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Measurement of Radon Concentration in Selected Buildings in Nnamdi Azikiwe University, Awka

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Radiation due to Radon gas and its progeny constitutes 50% of the total background radiation exposure. The odourless, colourless and tasteless property of the gas makes it difficult to detect its presence. It can only be detected when measured using a detector. The radioactive decay of radon has a deterministic effect on human lungs when inhaled. For this reason, the World Health Organization (WHO) grouped radon as a human lung carcinogen. The aim of this study was to estimate the average radon concentration in Nnamdi Azikiwe University. Radon levels were measured in eleven different buildings on the campus using the RD 200 radon-eye detector. The indoor radon concentration was measured in both ground floors and upstairs. The average radon concentration measured on the ground floor was 55.03 ± 9.51 $Bq.m^{-3}$ and 13.90 ± 3.83 $Bq.m^{-3}$ on the upper floor. The implication of this result is that a person that spends a total of 2000 *hrs/yr* in these ground floor locations will be exposed to an average effective dose of 0.38 $mSv.y^{-1}$, while a

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worker that spends equal time in the upstairs locations will accumulate an average of 0.096 $mSv.y^{-1}$. Generally, the mean radon concentration in the campus was measured to be 36.34 $Bq.m^{-3}$ which is a bit lower than the global average of 40 $Bq.m^{-3}$. The mean annual effective dose for this study was found to be 0.25 $mSv.y^{-1}$ which is lower than the recommended limit of 1 $mSv.y^{-1}$. The data from this research offers a reference point for designing the ventilation system of future buildings in the school.

Keywords: Radon; radium; carcinogen; progeny; concentration; effective dose; mean radon concentration.

1. INTRODUCTION

Radon is the main source of radioactivity in the earth's atmosphere. It is a noble gas and an immediate decay of product of radium from Uranium-238 [1]. Uranium-238, which is formed in soil and rocks in limited quality, disintegrates to compounds like radium then to radon which finds its way through cracks in the rocks to the outer surface and penetrates ground water [2]. The highest known human exposure to natural ionizing radiation is caused by radon gas [3]. The high density of radon also makes it possible for it to accumulate in a poorly ventilated house as it escapes the sub-surface.

"Radon is known to decay quickly with half-life of 3.82 days by alpha emission causing significant damage to the cells in the lungs. Exposure to radon over a long period result to the damage of the pulmonary mucosa, this leads to lung cancer" [4]. "Radon is categorized as a human lung carcinogen by the International Agency for Research on Cancer (IARC) and the World Health Organization" [5,6].

In line with the suggestion of ICRP [1], "radon concentration in different parts of the country (Nigeria) is actively being measured in other to determine areas and geographical locations that are radon-prone".

"Concentration of radon gas in dwellings has been found to depend on geological condition, meteorological condition, construction material and ventilation of the building" [7]. $^{222"}$Rn exposure levels in large buildings such as commercial buildings, schools and multi-unit residential structures, may be different from exposure patterns in detached houses due to differences in operation going on in the building" [2].

Hence, the aim of this study is to investigate the concentration of radon levels in selected classrooms and offices in Nnamdi Azikiwe University, Awka, Nigeria. The results will be used to estimate the annual effective dose for the university community that occupies these areas. This study will help to show the amount of background radiation absorbed on daily basis by students of Nnamdi Azikiwe University and offer a reference point in the battle against cancer due to high radon concentration. It will also inform the administration on how buildings should be constructed and also properly ventilated so as to reduce radon levels, thus, will be an important consideration on future construction by the administration [8,9,10].

This work is organized as follows: Section 1 contains Introduction to the research topic, Section 2 deals with area under study, Section 3 contains related works to radon measurement in Nigeria, and Section 4 presents the Methodology, followed by Sections 5 and 6 which present Results and Discussion and Conclusion respectively.

2. AREA UNDER STUDY

This study was carried out in Nnamdi Azikiwe University, located in the sub-urban setting of the city of Awka (capital), Anambra state Nigeria. Awka lies below 300 meters above sea level in a valley on the plains of the Mamu River. Nnamdi Azikiwe University was established in 1991 and was named after Dr. Benjamin Nnamdi Azikiwe. Its geographical coordinates are 6˚14'34.4"N and 7˚7'5.84"E. The university has an average population of 70,000 students. It has 14 faculties and 57 departments. The selected buildings in the university where the readings were taken include:

- Physics and Industrial Physics laboratory
- Advanced Physics laboratory
- Final year Classroom (science village)
- Festus Aghagbo Nwako Library (General, Engineering and Math reading halls)
- Faculty building Management Sciences (Lecture hall 1, Lecture hall 2 and lecture hall 15)

- Faculty of Social Sciences (Diploma hall)
- Nnamdi Azikiwe High School (Physics laboratory).

3. RELATED WORK

Ademola et al. [11], “measured indoor radon level in a private university campus (Bells University of Technology) located in Ota Industrial Area, Nigeria. The study was to determine the health risk of the workers in the community. The measurements were performed using a passive radon dosimeters comprising (CR-39) solid state nuclear track detector. The mean radon concentration and the effective dose obtained in this work are 18.8 $Bq.m^{-3}$ and 0.02 $mSv.y^{-1}$ respectively”.

Obed, et al., [12], in 2010 “conducted an indoor Radon survey in University of Ibadan, Nigeria; they measured the Radon concentration in 24 offices at the University. CR-39 track etch detectors were used for the measurements. This work was carried out by the researchers in order to estimate the effective dose to the occupants from ^{222}Rn and its progeny. Based on 24 measurements, the arithmetic mean and standard deviation of the ^{222}Rn concentrations were 293.3 $Bq.m^{-3}$ and 79.6 $Bq.m^{-3}$, respectively. The values are below the upper value of the ICRP reference level of 1500 $Bq.m^{-3}$ for workplaces” [13].

Afolabi et al. [14], “measured the environmental concentration of radon in selective offices in Obafemi Awolowo University Ile-Ife. A pro 3-series radon detector was used to determine the radon levels in randomly selected offices. The result revealed that the radon level obtained in the sampled offices ranged from 0.0 to 5.3 pCi/L (196 $Bq.m^{-3}$). They observed that 95% of the offices surveyed had radon levels within the permissible reference level”.

Asere and Ajayi [15], “measured radon in some homes built of different types of building materials (cement bricks or mud bricks) in Akoko region of Ondo state, Nigeria. The test was conducted using Accustar alpha track long term passive test devices containing CR-39 solid state nuclear track detector foil. Their results showed that radon concentration varies between 15.00 $Bq.m^{-3}$ to 141.00 $Bq.m^{-3}$ with a mean of 35.54 $Bq.m^{-3}$ and geometric mean of 29.95 $Bq.m^{-3}$. Annual effective dose varied between 0.38 $mSv.y^{-1}$ to 0.69 $mSv.y^{-1}$ with a mean of 0.50 $mSv.y^{-1}$.

Oni et al. [16], “estimated lifetime fatality risk from the measured Indoor radon concentrations in some offices in Ladoke Akintola University of Technology (LAUTECH) Ogbomoso, Nigeria. They determined radon levels in those offices with an active electronic radon gas detector, safety Pro 3 (model HS71512)”.

Assessment of indoor radon levels in University of Nigeria offices, Enugu Campus was carried out by Okeji et al., in [17]. “Their purpose was to establish potential for radiation hazards to persons using offices for extended periods of time. They randomly selected four offices from each of the five faculties in the campus, making a total of twenty surveyed offices. The type of radon monitoring device used was an Electret Passive Environmental Radon Monitor”.

4. MATERIALS AND METHODS

The method of collecting data used in this study was through experimental and analytical method. The measurement was taken by placing a detector on a desk or chair in the sampled areas. During the measurement windows were closed and fans were off in other to get accurate measurement. Records of the radon concentration were taking for time ranging from 1hour to 2 hours for accurate value.

The device used in this study is Radon Eye detector (RAD200). RD200 is a Smart and Real time Radon Detector made in South Korea. The RD200 has 20 times higher sensitivity than the other handy radon detectors. It is a type of gas filled detector. The RD200 has the dual structured pulsed-ionization chamber system and highly accurate detection circuit designed by FTLab’s own technology. It displaces measured value for every 10min and gives more accurate value in just one hour which is its minimum measuring time. Also, it offers huge convenience for data logger, graph display, alarm setting (using Bluetooth function with Smartphone).

Detector specification:

- Sensor type: pulsed ion chamber
- First reliable data out: < 1 hour
- Data display interval: 10 min update (1 hour moving average)
- Sensitivity: 0.5cpm/pCi/l (1.35cpm/100Bq/)
- Operating range: 10℃ ~ 40℃, RH < 90%
- Range: 0.1 ~ 99.99 pCi/l (1~3700Bq/ m^3)
- Precision: < 10% at 10pCi/l (370Bq/ m^3)

- Accuracy: < ±10% (min. error < ±0.5pCi/l (±15Bq/m^3))
- Power consumption: DC 12 ± 0.1V, 65mA (12V DC adapter)
- Size: Φ80(mm) x 120(mm) , 240g
- Data communication: Bluetooth LE (Android / IOS)
- Data log: max. 1 year (1 hour step)
- Display: 0.96 inch OLED

Recommended measuring procedure:

Measurement preparation:

- Close the window and door of house
- Place the Radon Eye on the table or desk
- Avoid strong wind from the fan

Power ON/OFF:

- Connect the 12V adapter at Radon Eye and it automatically starts
- Power off: Separate the adapter from unit

Measuring: After measurement starting, do not touch the unit if possible**.** The first reading shows 10 minutes after start while the data is updated every 10 minutes interval. Reliable data will be gotten after an hour.

Each location of the study was used to estimate the annual effective dose and annual absorbed dose of the building. The annual absorbed dose was calculated using equation 1.

$$D\ (mSv.y^{-1}) = C_{Rn} \times D_c \times F \times H \times T \quad (1)$$

Where D is the annual absorbed dose (mSv.y^{-1}); C_{Rn} is the radon concentration (Bq.m^{-3}); D_c is the dose conversion factor (9.0×10^{-6} mSv.h^{-1} per Bq.m^{-3}); F is the equilibrium factor (0.4); T is working hours in a year (2000 hrs); H is the occupancy factor (0.4) [2]. The annual effective dose was calculated by using equation 2.

$$E\ (mSv.y^{-1}) = D \times W_R \times W_T \quad (2)$$

where E is the annual effective dose; D is the annual absorbed dose (mSv.y^{-1}); W_R is the radiation weighting factor for alpha particles (20) according to [1]; W_T is the tissue weighting factor for the lung (0.12) according to [1]. The Lifetime cancer risk was calculated using equation 3.

$$LCR = D \times L \times RF \quad (3)$$

where LCR is lifetime cancer risk; D is the annual effective dose and RF is the risk factor per sievert 0.05 *Sv^{-1}*, L is lifetime expectancy in Nigeria which is about 70 years. The LCR has no unit.

The average of the value is computed using: $\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$, where $\boldsymbol{x_i}$ is individual values of the radon concentration.

The uncertainty in the average value, assuming the uncertainties are independent and follow Gaussian statistics, can be found using: $\sigma_{\bar{x}} = \frac{1}{n}\sqrt{\sum_{i=1}^{n} {\sigma_i}^2}$, σ_i (sigma) is the uncertainty associated with the measurement $\boldsymbol{x_i}$.

5. RESULTS AND DISCUSSION

The Table 1 contains the values of the measured mean radon concentration, estimated annual effective dose, annual absorbed and the average lifetime cancer risk in the study areas. The first segment of the Table 1 shows the data obtained from measurements carried out in ground floors of selected school buildings. The second segment holds the data obtained from storey buildings.

From the investigation, the overall mean radon concentration in measured portions of Nnamdi Azikiwe University was found to be 36.34 *Bq.m^{-3}*, a bit less than the global average of 40 *Bq.m^{-3}.* This average is a little higher than the global average if we restrict the monitoring to only ground floors and underground floors of school buildings.

The mean radon concentration for ground floors of selected buildings was found to be 55.03 *Bq.m^{-3}* which is a bit above the global average. The annual effective dose was found to be 0.3 mSv.y^{-1}. This value is not high enough to constitute to any significant risk. The recommended exposure limit for general public's annual effective dose as recommended by ICRP is 1 *mSv.y^{-1}*.

In locations 2, 3 and 5, the highest average concentrations were recorded as 71.41 *Bq.m^{-3}*, 74.37 *Bq.m^{-3}* and 73.82 *Bq.m^{-3}* respectively. These higher values of radon level could be attributed to the radiological properties of the soil and also, radium containing building materials must have contributed to the increase in radon levels. Though these values are below the safe limit but they still constitute to an average effective dose of 0.5 *mSv.y^{-1}*.

Table 1. Indoor Radon Concentration, annual absorbed dose, annual effective dose and lifetime cancer risk of selected buildings in Nnamdi Azikiwe University, Awka

S/N	Location (Ground-Floor)	Mean Radon Concentration (*Bqm*$^{-3}$)	Annual Absorbed Dose (*mSvy*$^{-1}$)	Annual effective dose (*mSvy*$^{-1}$)	Lifetime Cancer Risk (10-3)
1.	Physics Lab. (First Year)	44.00 ± 10.50	0.127	0.304	1.06
2.	Mgmt. Sciences (Hall 1)	71.41 ± 9.91	0.206	0.494	1.73
3.	Mgmt. Sciences (Hall 2)	74.37 ± 9.87	0.214	0.514	1.80
4.	Mgmt. Sciences (Hall 15)	47.73 ± 16.77	0.137	0.330	1.15
5.	Diploma Hall (Social Sci.)	73.82 ± 4.43	0.213	0.510	1.79
6.	Unizik High School (Phy. Lab)	18.86 ± 5.59	0.054	0.130	0.46
	Average	**55.03 ± 3.34**	**0.158**	**0.380**	**1.33**
	(Upstairs)				
7.	Final Year classroom (Physics)	2.50 ± 1.50	0.007	0.017	0.06
8.	Advanced Physics Lab.	22.60 ± 8.00	0.065	0.156	0.55
9.	General Reading Hall (Lib.)	25.16 ± 2.62	0.072	0.173	0.61
10.	Engineering Reading Hall (Lib.)	9.62 ± 3.51	0.028	0.066	0.23
11.	Math Reading Hall (Lib.)	9.62 ± 3.51	0.028	0.066	0.23
	Average	**13.90 ± 1.98**	**0.040**	**0.096**	**0.33**
	(Combined Exposure)	**36.34 ± 1.94**	**0.105**	**0.251**	**0.88**

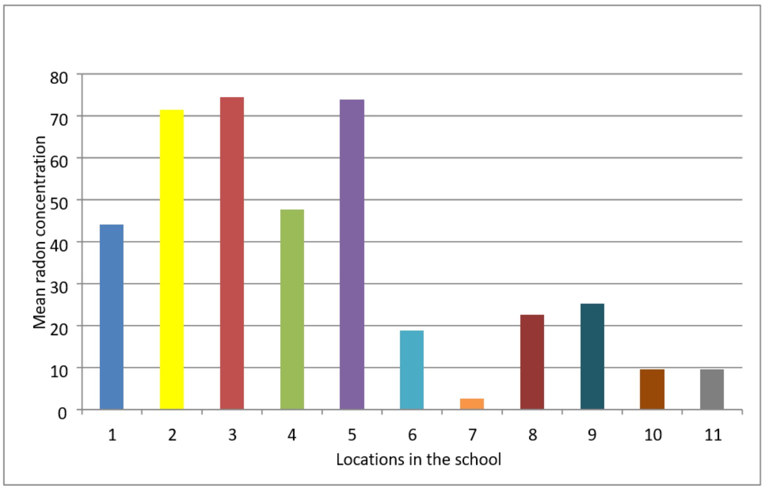

Fig. 1. Variation of Radon Concentration in the Locations

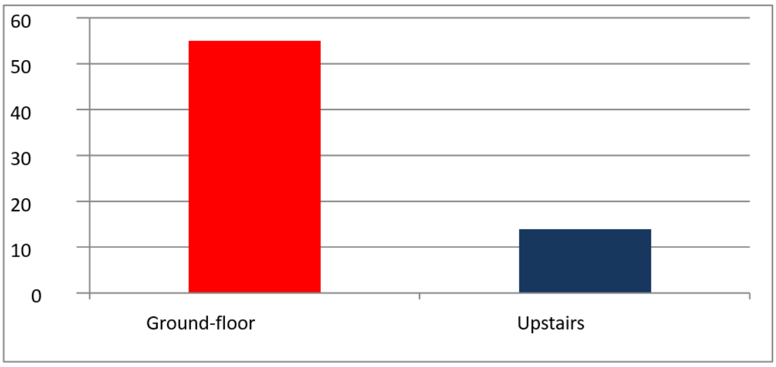

Fig. 2. Shows the variation in radon concentration between ground floors and upstairs

Measurements taken from high-rise floors showed that the risk of cancer is very little compared to readings gotten from ground floors.

The radon concentration is mainly caused by radon gas escaping from the ground and entering the building through cracks in the wall and floor. The close proximity of ground floors/basements to the ground makes such buildings a dumping ground for radon gas leaking from the rocks and the ground. Higher floors have a relatively low radon concentration. One reason for this is the distance to the ground and the underlying rock. The source of radon radiation on high floors can be traced back to the emission of radium-containing building materials.

4. CONCLUSION

The radon measurement was conducted in eleven different locations in Nnamdi Azikiwe University using (RD 200) Radon-Eye detector. The average value of indoor radon concentration was found to be 55.03 ± 9.51 $Bq.m^{-3}$ in ground floor buildings and 13.90 ± 3.83 $Bq.m^{-3}$ for upstairs. The implication of these results is that a person that spends a total of 2000 *hrs/yr* in these ground floor locations will be exposed to an average effective dose of 0.38 $mSv.y^{-1}$, while a worker that spends equal time in the upstairs locations will accumulate an average of 0.096 $mSv.y^{-1}$.

The average radon concentration for all locations put together was found to be 36.34 $Bq.m^{-3}$ which is a bit lower than the global average of 40 $Bq.m^{-3}$. The mean annual effective dose for this study was found to be 0.25 $mSv.y^{-1}$ which is lower than the recommended limit of 1 $mSv.y^{-1}$. With the result of this study, it is safe to say that the risk of cancer due to exposures from the school environment is very minimal.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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