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A Study on Radon (Ra-222) Fluctuations in Rijau for the Purpose of Validating Airthings Digital Radon Monitor (Corentium)

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Abstract: The use of active survey instruments for the purpose of background nuclear radiation measurements and surveys is becoming more convenient with the emergence of high precision devices that requires no recalibration. The ability of such devices to display measured values within a short time frame compared to passive measurements can be a source of error hence the need to ascertain the minimum duration for which convergence can be attained. The Airthings Digital Radon Monitor by Corentium is an active airborne Radon monitor capable of instantaneously measuring Radon concentrations in three categories; Long-Term Average (LTA), Short Term Average (STA) and Seven Days Average (SDA). This research conveys a study on indoor Radon 222 fluctuations at GPS 11.1° N, 5.3° E location in Rijau Local Government Area using Airthings Radon Monitor obtained from Physical Sciences Department of Niger State Polytechnic Zungeru. Rijau is in Niger State, North-Central Nigeria. Radon is the major contributor of background radiation and the major natural cause of cancer in humans. The measured radon was categorized as Long-Term Average (LTA), Short Term Average (STA) and Seven Days Average (SDA) in accordance with the LCD display of the monitor. In this order, the minimum, maximum and average values obtained were; 19.98, 60.9, 37.6 ± 17.44; 6.29, 86.8, 30.6 ± 23.47; 14.8, 259.7, 76.5 ± 82.6 Bq/m^3 respectively. All the recorded values were below the 200 Bq/m^3 recommended exposure limit of ICRP. The major specific objective of this experiment is to validate the suitability of long-term measurement over short term and determine the minimum acceptable measurement period for the Airthings Radon Monitoring Device. The outcome of this research will serve as a baseline data for radon survey at the sampling location and a validation on the suitability of the airthings radon monitor.

Keywords: Radon-222, Rijau, Radiation, Airthings

1. Background

Radon is a naturally-occurring radioactive gas that can cause lung cancer. Radon gas is inert, colourless and odourless. Radon is naturally in the atmosphere in trace amounts. Outdoors, radon disperses rapidly and, generally, is not a health issue. Indoor Radon 222 concentration in residential buildings is one of the newest environmental pollution concerns [1]. Level of indoor radon concentration always hints on the concentration of radon in water and soil at the same sampling location as the three correlates positively (Kandari *et al.,* 2016). Radon is a major contributor to radioactivity levels indoor air, groundwater and soil [2, 3].

Soil is the major contributor of radon concentration either indoor or in water [4]. Assessment of radon level in inhabited dwellings is of importance to public health [5].

Countries such as Jordan conducts radon survey for the purpose of establishing a countrywide radon map as part of its public health policy. The radon map can be approximated from continues monitoring of radon concentration from major cities of a country [6].

Most radon exposure occurs inside homes, schools and workplaces. Radon gas becomes trapped indoors after it enters buildings through cracks and other holes in the foundation. Indoor radon can be controlled and managed with proven, cost-effective techniques.

Breathing radon over time increases risk of lung cancer. Radon is the second leading cause of lung cancer in the United States. Nationally, the EPA estimates that about 21,000 people die each year from radon-related lung cancer. Only smoking causes more lung cancer deaths [7].

Radon is a chemical element with the symbol Rn and atomic number 86. It is a radioactive, colorless, odorless, tasteless noble gas [8]. Radon-222 is the most stable isotope of radon, with a half-life of approximately 3.8 days. It is transient in the decay chain of primordial uranium-238 and is the immediate decay product of radium-226. Radon-222 was discovered in 1899, and later identified as an isotope of a new element several years later [9].

Physical properties of radon are summarized in Table 1 [9].

Table 1. *Physical Properties of radon.*

Property	Magnitude
Symbol:	Rn
Electron configuration	[Xe] $4f^{14}5d^{10}6s^{2}6p^{6}$
Atomic number	86
Atomic mass	222 u
Electrons per shell	2, 8, 18, 32, 18, 8
Melting point	-71°C
Boiling point	-61.7°C

2. Aim and Objectives

The aim of this research is to study indoor radon 222 fluctuations at GPS 11.1°N, 5.3°E location in Rijau Local Government Area using Airthings Radon Monitor. The specific objectives of the project are:

1) To determine a suitable sampling location using e-trax GPS monitor with complementation from GPS camera.
2) To measure the indoor radon concentration at the location of interest using Airthings Radon Monitor in Long-term, Short-term and Seven-Days averages.
3) To validate the suitability of long-term measurement over short term and determine the minimum acceptable measurement period for the airthings radon monitoring device.
4) To compare the measured output to standard limits set by radiation protection agencies.

3. Justification

Researchers had suggested the need for evaluating the reliability and performance of emerging low-cost active Radon Monitors [10]. One of these emerging radon survey devices is the Airthings Radon Monitor.

The Airthings Radon Monitor capable of simultaneous updating of long term, short term and seven days averages is suitable for indoor radon concentration and estimations of radiological hazards [11-13].

Long term radon monitoring is the only reliable measurement permitted in devices that are passive. Active radon measuring devices such as the airthings radon monitor can give results in hours (mostly in 24 hours). The readings on these devices continue to fluctuate with time until they stabilize for a given category. Although continues monitoring for several months is recommended by literature, the specific duration for which the measurement can be judged acceptable is not usually provide by the manual hence the need to experiment and study the trend of measurements in each category. Another validation of this research is to ascertain how the STA and SDA compares with the long-term average when studies as a pattern over a long period of data generation. The amount of radon 222 concentration in the sampling dwelling is also of interest as a validation data information and for healthcare radiation risk assessment information.

4. Scope and Limitation

The present work is restricted to only measurement of radiation magnitude arising from radon 222 exposure and simple comparism with regulatory exposure limit set by ICRP [14] without consideration for radiological hazards and parameters to dwellers. The entire experiment was conducted using airthings radon and e-trax GPS monitors only.

5. Materials

1) Airthings Radon Monitor;
2) e-trax GPS monitor;
3) Smart phone;
4) Laptop Computer.

6. Method

The fluctuation study is an aspect of an earlier mapping tool developed for the purpose of a more generic Radon Survey in Residential Buildings in Rijau LGA. The project is sponsored through an Industrial Based Research window of Tertiary Education Fund (TETFund) intervention of Nigerian Government to Salihu Mohammed research group of Niger state Polytechnic, Zungeru.

The following methodology was adopted to achieve the objectives of the research.

1) The e-trax GPS Monitor was used to determine the longitude and latitude coordinates of the sampling location of interest.
2) The location was about 1-meter away from the inside wall of a closed bedroom.

3) The height of the detector support was also about ½ meter above the ground.
4) Brand new AAA standard battery were inserted into the battery slot of the monitor to mark the commencement of calibration.
5) Once the battery was inserted and the monitor placed at the location of interest, the monitor remains at that location without any form of movement or interference until all experiment at that location was completed.
6) As soon as the calibration was done, the device begins to acquire and display the first result after 24 hours.
7) Within day 1 to day 6, the displayed results were in the categories of LTA and STA.
8) The first result of SDA only appears after the seven days.
9) The LCD screen of the detector was screenshot using a smartphone and uploaded on a WhatsApp group created for the purpose of data collection, storage and tracking.
10) The readings of LTA, STA and SDA were extracted, tabulated and analyzed using EXCEL Spreadsheet statistical tool and Microsoft Word.
11) For convenience the Bq/m^3 unit is sometimes used by the Author for ease of referencing and comparism with limits set by ICRP and other published data in literature.

A pictorial of the airthings radon monitoring device in operation is depicted in Figure 1.

Figure 1. *An operational Airthings Radon Monitor at the sampling location.*

Standard Deviations (SD)

The standard deviations were computed using equation (1).

$$SD = \sqrt{\frac{\sum(x_i - \mu)^2}{N-1}} \quad (1)$$

Where; N is the population size;
x_i is each value from the population;
μ is the population mean.

7. Result

Summary of the radon concentration as measured over a period of December, 6th 2021 to January 6th 2022 is presented in Table 2.

Table 2. *Summary of computed and converted averages.*

Days	Date	LTA (Bq/m^3)	STA (Bq/m^3)	SDA (Bq/m^3)
1	Dec-12	20.72	44.77	20.72
2	Dec-13	20.72	25.9	20.72
3	Dec-14	22.94	18.685	20.35
4	Dec-15	22.94	26.64	20.72
5	Dec-16	22.385	12.765	20.72
6	Dec-17	20.72	10.915	18.87
7	Dec-18	19.98	86.765	18.87
8	Dec-19	27.195	79.92	23.31
9	Dec-20	26.64	8.325	23.68
10	Dec-21	24.79	7.77	21.83
11	Dec-22	23.68	6.29	16.65
12	Dec-23	22.94	14.245	15.91
13	Dec-24	21.275	14.8	17.76
14	Dec-25	20.72	13.69	14.8
15	Dec-28	57.72	15.91	172.42
16	Dec-29	55.685	20.905	181.3
17	Dec-30	55.315	44.4	196.84
18	Dec-31	56.98	29.415	218.3
19	Jan-01	56.98	73.815	228.66
20	Jan-02	60.68	49.21	259.74
21	Jan-03	60.865	20.905	68.45
22	Jan-04	60.865	70.855	71.78
23	Jan-05	60.865	19.795	81.215
24	Jan-06	59.94	17.76	81.77

8. Discussion

From the trend of Figure 2, the fluctuation is more chaotic for the STA measurement. This implies that daily or instantaneous measurements of radon cannot be taken as the true value of radon concentration of a location of interest. From the trend, even though convergence was yet to be achieved, the LTA and SDA appeared to be much more acceptable which validated the recommendation of using LTA as the true radon concentration in any continuous measurement [15].

Previous research [15] established that active electronic Radon monitoring devices have a range of uncertainty from 2%–15%, precision from 1%–24% and are characterized by different response time [16].

All the measured values compare well with safe recommended limits. The values are all less than the 200 Bq/m^3 International Commission for Radiation Protection limit.

9. Conclusion

Result of the standard deviation showed that the LTA has the least error margin followed by the short time average. The seven days average has the highest error margin hence not suitable as a representative of indoor radon level at the location of interest except where the purpose is to determine the SDA.

From the trend of Figure 2 the experimental result depicts a work that is yet to converge. However, an inference can be drawn from the stability of the LTA curve which appears to be the most stabilized of the studied fluctuations. On this strength it can be reasonably concluded that LTA reading appearing after seven days continues measurement can be considered the most acceptable of the three measurements.

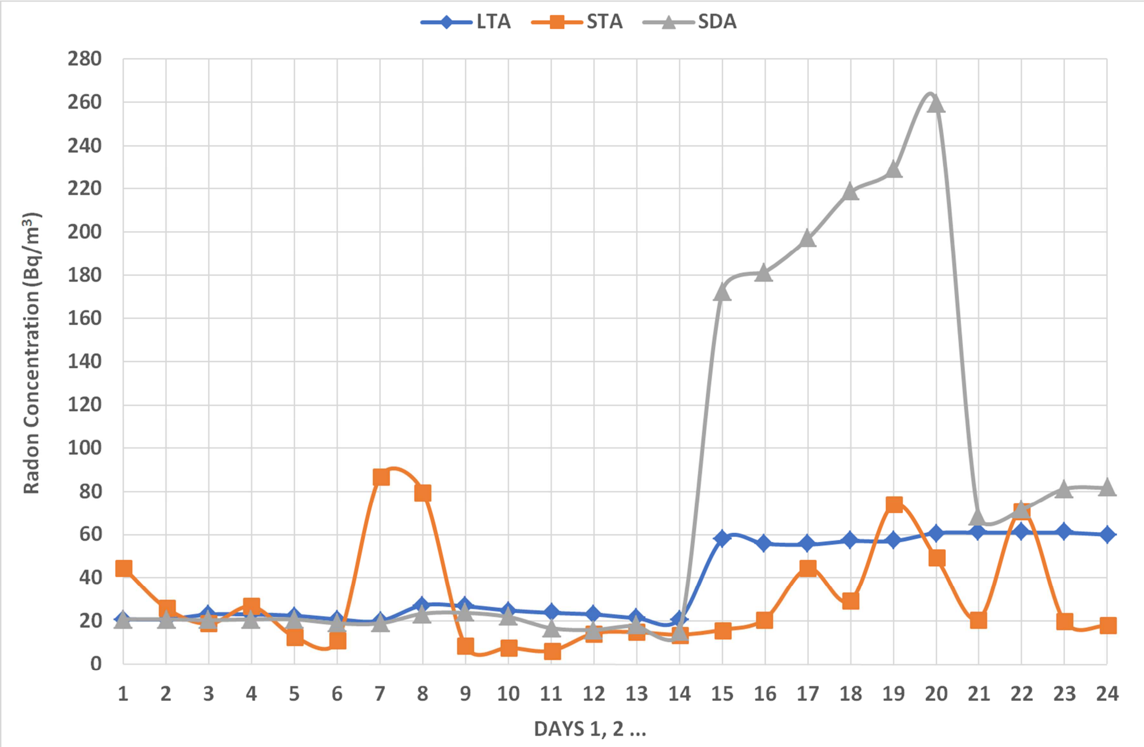

Figure 2. *Radon Fluctuations.*

10. Recommendations

Taking into consideration that lung cancer risk for dwellers increases by about 16% per 100 Bq/m^3 increase in long time average radon concentration, its strongly recommended that the study should continue until convergence is attained using other makes of Radon monitors for the purpose of confirmation and systemic error inferences. This should be done using methods developed by Pam W. *et al.* [16] where performance of different brands of electronic monitors were evaluated in a radon-controlled environment.

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Appendix

Table 3. *Summary of Experimental Results.*

	Date	Spec.	LTA 1 (pCi/L)	LTA 2 (pCi/L)	STA 1 (pCi/L)	STA 2 (pCi/L)	SDA1 (pCi/L)	SDA 2 (pCi/L)
1	6	Dec-06	0.75	0.75	0.51	0.51	0	****
2	7	Dec-07	0.75	0.75	1.13	0.91	0	****
3	8	Dec-08	0.56	0.56	0.27	0.21	0	****
4	9	Dec-09	0.48	0.48	0.24	0.27	0	****
5	10	Dec-10	0.48	0.48	0.16	0.24	0	****
6	11	Dec-11	0.43	0.43	0.24	0.89	0	
7	12	Dec-12	0.56	0.56	1.21	****	0.56	****
8	13	Dec-13	0.56	0.56	0.7	****	0.56	****
9	14	Dec-14	0.62	0.62	0.29	0.72	0.54	0.56
10	15	Dec-15	0.62	****	0.72	****	0.56	****
11	16	Dec-16	0.59	0.62	0.32	0.37	0.56	0.56
12	17	Dec-17	0.56	0.56	0.35	0.24	0.51	0.51
13	18	Dec-18	0.54	0.54	0.32	4.37	0.51	0.51
14	19	Dec-19	0.75	0.72	3.97	0.35	0.62	0.64
15	20	Dec-20	0.72	0.72	0.27	0.18	0.64	0.64
16	21	Dec-21	0.67	0.67	0.24	0.18	0.64	0.54
17	22	Dec-22	0.64	0.64	0.1	0.24	0.45	0.45
18	23	Dec-23	0.62	0.62	0.37	0.4	0.43	0.43

	Date	Spec.	LTA 1 (pCi/L)	LTA 2 (pCi/L)	STA 1 (pCi/L)	STA 2 (pCi/L)	SDA1 (pCi/L)	SDA 2 (pCi/L)
19	24	Dec-24	0.59	0.56	0.45	0.35	0.48	0.48
20	25	Dec-25	0.56	0.56	0.45	0.29	0.48	0.32
21	26	Dec-26	0.56	0.56	0.37	99.94	0.32	0.32
22	27	Dec-27	1.59	1.59	72.89	0.83	4	4
23	28	Dec-28	1.56	1.56	0.54	0.32	4.54	4.78
24	29	Dec-29	1.56	1.45	0.81	0.32	4.78	5.02
25	30	Dec-30	1.45	1.54	1.08	1.32	5.02	5.62
26	31	Dec-31	1.54	1.54	0.54	1.05	5.62	6.18
27	1	Jan-01	1.54	1.54	1.08	2.91	6.18	6.18
28	2	Jan-02	1.64	1.64	1.45	1.21	7.02	7.02
29	3	Jan-03	1.67	1.62	1	0.13	2	1.7
30	4	Jan-04	1.62	1.67	0.43	3.4	1.7	2.18
31	5	Jan-05	1.67	1.62	****	0.45	2.18	2.21
32	6	Jan-06	1.62	1.62	0.48	0.48	2.21	2.21

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