Intercomparison of commercially available active radon measurement devices in a “discovered” radon chamber

Marco Carmona, Fangbo Yuan, Edgar Long Kiu Chung, Loren Mata,
Jonathan Miller, David Trimas, Jeffery Xiao, Kimberlee Kearfott
Radiological Health Engineering Laboratory
Department of Nuclear Engineering and Radiological Sciences, University of Michigan, Ann Arbor

Abstract

An unventilated room, with an inner set of concrete walls to damp vibrations in the laboratory directly above it, was discovered to have relatively stable radon levels of roughly 1,000 Bq m^{-3} over a 1-y time period. While unsuitable for precise calibrations, this 70 m^3 space with 2.1 m high ceilings was placed into function as a radon chamber adequate for general research and teaching without significant modification other than removal of stored items. The addition of radium sources was not required to achieve the radon levels, as these arise naturally in the space. Several commercially available active radon monitoring devices designed for homeowners, radon screeners, radon mitigation professionals, and researchers were chosen for initial testing in the newly "commissioned" radon chamber. These devices are variable in both cost and intended user sophistication. Radon concentration data were collected at the minimal time intervals of 15 min, as possible, for each device. A cellphone was deployed with an available camera application to periodically capture photographs of the displays of devices not enabled for automatic temporal recording. Attempts were made to lower the radon concentration using fans, increase the radon level by the placement of radium-laden objects, and stabilize the radon level using radon impermeable sheets. Statistics were employed to compare the performance of the various devices under the minor radon transients encountered during the test period. While not purpose-built, the unoccupiable space serving as the radon chamber had a sufficiently high and stable radon concentration to be useful. A means of easily altering the radon level in the space in a significant way was not apparent. However, it was previously demonstrated that higher levels of radon may be readily generated by placing radium dials within a 0.2 m^3 steel drum when needed for future research. The evaluation of the overall calibration accuracy, noise, and response to transients revealed weaknesses for some devices and exceptional performance for others.

Methods

- Measured Rn levels over 28 d for 14 devices
- Set devices to collect at most frequent interval with a minimum interval of 15 min
- Used Ra-226 radium dials ranging in activity from 1,600 to 100,000 Bq, a 22 MBq Ra-226 laden Revigator, and fans to alter radon levels
- Used Lapse It application with an iPhone5 to automatically record photos of displays of devices without temporal data recording
- Saphymo AlphaGuard selected as the standard for comparison
- Chi-squared statistic, used to quantify agreement of each device with the AlphaGuard, computed from:

$$\chi^2 = \sum \frac{(O-E)^2}{E}$$

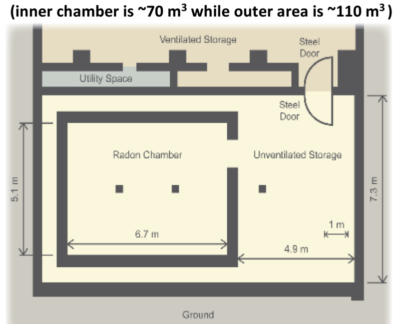
where O is the radon concentration measured by the device and E represents the AlphaGuard value.

Sample Lapse It Image

Radon Eye

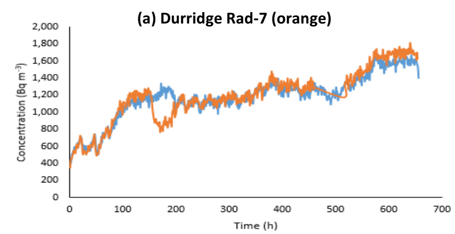
Radon measuring devices in Rn Chamber during the test

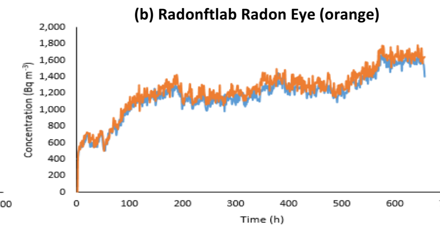
Floorplan of the Rn Chamber
(inner chamber is ~70 m^3 while outer area is ~110 m^3)

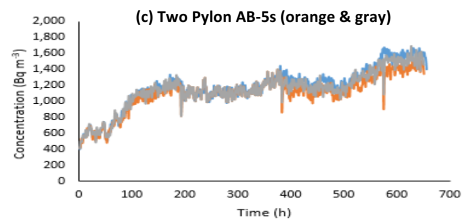


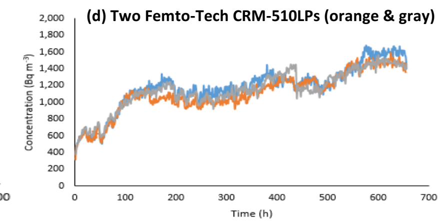
Results

Measured Rn concentration as a function of time over 28 d period, compared to AlphaGuard (blue) results









Comparison of radon measuring device specifications and calculated chi-squared value relative to the AlphaGuard

Company	Device	Price	Memory*	Battery*	Intervals	Accuracy*	Sensitivity*	Range*	Chi-Squared
Saphymo	AlphaGuard	$10,000	4,800 points	10 d	10, 60 min	3%	0.14 cpm/(Bq/m^{-3})	2-2,000,000 Bq m^{-3}	(Control)
Pylon	(2) AB-5	$8,000	675 intervals	75 h without pump, 48 h at 100 ml m^{-1}, 8 at 3 l m^{-1}	1 min-24 h	Depends on calibration	0.4 cpm/(Bq/m^{-3})	NA	5.44, 8.25
Durridge	Rad-7	$6,900	1,000 cycles in up to 100 runs	24 h in sniff, 72 h in monitor	0.5, 1, 2, 4, 8, 12, 16, 20 or 24-h intervals	5%	0.013 cpm/(Bq m^{-3})	4-750,000 Bq m^{-3}	4.59
Femto-Tech	(2) CRM-510 LP	$4,200	192 1 h data points	1 y	1 h	NA	0.008 cpm/(Bq m^{-3})	1 to 7,400 Bq m^{-3}	5.43, 10.6
Sun Nuclear	Model 1030	$1,200	90 measurements	20 h	1 h	25%	0.0675 cph/(Bq m^{-3})	1-369,996 Bq m^{-3}	13.0, 14.2
Sun Nuclear	Model 1027	$900	1,000 measurements, 2 runs	300+ h	0.5, 1, 2, 4, 8, 12, 16, 20 or 24-h intervals	20%	0.4 cph/(Bq m^{-3})	1-369,996 Bq m^{-3}	7.86
Airthings	Wave	$200	1 y	1.5 y	1 h	1 standard deviation within 20% after 7 d, 10% after one mo	NA	0-50,000 Bq m^{-3}	9.92
Airthings	Digital Radon Monitor (older verison)	$200	Rolling average	2 y	Can display last d or last 7 d	20%-7 d, 10%-1 mo	NA	0-18,500 Bq m^{-3}	12.0
Airthings	Digital Radon Monitor	$200	Rolling average	2 y	Last d, 7 d, or long term average	10%-7 d, 5%-2 mo	NA	0-18,500 Bq m^{-3}	9.77
Radonftlab	Radon Eye	$180	1 y	None	1 h	10%	0.0135 cpm/(Bq m^{-3})	0.1-3,699 Bq m^{-3}	6.73
Sylvane	Pro Series 3	$130	5 y	None	Rolling Average or last seven d	20% or 37 Bq/m^3 (larger one)	NA	0.1-3,699 Bq m^{-3}	13.1

* Indicates a manufacturer reported value

Conclusions

- The research grade devices, the Rad-7 and the AB-5s, agreed generally best with the AlphaGuard, possessing $4.6 \leq \chi^2 \leq 8.3$.
- The Radon Eye performed significantly better than expected for an extremely affordable device, with $\chi^2 = 6.7$. It demonstrated performance comparable to all the research grade devices.
- All of the devices possessed strong correlations with the AlphaGuard, with none performing particularly poorly.
- The Radon Eye was identified as a potential candidate to be implemented for the University of Michigan Radiation Weather Station due to its low cost and high accuracy.

Acknowledgements: The authors wish to thank Mark Matusko and Edward Birdsall for assistance in preparing the Radon Chamber space, Prof. Ron Gilgenbach for his support for creation of the Radon Chamber, and Dr. Sungsoo Kim of Radonftlab for donation of the Radon Eyes. This work was funded in part by the Consortium for Verification Technology under the Department of Energy National Nuclear Security Administration, award number DE-NA0002534.

Consortium for Verification Technology