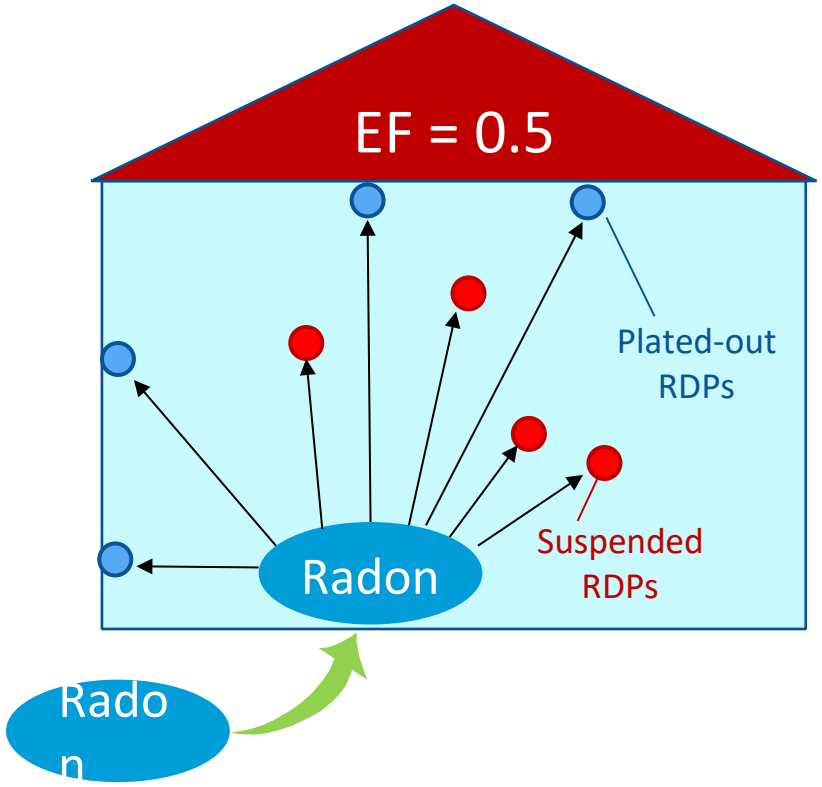
- Funding is the primary factor determining the mitigation timeline
  - Installing ASD system(s) or HVAC replacement could take months to years due to contracting constraints and funding
- There may be some buildings where conventional mitigation strategies such as ASD are not practical
  - Complex building footprint
  - Sensitive Compartment Information Facility (SCIF)
- RDP mitigation strategies, such as increasing air circulation with fans and filters, increase plate-out and reduce potential exposure (Hopke 1994, 1996; Wołoszczuk et al. 2026; Martínez et al. 2026) and can be effective, *interim* mitigation strategies

Radon Decay Products (RDPs)

- RDPs come from the radioactive decay (i.e., “breakdown”) of radon gas
- A portion of RDPs “plate out” by attaching to solid surfaces and are not inhaled
- The other portion of RDPs stay suspended in the air and may be inhaled
- The alpha particles emitted by RDPs provide **over 95%** of the radiation dose to the lungs (mainly from Polonium-218 and Polonium-214; NRC, 1988)



RDPs and Equilibrium Factor (EF)



Positive internal pressure helps keep radon gas out! Negative pressure draws in radon gas (and other soil gases) from under the slab!

EF expresses the state of radioactive equilibrium between the radon gas and RDPs

- High EF means more RDPs are suspended in the air and will get inhaled (higher health risk)
- **Lower** EF means more RDPs are plating out and fewer are in the air (**lower** health risk)
- What contributes to lower EF values?
  - Good air circulation/fans – increase rate of collisions of RDPs with surfaces and improves RDP plate-out
  - Clean air – low indoor dust, smoke, and other pollutants reduce airborne particles for RDPs to adhere to (i.e., air pollution interferes and reduces plate-out)
  - Air cleaners/filters – increase air movement and provide additional surface area (filters) for RDP plate-out (see MAH 2023 Companion Guide D)

Measurements Review

- RDP devices measure alpha radiation in the air and potential exposure but require air flow
  - RDPs are measured in working levels (WL) derived from exposure "levels" that miners worked in
  - The annual average threshold of 0.02 WL was developed in response to properties contaminated with waste from uranium processing
  - It is the only residential threshold codified into law (40 CFR Part 192.12(b), 1983)
- Radon measurements (pCi/L) are ***surrogate measurements*** for RDPs. In fact, EPA's radon action level of 4 pCi/L was derived using 0.02 WL and an assumed EF of 50% in 1986 (reduced to 40% EF and 0.016 WL by the EPA in 1992).

$$\text{Rn (pCi/L)} = \frac{\text{RDPs (WL) x 100}}{\text{Equilibrium Factor (EF)}} \qquad \frac{\text{0.02 (WL) x 100}}{\text{0.50 (EF)}} = \text{4 (pCi/L)}$$

This is accurate ONLY if the assumed EF equals the actual EF!

For example, locations with poor indoor air quality or air circulation and a radon level of 3.5 pCi/L could easily have radiation exposures *higher* than the legal limit of 0.02 WL!

Measurements Review

- Equivalent Radon - If WL are measured directly, one can calculate equivalent radon gas concentrations by using the known WL and an assumed EF of 50% (NAVRAMP 2023)

$$\text{Equivalent Rn (pCi/L)} = \frac{\text{RDPs (WL) x 100}}{\text{Equilibrium Factor (EF)}}$$

For example, for a known RDP measurement of only 0.01 WL, the equivalent radon is:

$$\frac{0.01\ (WL) \times 100}{0.50\ (EF)} = 2\ pCi/L$$

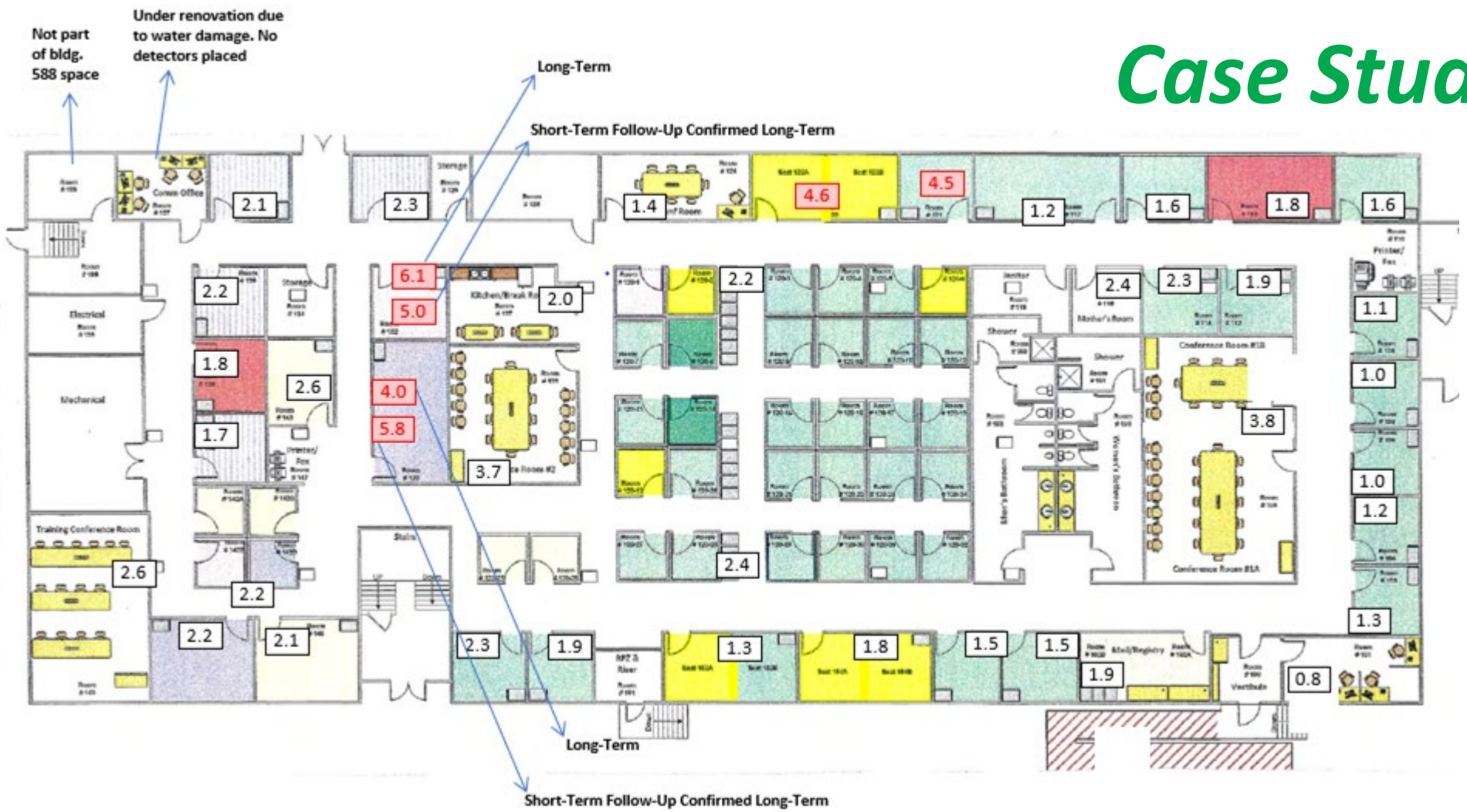
NOTE: We have many RDP and radon measurements taken together that demonstrate much lower EFs in nonresidential buildings with robust HVAC systems – sometimes as low as 10%!

Case Studies

Radon testing completed at two Naval installations using long-term radon measurement devices (E-PERMs) per Navy Radon Assessment and Mitigation Program (NAVRAMP) protocols

- ***Case Study 1***
  - Office style building with cubicles, offices, conference rooms
  - Not typically occupied 24/7, but could be occupied after hours/on weekends
  - Slab on grade
- ***Case Study 2***
  - Isolated rooms (SCIF) located in basement and sub-basement of a large building with laboratories and offices in upper levels

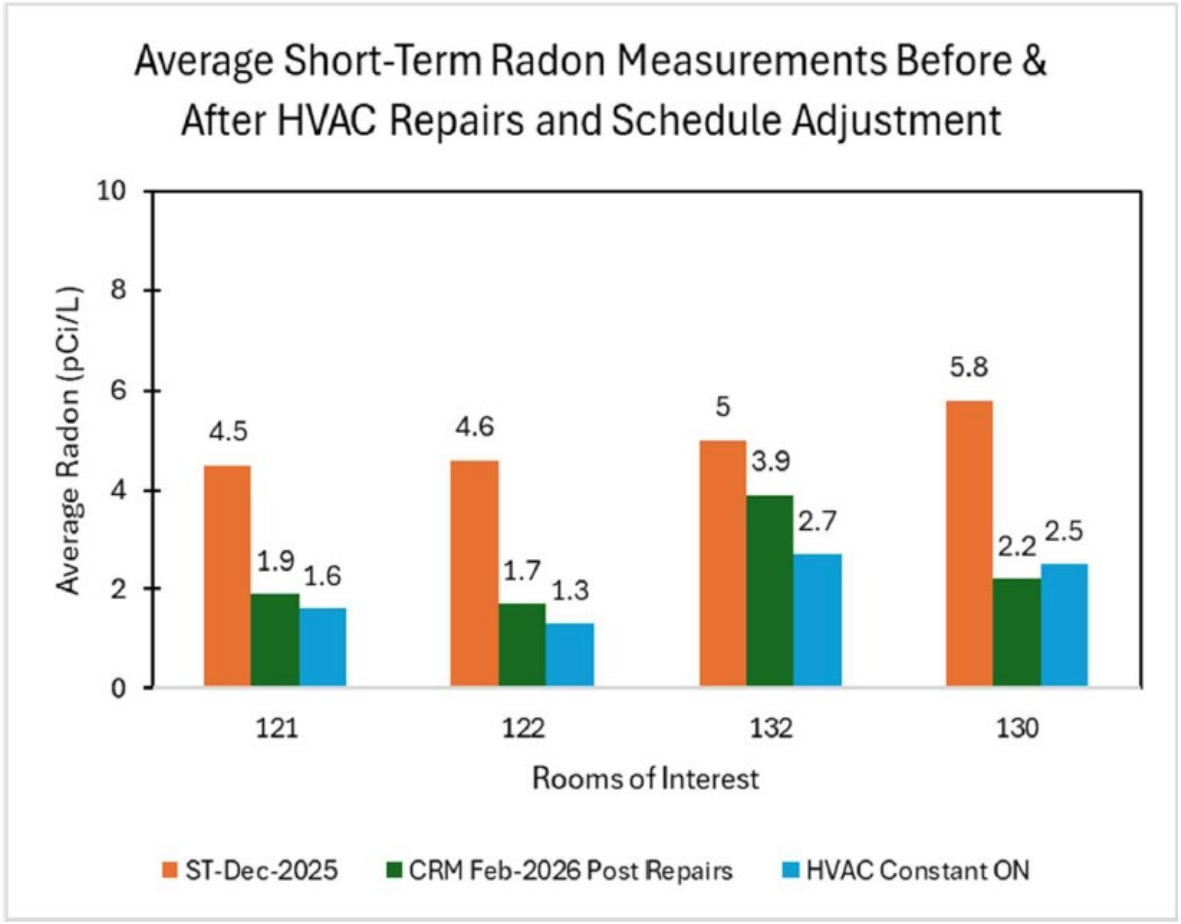
Case Study 1



- Long-term testing February – May 2025. Two invalid rooms (121, 122) and two elevated rooms (130, 132).
- Short-term follow-up testing December 2025 confirmed four elevated rooms (121, 122, 130, 132)
- Four elevated locations out of 40 tested locations suggested localized HVAC distribution issue caused by an imbalanced HVAC serving those areas compared to the rest of the building

Case Study 1

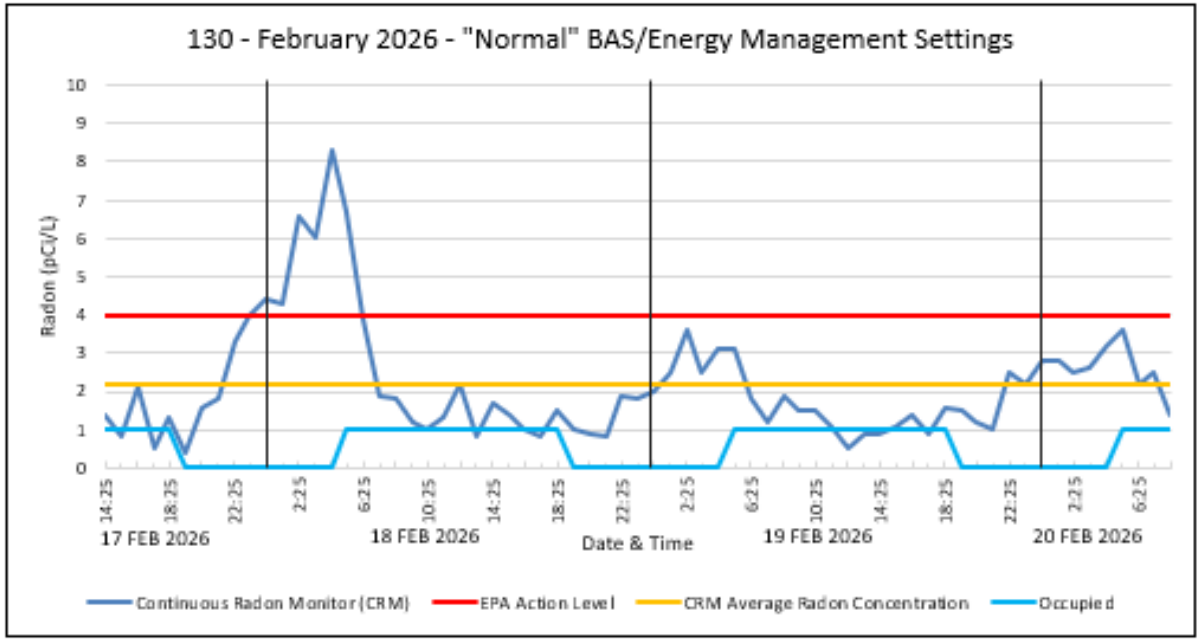
- Maintenance personnel conducted HVAC investigation
  - Noted single HVAC unit serviced entire floor
  - Adjusted air dampers to ensure balanced air flow between rooms
  - Adjustments made to allow fresh air exchange
  - Checked filters and coils
  - Reconfigured Building Automation System (BAS) to ensure energy management started after business hours
- Conducted short-term testing using Continuous Radon Monitors (CRMs) after repairs in all four rooms and some additional rooms
- Building occupants also requested additional CRM testing with air running 24/7 to compare radon levels to how BAS is programmed normally

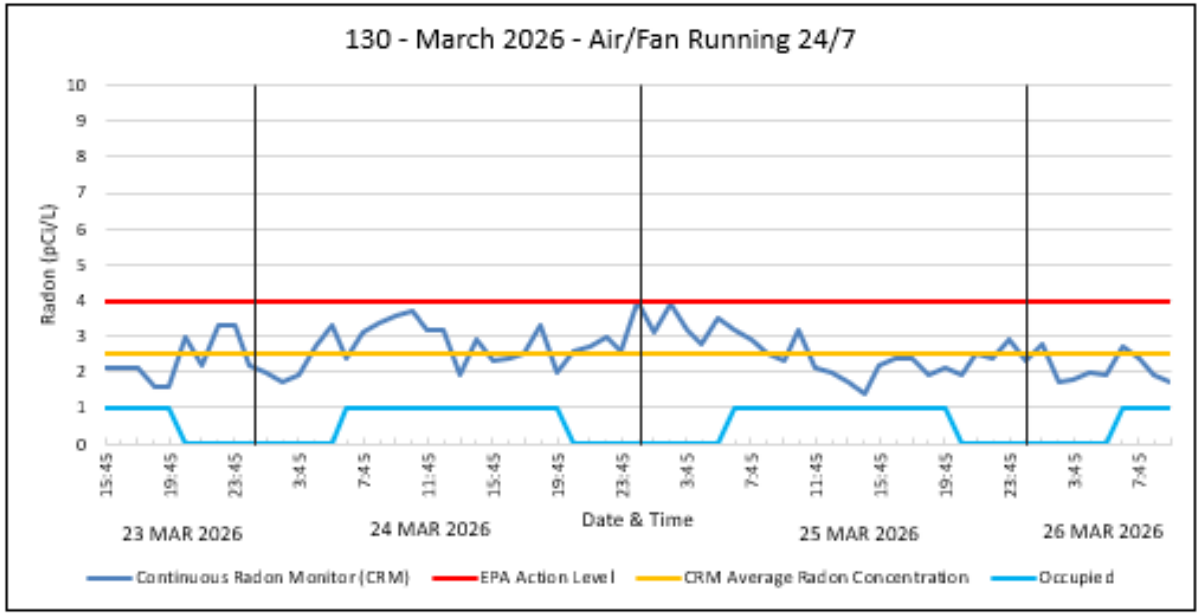


Case Study 1



- CRMs placed in four elevated rooms and two additional rooms February 2026 to monitor radon levels during occupied versus unoccupied hours under normal BAS energy management system settings
- Second round of CRM testing conducted March 2026 to see difference when fans/air was running 24/7

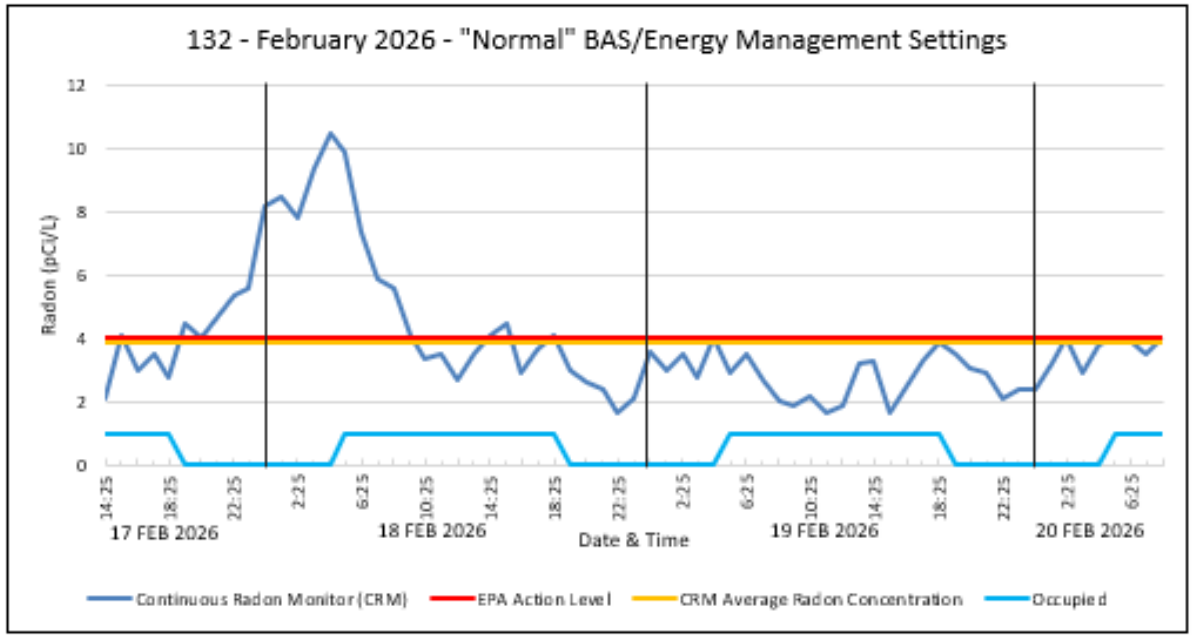


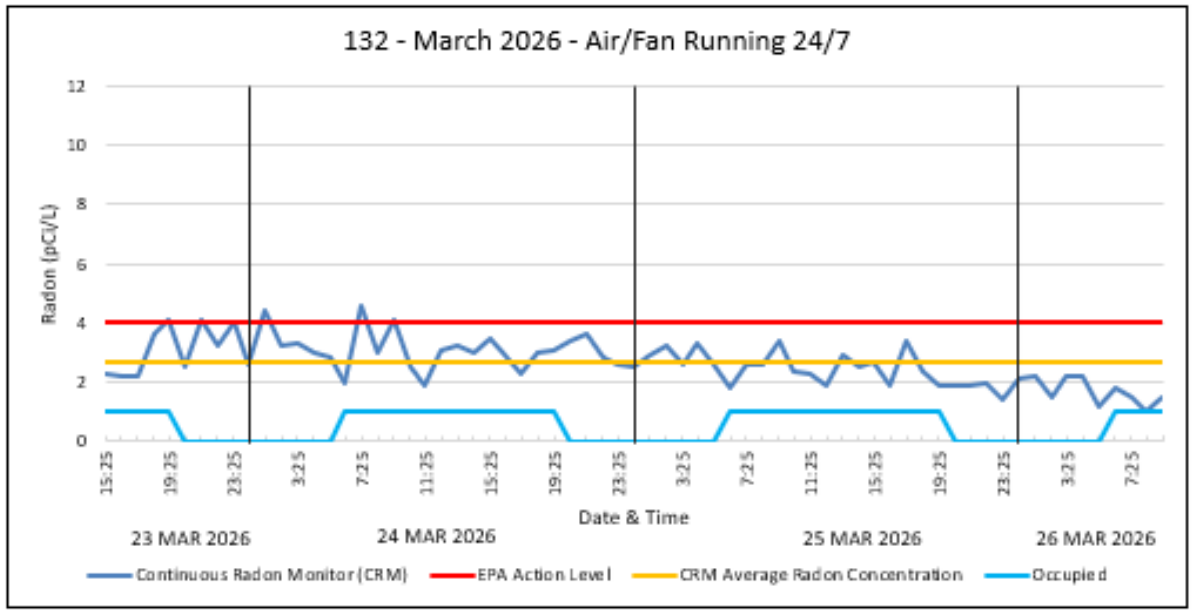


Case Study 1

Room 130

- Running air/fan 24/7 reduced after hour peaks observed when BAS/Energy Management System was on
- Did not significantly influence overall radon average over the testing period

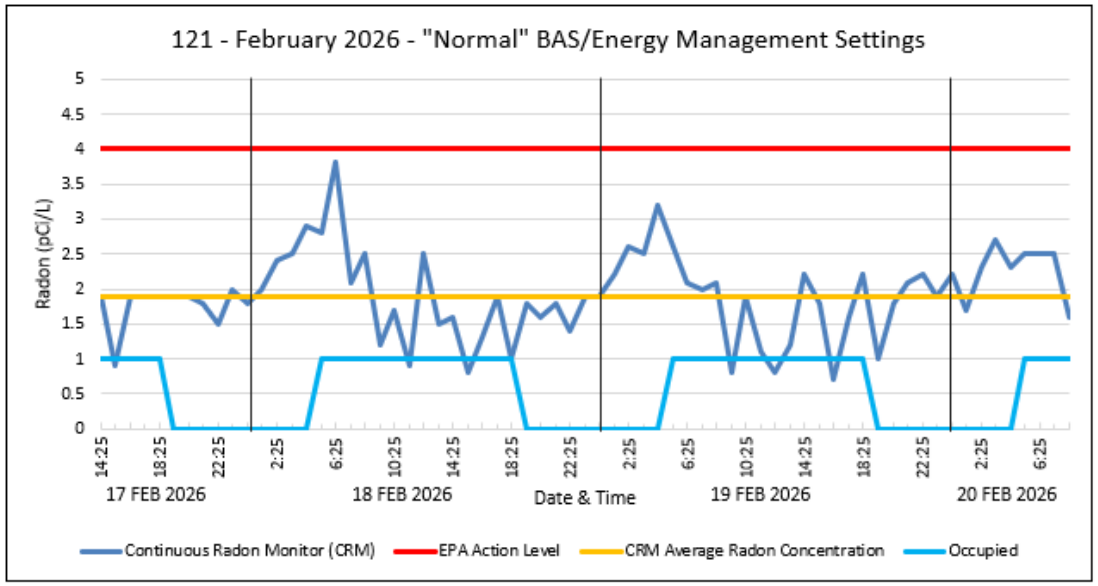


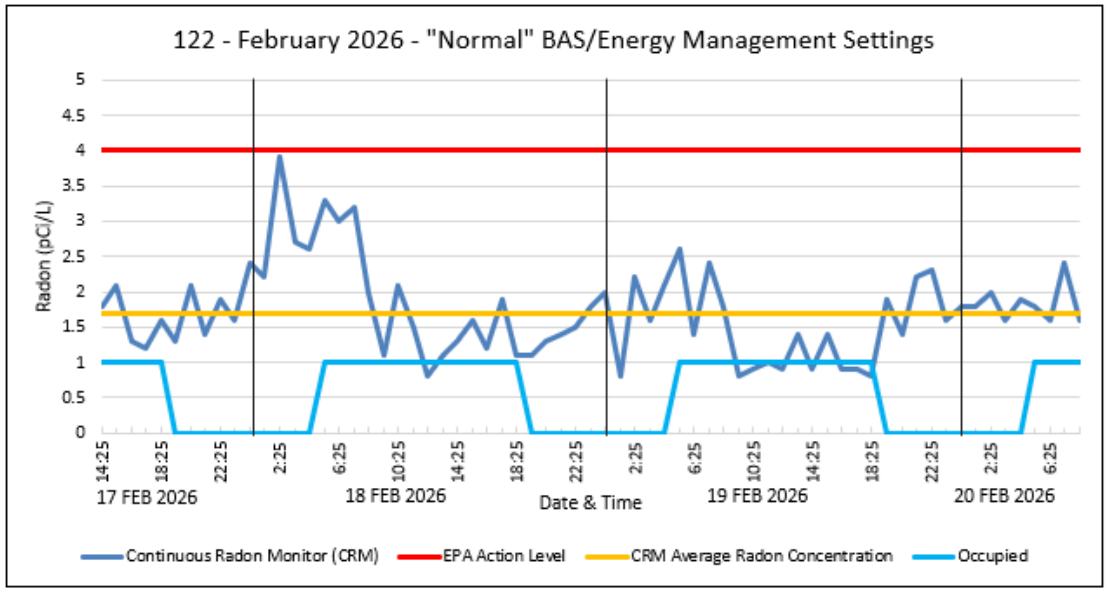


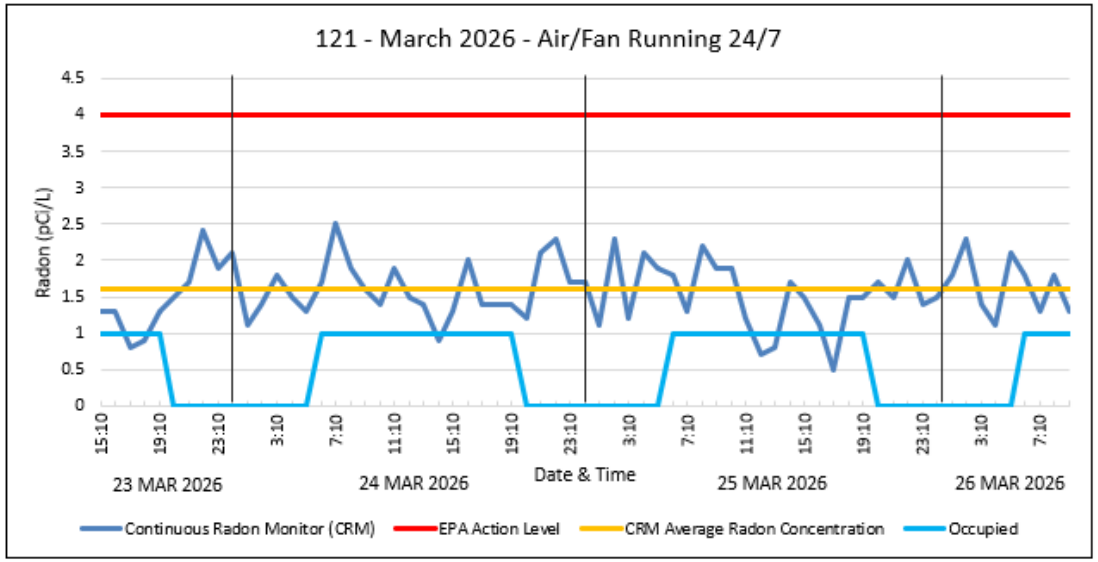
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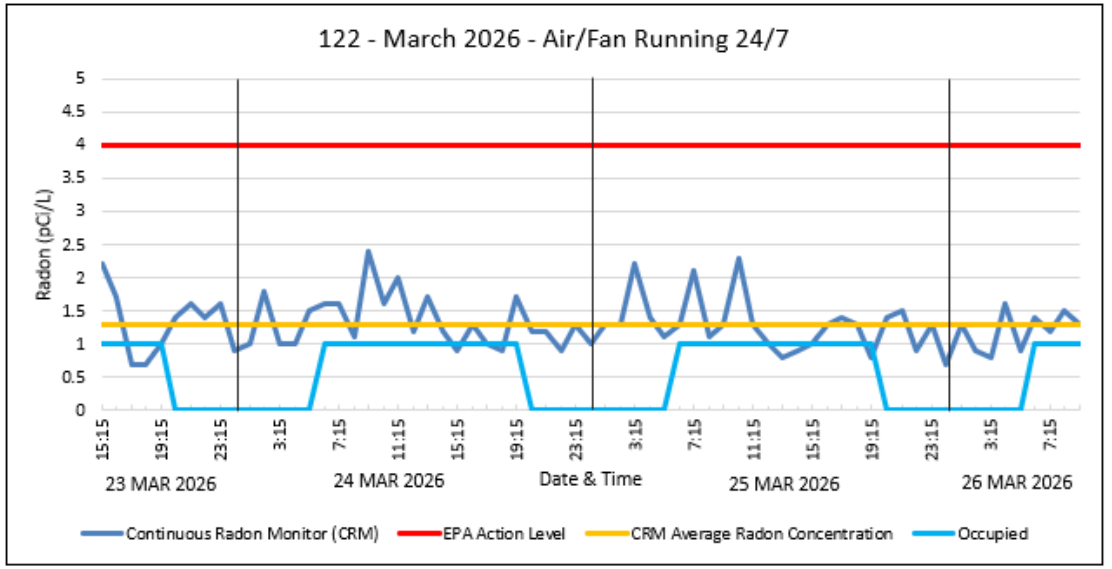
Room 132

- Running air/fan continuously reduced after hour peaks observed when BAS/Energy Management System was on
- Reduced radon small amount (~1 pCi/L)

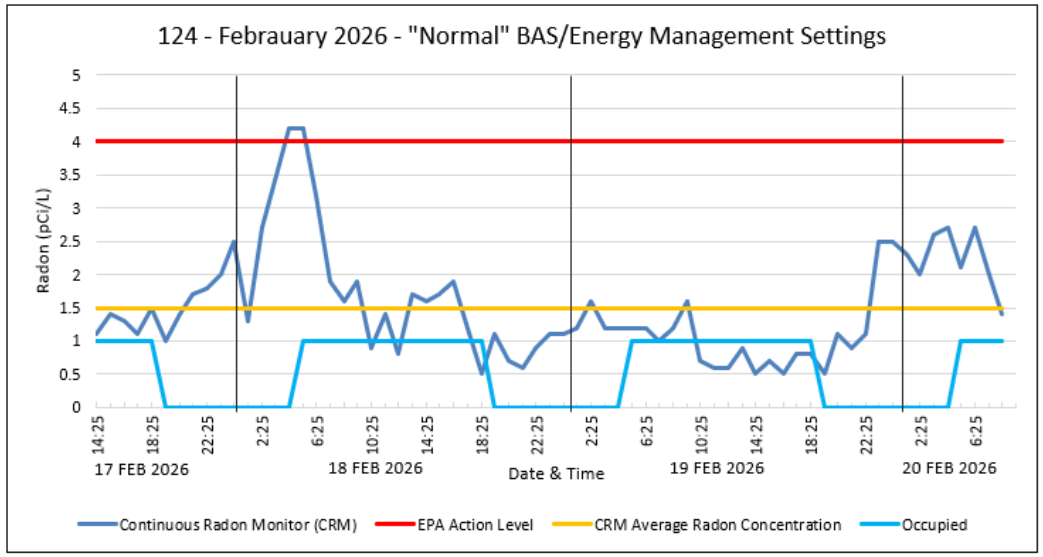


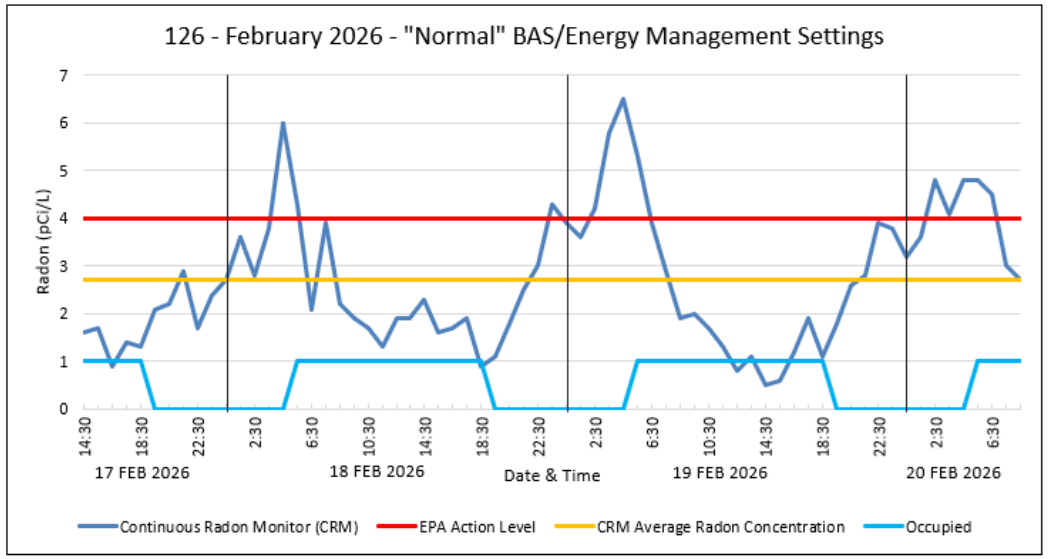


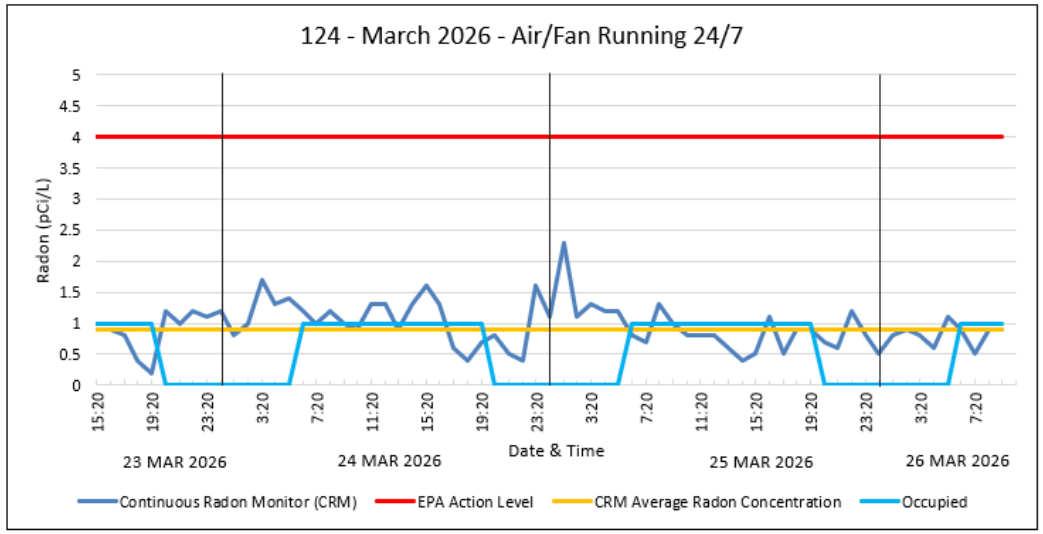


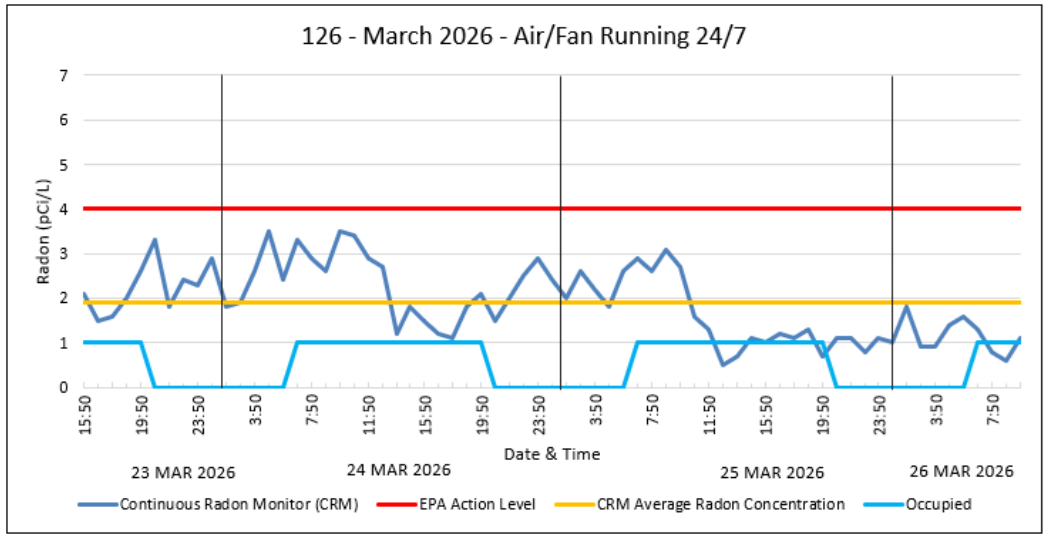


- Same pattern observed for Rooms 121 and 122







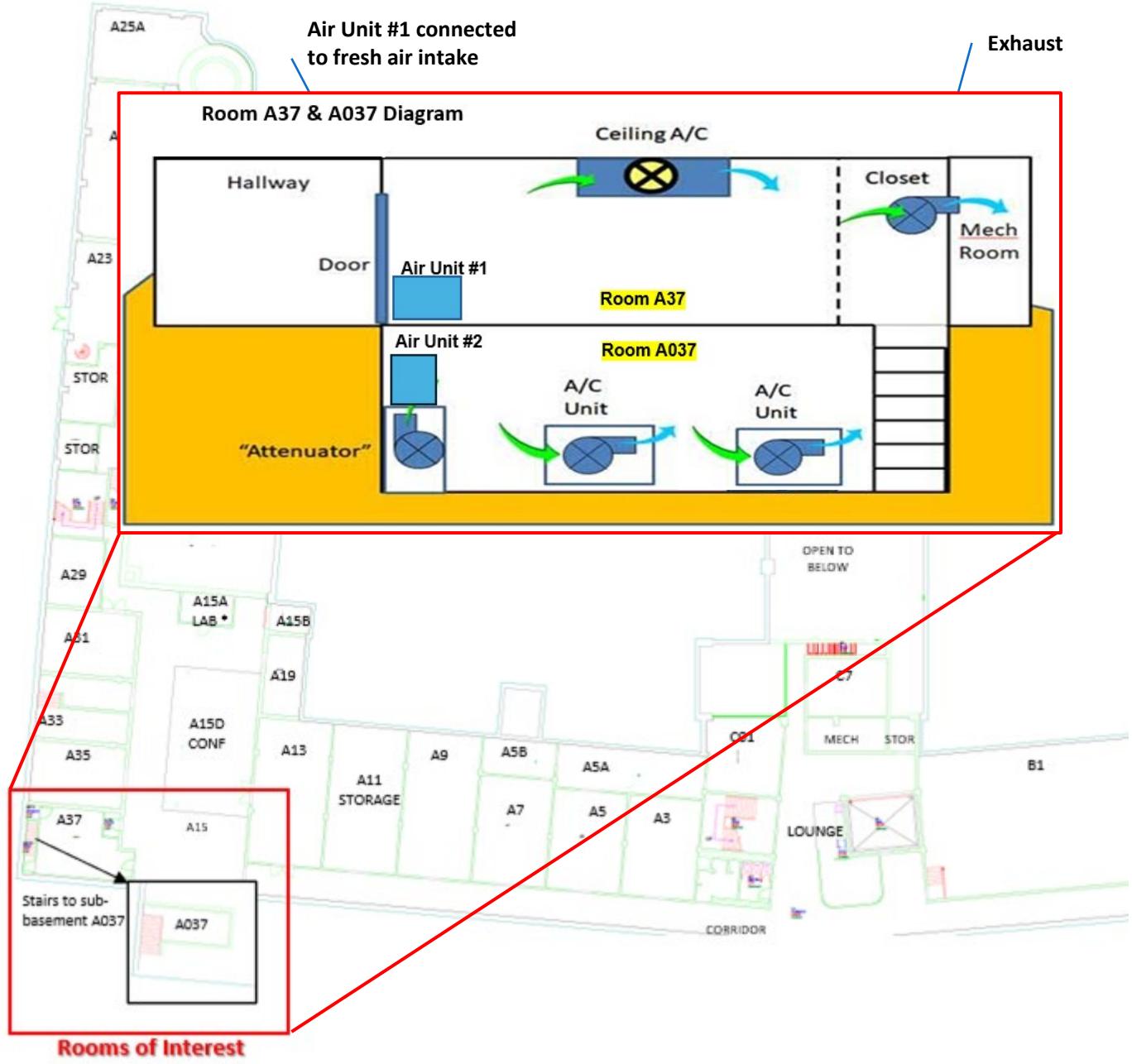


- Also saw same pattern when compared to two non-elevated rooms tested nearby the four rooms of interest (Conference Rooms 124 and 126)

Case Study 1
Summary & Recommendations

- The initial long-term measurements indicate that the underlying soil/geology has the potential for elevated indoor radon. However, proper operation of the HVAC system can control the levels as well as provide other indoor air quality benefits.
- Adjust the BAS to ensure fresh air make-up occurs three hours prior to occupied hours. A “night-mode” can be initiated on the hour all personnel vacate the building.
- BAS can be adjusted for fresh air make-up to be supplied continuously if personnel are working outside core business hours. Although doing so does not appear to reduce average radon levels that much further compared to operating as normal.
- Radon levels should be verified in all occupied ground-contact rooms after any major repairs to the HVAC system and at least every two years.
- Ensure a written procedure is developed and implemented that documents the recommended BAS settings. An annual review and training of the procedure should be conducted.

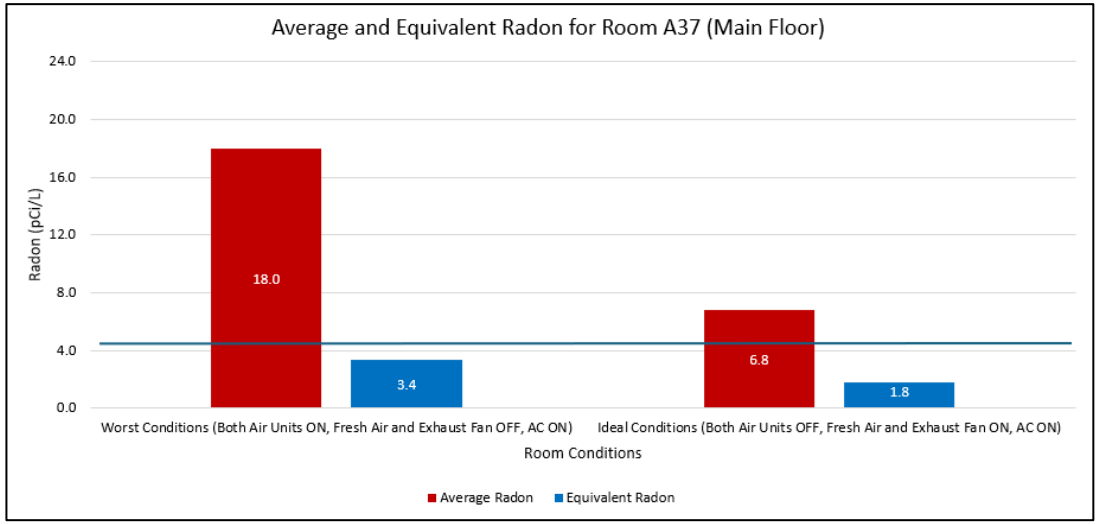
Case Study 2

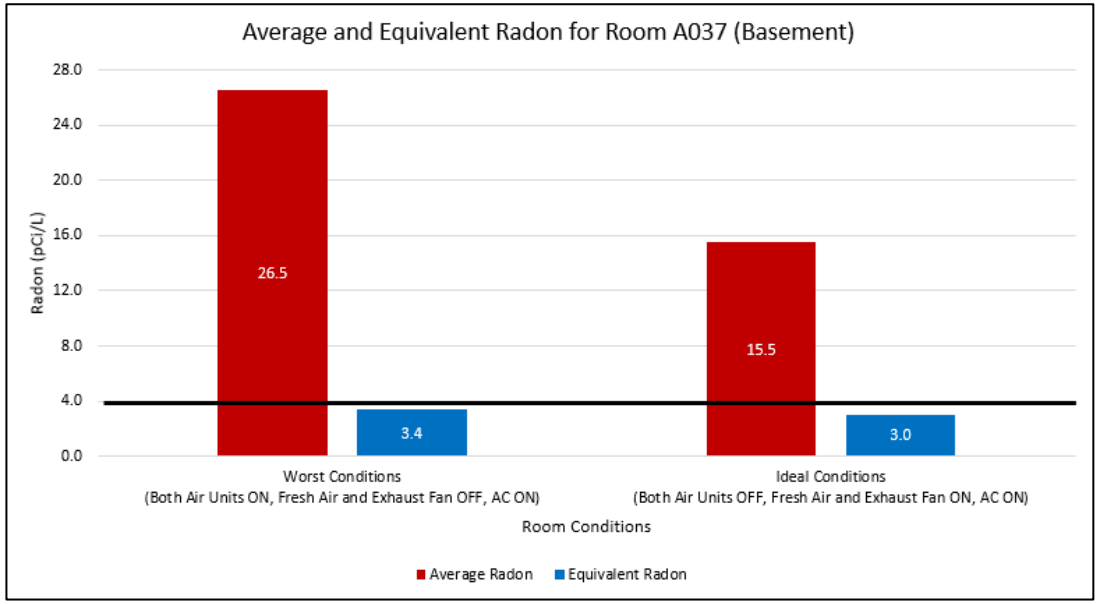


- Long-term testing January 30 – May 6, 2025. Elevated radon confirmed in A37/A037.
- No other occupied locations had elevated radon within the building, suggesting localized pathway for radon
- Rooms had previously tested high for radon in 2018-2019. Air Unit #2 was determined to be culprit (mining radon from under slab) and recommended to be turned OFF/removed. In years following a NEW unit was installed over Unit #2.
- Rooms are SCIF and ASD is not feasible
- Lots of surface area and air movement to cool servers present in the rooms

Case Study 2

- Over three-week period (March 16 – April 3, 2026), radon and RDPs were measured using continuous monitors under a variety of different conditions
  - Turning ON/OFF Air Unit #1 in A37
  - Turning ON/OFF Air Unit #2 in A037
  - Turning ON/OFF fresh air
  - Turning ON/OFF A37 exhaust fan
- Radon levels could not be lowered below 4 pCi/L
- EF was below 20% during all conditions, indicating high RDP plate-out due to air movement and increased surface area
- Average RDP were below 0.02 in all conditions. Equivalent radon was calculated to report results to client in more familiar units (pCi/L)





Case Study 2
Summary & Recommendations

- The initial long-term measurements indicate that the underlying soil/geology has the potential for elevated indoor radon. However, RDP WL and equivalent radon gas concentrations can be maintained under respective action levels when proper conditions are met.
- Increased surface area and air movement/flow facilitate RDP plate-out and lead to low EF (~20%).
- Highlights how *critical* it is that a written procedure/management plan is developed and implemented that documents the recommended settings to be followed, especially after personnel turnover. An annual review and training of the procedure should be conducted.

Conclusions

- Short-term investigations within elevated buildings using RDP measurements provides ACTUAL exposure to the client. This could reduce occupant health concerns in the interim before mitigation systems are installed or as an alternate option in difficult to mitigate buildings/spaces (e.g., SCIF).
- HVAC investigation and balancing/repair is a cost effective and time sensitive way to determine if the air ventilation system is the culprit. Other installation mitigation examples included adding fresh air make-up to spaces and opening air dampeners.
- Retest at least every two years in buildings that have implemented any mitigation strategy, including mechanical balance/repair.
- Written procedures/management plan is critical to ensure HVAC system settings are maintained and well known to maintenance personnel and building managers/staff.
- Every building/space is unique and requires diagnostics and investigation to provide the best and most cost-effective mitigation approach!

Questions?

References

Environmental Protection Agency. 1989. "Radon reduction techniques in schools-interim technical guidance." EPA-52011-89-020. October.

Environmental Protection Agency. 1992. “Technical support document for the 1992 citizen’s guide to radon.” EPA 400-R-92-011. May.

Environmental Protection Agency. 1993. “Radon measurements in schools. revised edition.” EPA 402-R-92-014. July.

Hopke, P.K., B. Jensen, and N. Montassier. 1994. Evaluation of several air cleaners for reducing indoor radon progeny. Journal of Aerosol Science 25:395-405.

Hopke, P.K. 1996. Studies of the performance of room air cleaners and their optimal reduction of dose from radon progeny. Final Report on Cooperative Agreement CR-820470.

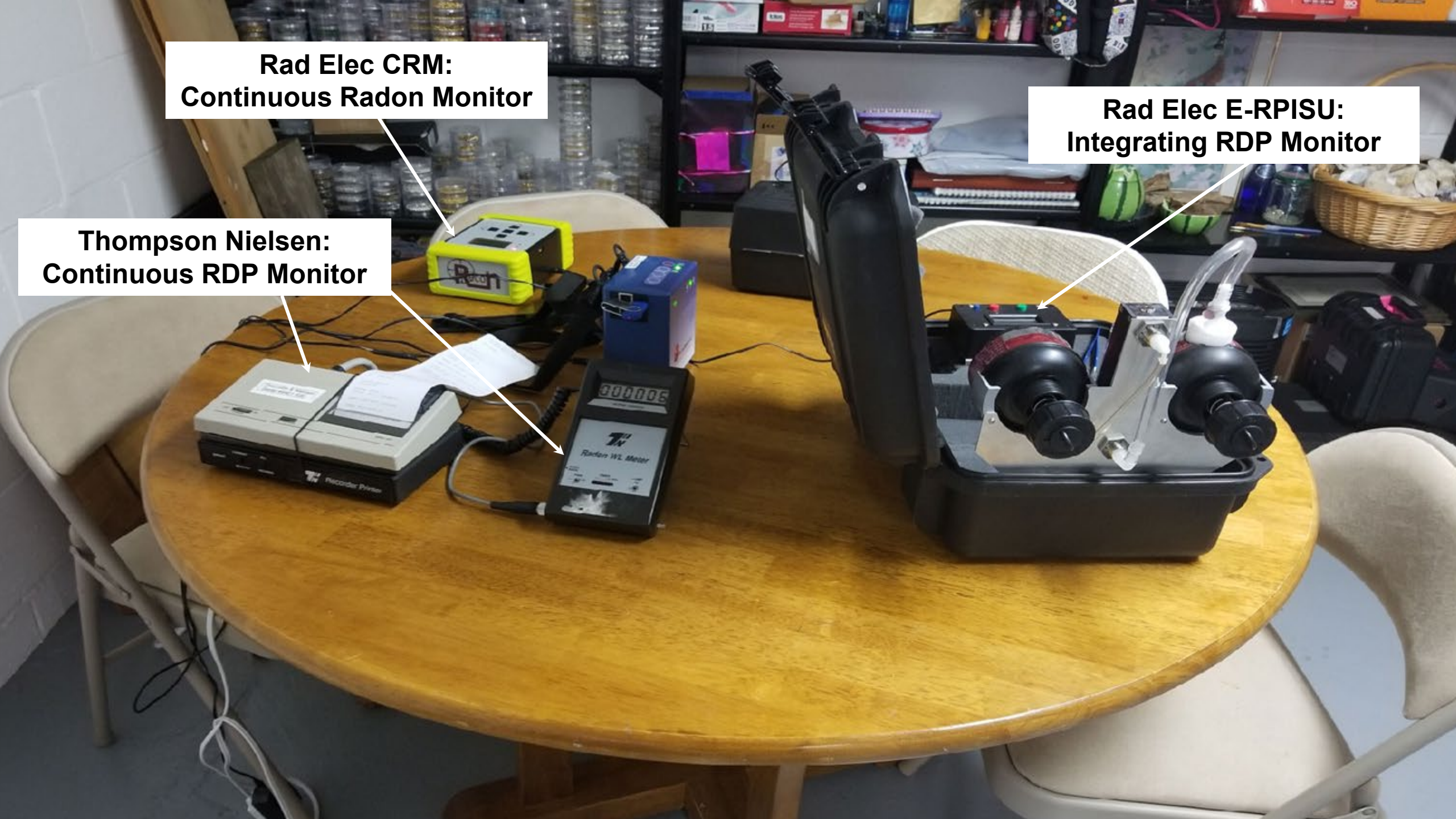
Kotrappa et al. 2003. An advanced E-Perm system for simultaneous measurement of concentrations of radon gas, radon progeny, equilibrium ratio and unattached radon progeny. Proceedings of the 2003 International Radon Symposium 2: 25-34.

Leovic et al. 1990. “Radon mitigation in schools: HVAC systems in schools tend to have greater impact on radon levels than hvac systems in homes. ASHRAE Journal 32(1):40,42,44.

Martínez, J.E., B. Juste, and G. Verdú. 2026. Evaluation of radon progeny mitigation techniques (HEPA filtration, ionization, electrostatic deposition) and their potential use in caves. Journal of Environmental Radioactivity 297:108063.

NRC. 1988. Health risks of radon and other internally deposited alpha-emitters: BEIR IV. Appendix III, the effects of radon progeny on laboratory animals. Washington, D.C., USA.

Wołoszczuk et al., 2026. Mitigating Indoor Radon Exposure: The Effect of Air Purifiers on Radon Progeny. Sustainability. January.


Rad Elec CRM:
Continuous Radon Monitor
Rad Elec E-RPISU:
Integrating RDP Monitor
Thompson Nielsen:
Continuous RDP Monitor