Radon Measurement Device Discussion Panel

Brian Hanson, NRPS

Alexandra Bahadori, Kansas Radon Program

Topics

- Introductory remarks
  - Testing protocols
  - Device types
- Open discussion

Introductory Remarks

What Are the Purposes for Radon Tests?

- Self-motivated home dweller
  - Assessing personal exposure and the need for mitigation
- Real estate transaction
  - Assessing the building's radon potential and the need for mitigation
- Post-mitigation measurements
  - Assessing the performance of radon mitigation systems
- Diagnostic measurements
  - Non-standard measurements to guide mitigation efforts or assess radon source strength/distribution – grab samples, sniffs

AARST MAH Extended Testing Protocol

- Conducted in the lowest level of the home **OCCUPIED**

5.3 The Extended Testing Protocol

Note—This protocol builds upon protocols developed by EPA relative to EPA's "*A Citizen's Guide to Radon*."

Table 5.3	Extended Testing Protocol (Required Procedure and Summary)
Step 1	***Single Short-Term Test*** Testing is conducted using a short-term detector at each test location.
Step 2	***Retest*** locations where the initial short-term tests meet or exceed the *action level*, e.g., 4 pCi/L.
	If the first short-term test is twice the *action level* or greater, a second short-term test is to be conducted without delay. [1]
	If the first short-term test exceeds the *action level* but is less than twice the *action level*, either a second short-term test or a long-term test is to be conducted.
Step 3	**Decisions to Fix the Building**
	Mitigation decisions are to be based on the long-term test results or the average of the two short-term test results. [2]
	Fix the building if test results meet or exceed the *action level*, e.g., 4 pCi/L. Consider fixing the building if results are greater than half the *action level*, e.g., between 2 and 4 pCi/L.
[1] Note—While decisions to mitigate at any time are not prohibited, the second test aids confidence that decisions are not being made based on a faulty test device or unexpected conditions	
[2] Note—If two short-term test results disagree in terms of making a *mitigation* decision, see Section 7.2	

AARST MAH Time-Sensitive Testing Protocol

- Conducted in the lowest level of the home that **COULD** be occupied

5.2 The Time-Sensitive Testing Protocol

Note—This protocol builds upon protocols developed by EPA relative to EPA's *"Home Buyer's and Seller's Guide to Radon"*.

Table 5.2	Time-Sensitive Testing Protocol (Required Procedure and Summary)	
Step 1 Options	***Simultaneous Testing***	Tests are to be conducted using two short-term test devices at the same time in the same location, 4 to 8 inches (10-20 cm) apart.
	Continuous Monitor	Tests are to be conducted using a monitor that records retrievable hourly measurements.
Step 2	**Decisions to Fix the Building**	
	Mitigation decisions are to be based on the average result from a continuous monitor or the average of two test results conducted at the same time in the same location. [1] **Fix the building** if test results meet or exceed the *action level*, e.g., 4 pCi/L. Consider fixing the building if results are greater than half the *action level*, e.g., between 2 and 4 pCi/L.	
[1] Note—If two short-term test results disagree in terms of making a *mitigation* decision, see Section 7.2		

AARST MAH Closed-Building Conditions

- Closed-building conditions (per winter heating season) are **REQUIRED** when short-term results are used for mitigation decisions
  - Initiated 12 hours prior to a test <96 hours **(KS)**
  - Maintained thru the test for tests <91 days

Table 4-A ESSENTIAL CLOSED-BUILDING PROTOCOL REQUIREMENTS	
Windows	**Keep closed** on all levels of the building including areas not being tested
Exterior doors (except for momentary entry and exit)	
Heating and cooling systems	**Set to normal** occupied operating conditions with temperature settings between 65˚and 80˚ F (18˚ - 27˚ C)
Systems that temporarily ventilate with outdoor air for seasonal comfort or energy savings	**Set to the lowest seasonal ventilation condition that occurs during the year**
Whole-house fans	**Do not operate**
Fireplaces (that burn solid, liquid or gas fuels unless a primary/normal source of heat for the building)	
Clothes dryers, range hoods and bathroom fans	**Avoid excessive operation**
Required building operation also includes components itemized for clarification in Exhibit 1	
Table 4-B ADDITIONAL REQUIREMENTS FOR NEW CONSTRUCTION, RENOVATIONS AND REPAIRS	
All openings to the exterior (due to incomplete construction, structural defect or disrepair)	**These opening to the exterior shall be closed or sealed at least 12 hours prior to initiating the test**
Heating/cooling systems active and set to a normal occupied temperature	**These items shall be completed or installed at least 12 hours prior to initiating the test**
All windows and exterior doors installed with hardware and seals	
All insulation and exterior siding	
All wall and ceiling coverings to be completed including interior drywall or paneling; does not include decorative finishing of walls, floors or ceilings	
All fireplaces and fireplace dampers installed	

Actions Based on Test Results

Action Level Guidance

Countries worldwide have adopted a*ction levels* for *radon* exposures. The *action level* observed should comply with the guidance of the country, state or local jurisdiction of authority where the test is being conducted.

U.S. Action Level. The following *action level* descriptions reflect guidance from the United States Environmental Protection Agency (EPA):

- **4 *pCi/L* or greater** (≥ 150 Bq/m^3)

  Fix the building. The higher the *radon* concentration, the more quickly action should be taken to reduce the concentrations.

- **Below 4 *pCi/L*** (< 150 Bq/m^3)

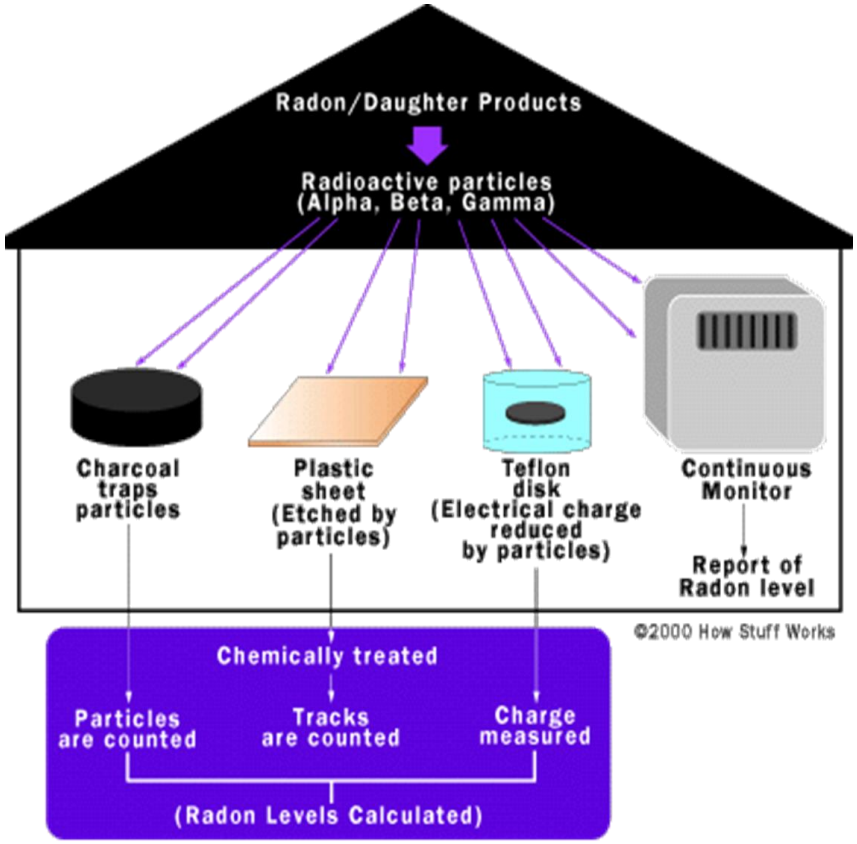
  Consider fixing the building if test results indicate that *radon* concentrations are greater than half the *action level*, such as between 2 and 4 *pCi/L* (75 and 150 Bq/m^3).

  With observance that hazards from *radon* are virtually the same for *radon* concentrations that are near *action level* thresholds, it is noteworthy that the World Health Organization recommends limiting *long-term* exposures to less than 2.7 *pCi/L* (100 Bq/m^3).

  When measurement devices indicate concentrations lower than about 2.0 *pCi/L* (75 Bq/m^3), test data should normally be interpreted as being lower than the test device can accurately measure.

How Do We Measure Radon?

- By deploying a device that will accept or capture radon by either naturally occurring diffusion, or by pumping air through the device
- By analyzing the device after deployment and counting something that we can use to calculate the radon
  - Some devices capture radon
  - Some devices record or respond to the decays or effect of the decays



4 Passive, Time Integrating Radon Measurement Devices and CRMs

- 1. Activated Charcoal Device*
  - Open Faced
  - Diffusion Barrier
- 2. Charcoal Liquid Scintillation*
- 3. Electret Ion Chamber
  - Short-term
  - Long-term
- 4. Alpha Track Detector
  - Filtered Alpha Track Detector

1. Radon Monitors - record real-time and continuously
   - Air goes through a filter
   - By an air pump (active mode) or
   - By diffusion (passive mode)
   - Into a counting chamber where alpha particles events are counted.
2. Three types of CRMs
   - Scintillation Cell and Photomultiplier Tube (PMT)
   - Pulsed Ion Chamber
   - Solid State Silicon Chip

Passive, Time Integrating Measurement Device Summary

Method	Measures	Description	Advantages	Disadvantages
Activated Charcoal	**Gamma from Bi 214 and Pb 214**	Adsorbs, desorbs Rn; **Open-face = 2-3 days** **Diffusion barrier = 5-7 days**	Very low cost; Easy to use; Easy to mail	Temperature, RH, airflow sensitive; Cannot read on-site
Charcoal Liquid Scintillation	Light pulse from **RDPs' alpha and beta** in scintillation fluid	(same as activated charcoal)	Very low cost; Easy to use; Easy to mail	Temperature, RH, airflow sensitive; Cannot read on-site
Alpha Track Detector	**Alpha**	Deployed **long-term**; damage tracks on plastic from alpha particles	Low cost; Easy to use; Easy to mail	Temperature, RH, airflow sensitive; Cannot read on-site
Electret Ion Chamber	**Ionization from alpha, beta, and gamma**	Ions reduce electret voltage (200 volts); 2 days to 1 year measurements	On-site reading; Multiple use of electrets; Easy to use	**Gamma** and Temperature, RH, airflow **sensitive**

Continuous Radon Monitor Summary

Method	Measures	Description	Advantages	Disadvantages
Scintillation cell and photo multiplier tube	**Alpha from Rn and subsequent Po 218 and Po 214**	Alpha particles from Rn and RDPs strike **zinc sulfide coating** creating light pulses which are counted	Real-time, on-site readings; Can reveal tampering	Very expensive; Highest sensitivity; User is an analytical laboratory
Pulsed ion chamber	(same as above)	Alpha particles create **ionization** in a counting chamber that in turn create electrical pulses	Real-time, on-site readings; Can reveal tampering	Expensive; High sensitivity; User is an analytical laboratory
Solid state silicon chip detector	(same as above)	Alpha particles strike a **solid state silicon chip** that creates electrical pulses	Real-time, on-site readings; Can reveal tampering	Lowest cost CRM; High sensitivity; User is an analytical laboratory

Overview of Consumer Digital Radon Measurement Devices

Kansas State University College of Engineering, Engineering Extension

Presented by: Alexandra Bahadori

What do these devices look like?

EcoQube

EcoBlu

RadonEye

Lüft

View Radon

Wave Radon

Corentium Home

Device Output- EID/CRM

- Single Data Point (Daily, 7 day, long term)
  - Detector A
  - EcoBlu
  - Corentium Home
- Online Interface with Hourly Data
  - Ecosense EcoQube
  - Ecosense Radon Eye
  - SunRadon Lüft
  - Airthings View Radon
  - Airthings Wave Radon

Issue #1

Calibration

Device Specifications

Manufacturer/Brand	Accuracy/Precision Specifications

Detector A	• Electronic integrating device
	• 48 h needed before an accurate reading can be displayed with recommendation of a longer timespan to give more accurate year-round average radon level
	• Accuracy/precision at 25 pCi/L
	  • For 7 d ± 12% pCi/L
	  • For 1 month ± 5%

Ecosense EcoQube	• Continuous radon monitor
	  • Uses app for hourly data collection
	• First reliable results in 1 hour
	• Accuracy/precision at 10 pCi/L
	  • < ± 10% after 10 h

Ecosense EcoBlu	• Electronic integrating device • First radon reading displayed after 10 min • Radon accuracy/precision at 10 pCi/L • < ± 14% after 10 h

Ecosense RadonEye	• Continuous radon monitor
	  • Uses app for hourly data collection
	• First reliable result within 1 h
	• Accuracy/precision at 10 pCi/L
	  • < ± 10% after 10 h

Device Specifications

Manufacturer/Brand	Accuracy/Precision Specifications
SunRadon Lüft	• Continuous radon monitor • Uses ap for data collection (used OneRadon database to collect hourly data) • Self calibrates in the first three hours and then continues to optimize over the following 7 d • Intended for long-term radon monitoring • 10% (7 d @ 4 pCi/L)

Airthings View Radon	• Continuous radon monitor
	  • Uses app for hourly data collection
	• Radon sensor is built for long-term monitoring
	• Typical accuracy after more than 30 d of continuous measuring at 5.4 pCi/L
	  • 7 d average: ±10%
	  • 2 month average: ±5%

Airthings Wave Radon	• Continuous radon monitor
	  • Uses app for hourly data collection
	• To obtain the most accurate readings, the radon sensor requires an initial 1 month period of data collection
	• Accuracy/precision at 5.4 pCi/L after 30 d continuous monitoring
	  • After 7 d ~ 10 %
	  • After 2 months ~ 5%

Airthings Corentium Home	• Electronic integrating device
	• First results in 24 h
	• Accuracy/precision at 5.4 pCi/L
	  • After 7 d ~ 10%
	  • After 2 months ~ 5%

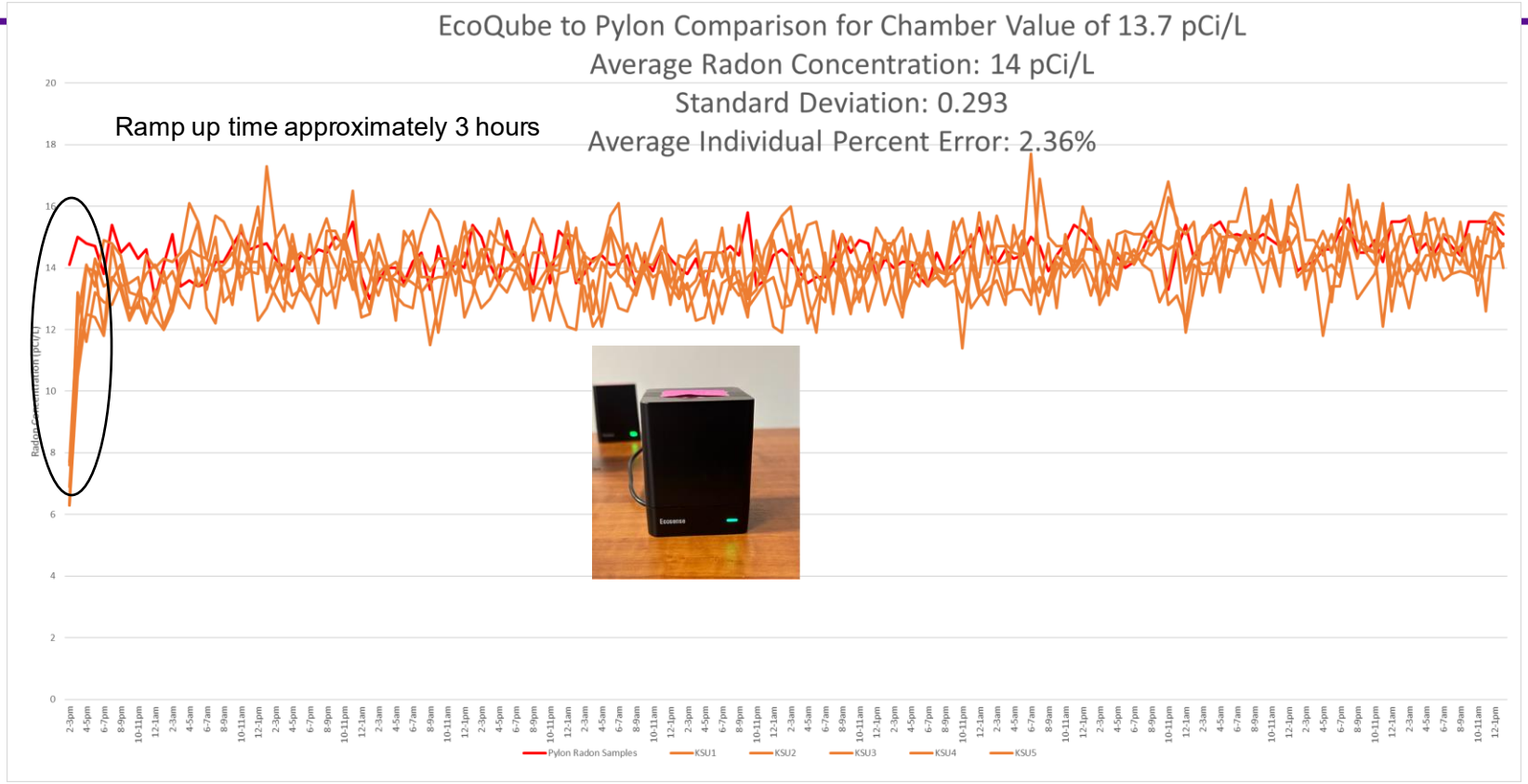
Non-Calibrated Devices

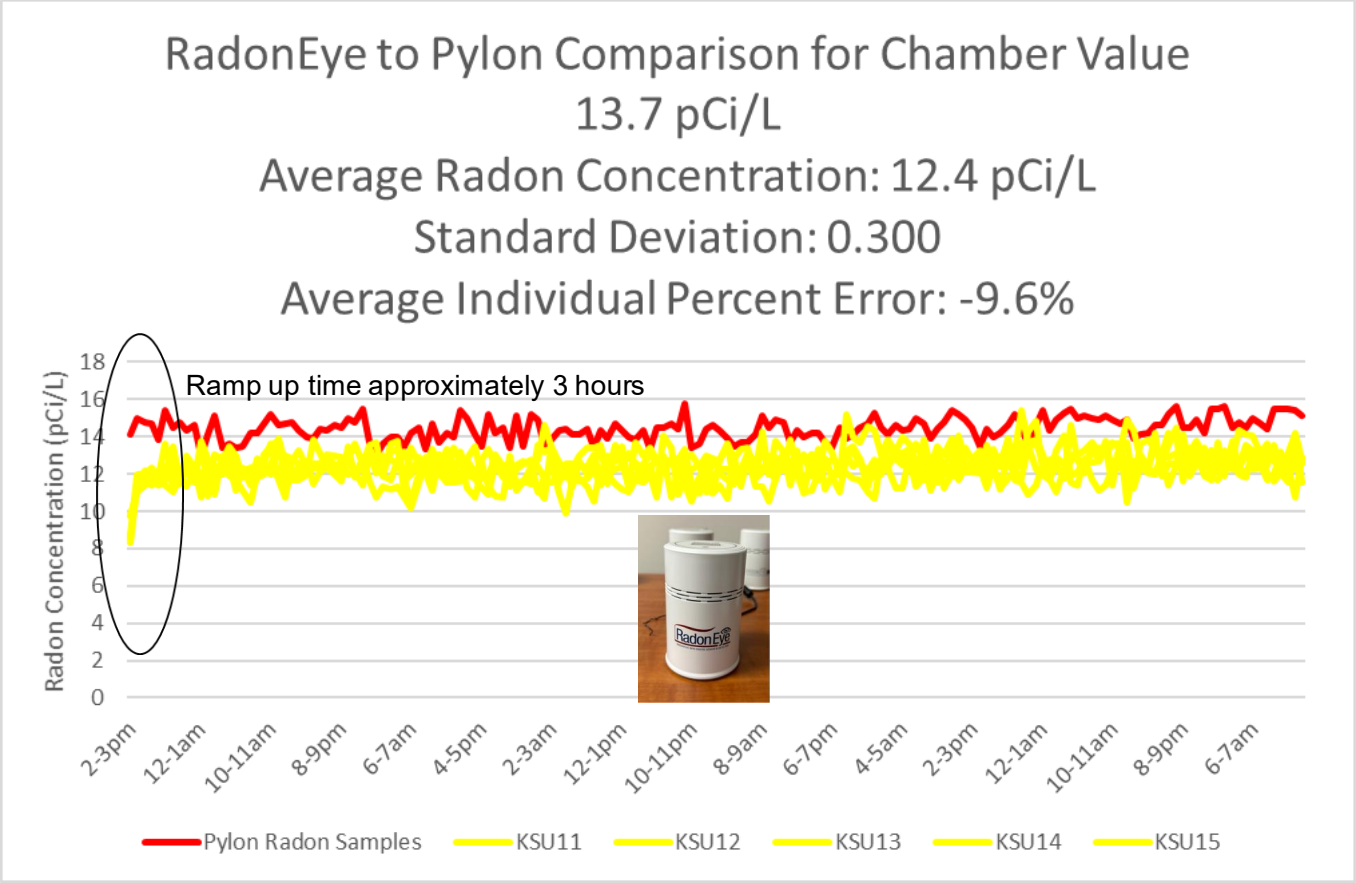
- Shipped out with initial accuracy/precision
  - How long does this last?
  - Is this updated/monitored through software and how often?

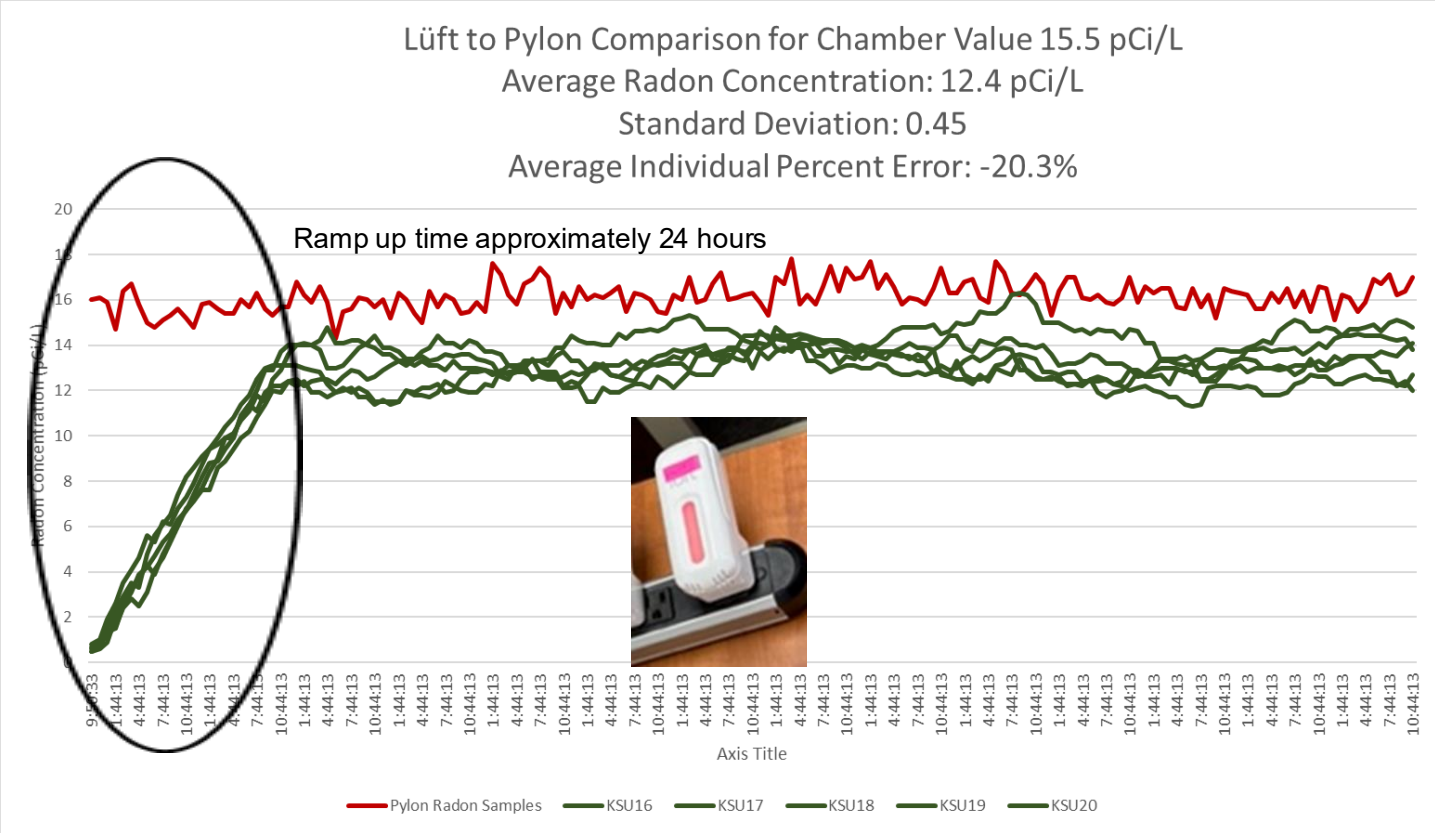
- What are we telling consumers who call the hotline?
  - These devices are useful for actively monitoring your radon levels in your home, however, an approved device still needs to be used to make mitigation decisions. These consumer digital radon measurement devices have not gone through the same process as a similar looking professional versions and when making the decision to mitigate it is best to use the single use kits or professional level digital machines.

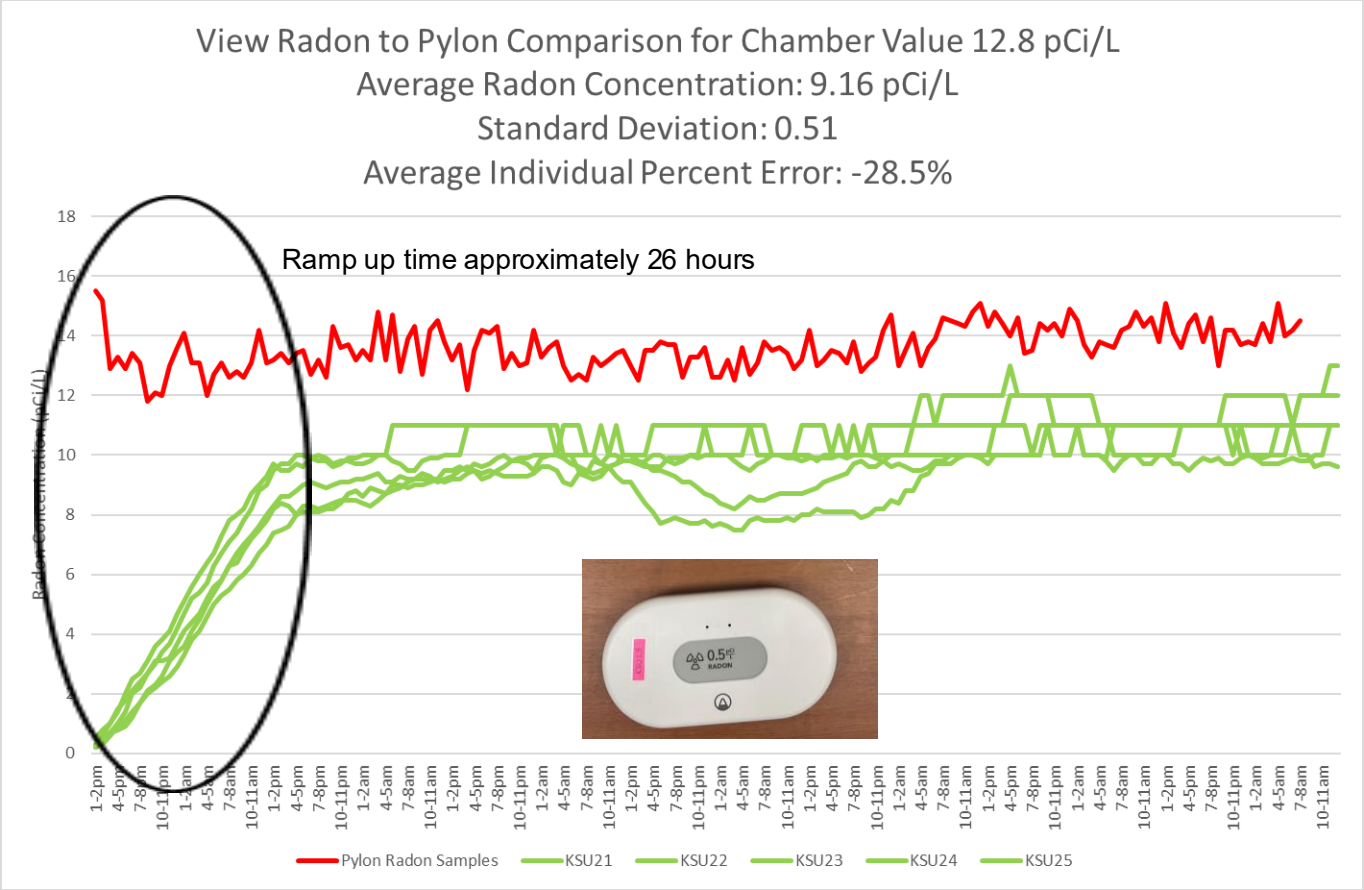
Issue #2

Ramp Up/Ramp Down Time

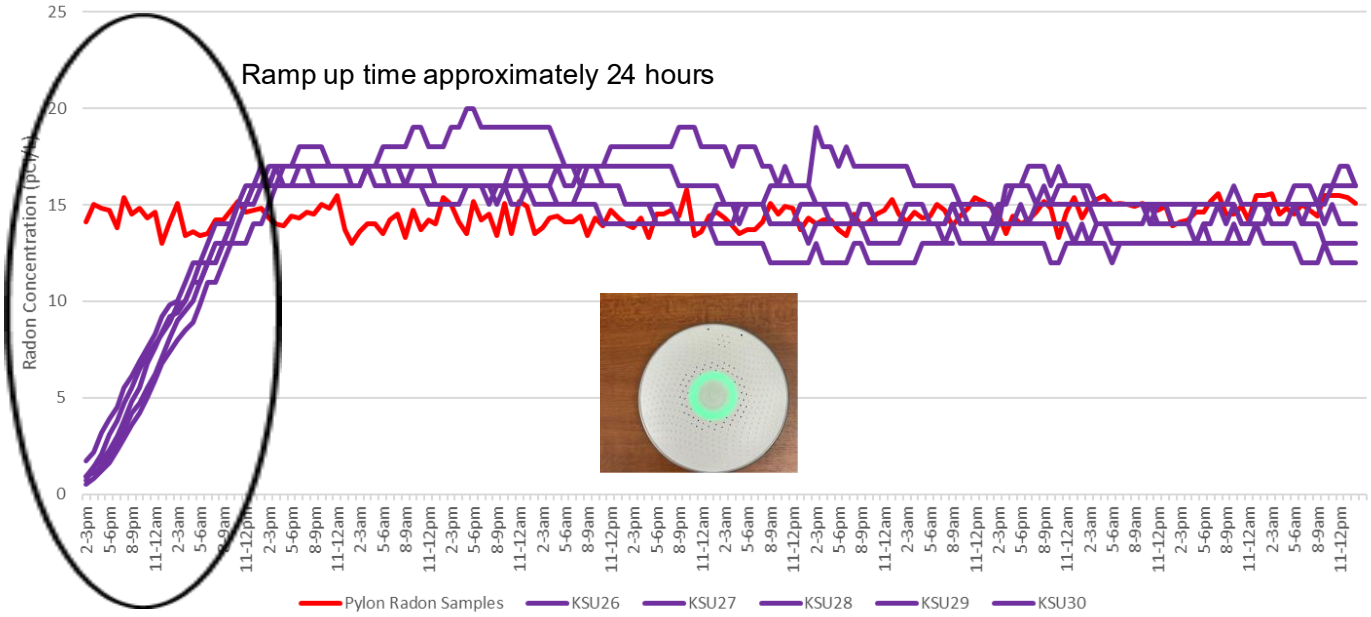

EcoQube to Pylon Comparison for Chamber Value of 13.7 pCi/L
Average Radon Concentration: 14 pCi/L
Standard Deviation: 0.293
Average Individual Percent Error: 2.36%
Ramp up time approximately 3 hours
Radon Concentration (pCi/L)
Pylon Radon Samples
KSU1
KSU2
KSU3
KSU4
KSU5


RadonEye to Pylon Comparison for Chamber Value
13.7 pCi/L
Average Radon Concentration: 12.4 pCi/L
Standard Deviation: 0.300
Average Individual Percent Error: -9.6%
Ramp up time approximately 3 hours
Radon Concentration (pCi/L)
18
16
14
12
10
8
6
4
2
0
2-3pm
12-1am
10-11am
8-9pm
6-7am
4-5pm
2-3am
12-1pm
10-11pm
8-9am
6-7pm
4-5am
2-3pm
12-1am
10-11am
8-9pm
6-7am
RadonEye
Pylon Radon Samples
KSU11
KSU12
KSU13
KSU14
KSU15


Lüft to Pylon Comparison for Chamber Value 15.5 pCi/L
Average Radon Concentration: 12.4 pCi/L
Standard Deviation: 0.45
Average Individual Percent Error: -20.3%
Ramp up time approximately 24 hours
Radon Concentration (pCi/L)
20
16
14
12
10
8
6
4
2
Axis Title
Pylon Radon Samples
KSU16
KSU17
KSU18
KSU19
KSU20


View Radon to Pylon Comparison for Chamber Value 12.8 pCi/L
Average Radon Concentration: 9.16 pCi/L
Standard Deviation: 0.51
Average Individual Percent Error: -28.5%
Ramp up time approximately 26 hours
Radon Concentration (pCi/L)
18
16
14
12
10
8
6
4
0
1-2pm
4-5pm
7-8pm
10-11pm
1-2am
4-5am
7-8am
10-11am
Pylon Radon Samples
KSU21
KSU22
KSU23
KSU24
KSU25

Wave Radon to Pylon Comparison for Chamber Value of 13.7 pCi/L
Average Radon Concentration: 14.2 pCi/L
Standard Deviation: 0.632
Average Individual Percent Error: 3.64%



Why is this an issue?

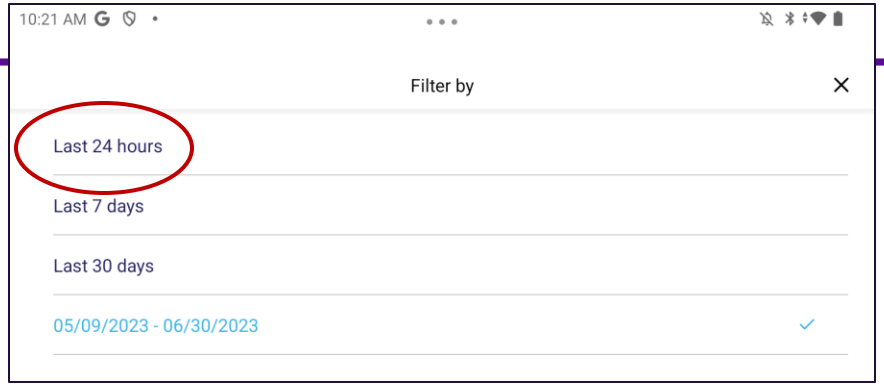
- Ramp up/ramp down times vary per device but can range from 3 hours to 36 hours
- Devices are still reporting 24-48 hour data averages without removing ramp up/ramp down times

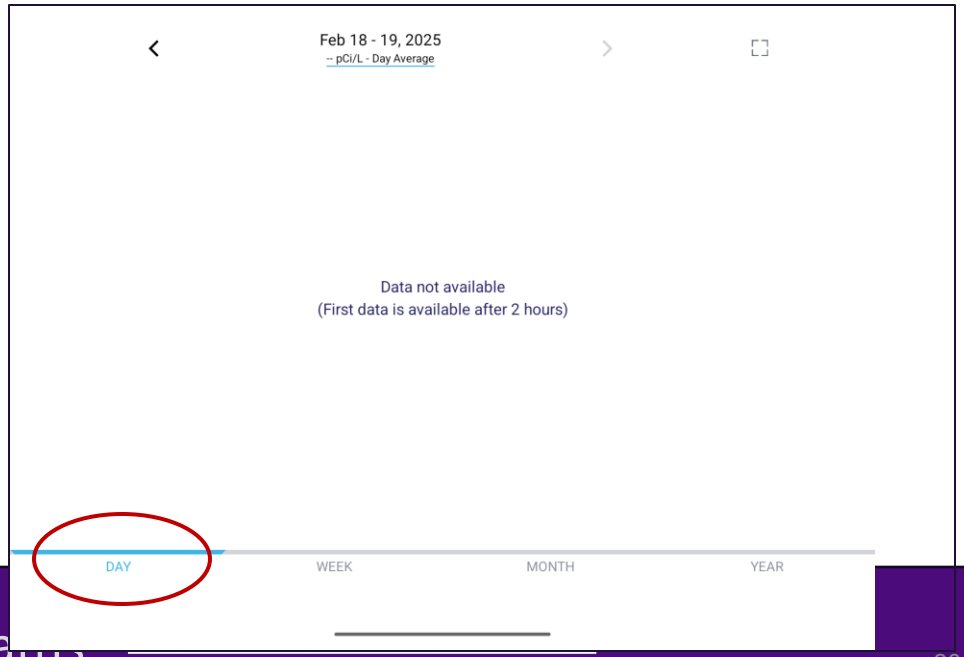
- What are we telling consumers?
  - Most of the consumer digital devices require they be left in the same location for a minimum of 7 days to provide an accurate long term estimate.

Issue #3

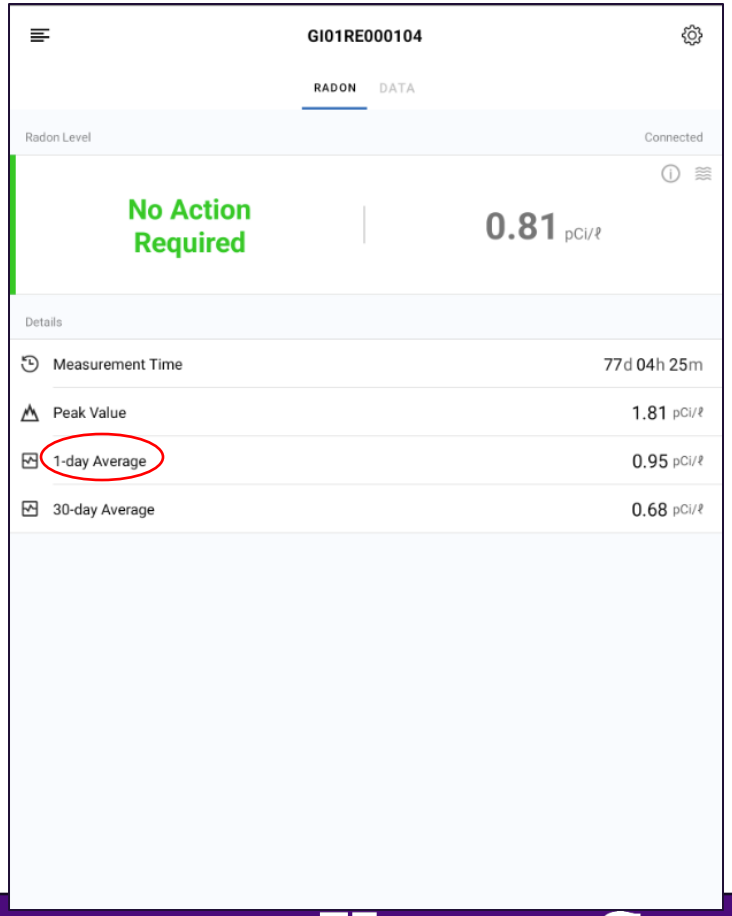
Measurement Period/Closed Building Conditions

EcoQube


10:21 AM
Filter by
Last 24 hours
Last 7 days
Last 30 days
05/09/2023 - 06/30/2023

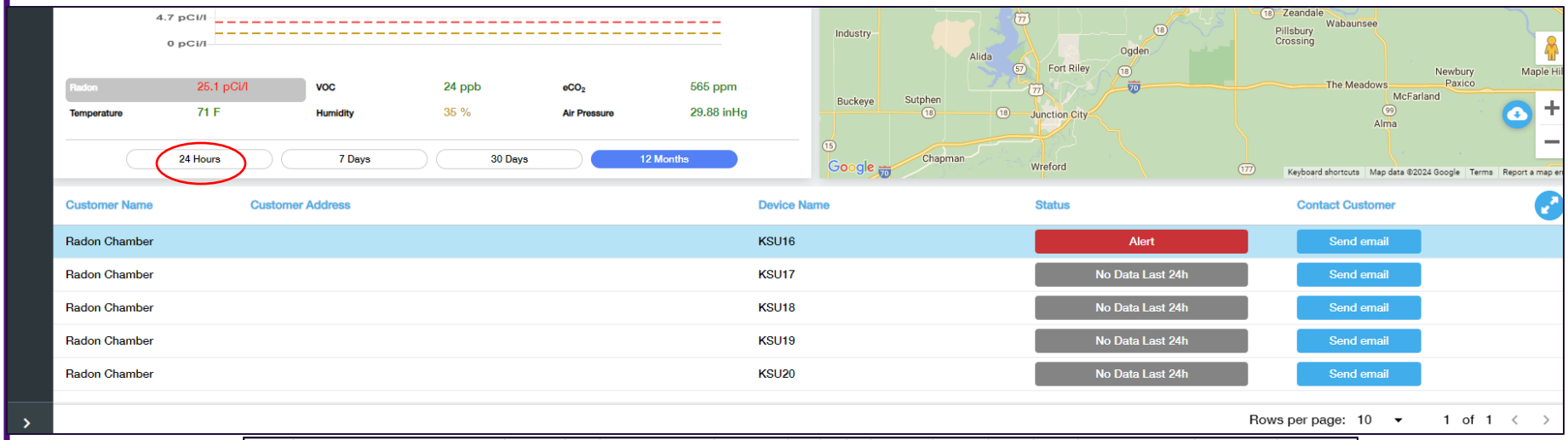

Feb 18 - 19, 2025
-- pCi/L - Day Average
Data not available
(First data is available after 2 hours)
DAY
WEEK
MONTH
YEAR

RadonEye



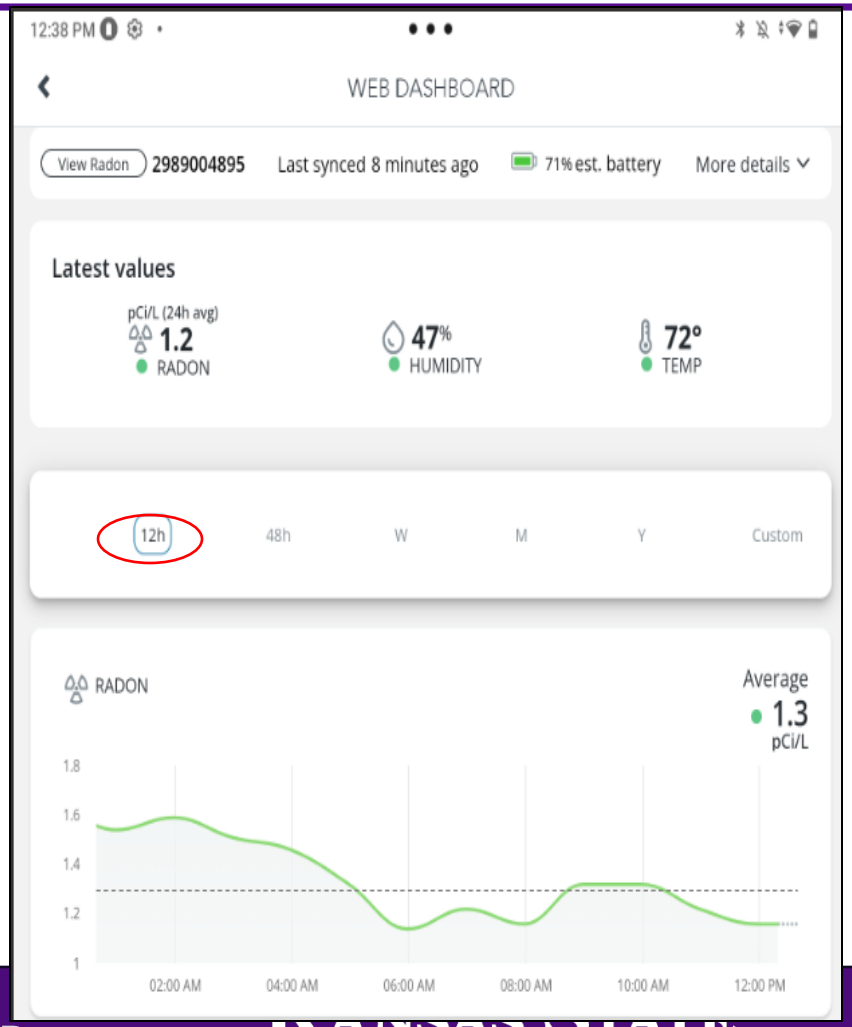

```
FTLAB RADON DATA FILE
MODEL NAME:     RD200
S/N:    GI01RE000104
Unit:   pCi/l
Time step:      1hour
Data No :       5225
1)      15.38
2)      19.41
3)      20.38
4)      21.43
5)      21.89
6)      23.24
7)      22.70
8)      25.24
9)      22.30
10)     21.70
11)     23.84
12)     23.65
13)     23.65
14)     24.43
15)     25.65
16)     28.59
17)     24.73
18)     26.14
19)     26.95
20)     25.16
21)     25.08
22)     26.16
23)     25.27
24)     24.73
25)     24.38
26)     24.27
27)     25.16
28)     25.14
29)     25.95
30)     24.46
31)     25.38
32)     25.65
33)     26.68
34)     24.95
35)     26.14
36)     25.32
37)     25.46
38)     25.03
39)     25.65
40)     26.03
```

SunRadon Lüft



Serialid	Location	DeviceName	Owner	Email	SyncDate	Radon	eC02	VOC	Temperature	AirPressure	Humidity	LogIndex	BuildingType	MitigationSystem	DeviceTimeZone
Luft_5E3A	2323 Anderson Ave, Manhattan, KS 66502, USA	KSU16		radonchamber@ksu.edu	8/7/2023 14:43	0	403	0	71	30.01	29	616	Residential Single Family	None	CDT
Luft_5E3A	2323 Anderson Ave, Manhattan, KS 66502, USA	KSU16		radonchamber@ksu.edu	8/7/2023 15:43	2.1	405	0	73	29.99	27	617	Residential Single Family	None	CDT
Luft_5E3A	2323 Anderson Ave, Manhattan, KS 66502, USA	KSU16		radonchamber@ksu.edu	8/7/2023 16:43	10.1	407	0	73	29.97	26	618	Residential Single Family	None	CDT
Luft_5E3A	2323 Anderson Ave, Manhattan, KS 66502, USA	KSU16		radonchamber@ksu.edu	8/7/2023 17:43	12.2	415	1	73	29.96	26	619	Residential Single Family	None	CDT
Luft_5E3A	2323 Anderson Ave, Manhattan, KS 66502, USA	KSU16		radonchamber@ksu.edu	8/7/2023 18:43	15.1	425	3	73	29.95	25	620	Residential Single Family	None	CDT
Luft_5E3A	2323 Anderson Ave, Manhattan, KS 66502, USA	KSU16		radonchamber@ksu.edu	8/7/2023 19:43	17	437	5	73	29.95	25	621	Residential Single Family	None	CDT
Luft_5E3A	2323 Anderson Ave, Manhattan, KS 66502, USA	KSU16		radonchamber@ksu.edu	8/7/2023 20:43	19.6	451	7	73	29.94	25	622	Residential Single Family	None	CDT
Luft_5E3A	2323 Anderson Ave, Manhattan, KS 66502, USA	KSU16		radonchamber@ksu.edu	8/7/2023 21:43	20.4	462	9	73	29.95	25	623	Residential Single Family	None	CDT
Luft_5E3A	2323 Anderson Ave, Manhattan, KS 66502, USA	KSU16		radonchamber@ksu.edu	8/7/2023 22:43	20.9	467	9	72	29.97	25	624	Residential Single Family	None	CDT

View/Wave Radon



Measurement Period/Closed Building Conditions

- All these devices have different minimum measurement periods, but the app allows them to filter for shorter time periods leading to confusion for consumer
- Closed building conditions are confusing for consumer's even when using a short term kit. More language to clarify closed building conditions and that they are necessary for entire measurement period less than 90 days.

What are we telling consumer's?

- Place device in same location for 7 days and check with manufacturer to determine the minimum length of time necessary for a test
- If you are allowed to test less than 3 days, establish closed building conditions before starting test and throughout test.
- If test is longer than 3 days maintain closed building conditions during test.

Issue #4

Detector Placement

Detector Placement

- Many consumer's want to move device from room to room, floor to floor etc. especially the devices that are battery operated
- What are we telling consumer's?
  - It may be tempting to move your device from room to room, but you need to make sure that you've collected enough data in each location before you move on to the next. Additionally, once you start a test, you must leave the device there for the minimum amount of time as recommended by the manufacturer. Again, please always follow up with an approved at home short term test kit before you make any sort of mitigation decision

Evaluation of consumer digital radon measurement devices: a comparative analysis

- Evaluation of 8 devices published recently in the Journal of Radiological Protection:
  - https://iopscience.iop.org/article/10.1088/1361-6498/ad4bf1

Menti Questions

Contact Information

- Alexandra Bahadori
  - 785.532.6026 (general office)
  - 785.532.3957 (direct)
  - adbaha@ksu.edu
- Brian Hanson
  - 785.532.4996 (direct)
  - bhandon@ksu.edu
- NRPS Contact
  - radon@ksu.edu
- KSU Radon Training
  - radoncourse@ksu.edu
- KSU Radon Chamber
  - radonchamber@ksu.edu