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MEASUREMENT AND ANALYSES OF INDOOR RADON LEVEL AT A UNIVERSITY IN SOUTH-EASTERN NIGERIA

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ABSTRACT: *Lung cancer has been linked to exposure to the naturally occurring ionizing radiation, radon gas (^{22}Rn). Radon is ubiquitous in our environment. However, the level of concentration of this gas is influenced by the geological, geographical, meteorological conditions of a particular environment. The indoor radon concentration is also influenced by factors such as air-conditioning system, ventilation, age of building etc. In this study, the level of indoor radon was measured in 55 offices located within Abia State University, Uturu* ($longitude\ 5^0 42^I N\ and\ latitude\ 6^0 48^I E$)*in South Eastern Nigeria using a Corentium digital radon detector. Uturu is well known for vegetation with high granitic and sedimentary rocks. Offices were chosen to vary between those that are furnished with air conditioning systems and those that are without such facility. Measurements were taken between December 2017 to June 2018. The result of the measurements showed that the indoor radon concentration for all the offices varied between*$0.74 \pm 0.01\ Bq\ m^{-3}$ *to* $39.04 \pm 1.61\ Bq\ m^{-3}$. *This value is lower than the intervention level of* $200 - 600\ Bq\ m^{-3}$ *recommended by International Commission on Radiological Protection (ICRP). The annual effective dose for the offices ranged from* $0.04\ mSv\ y^{-1}$ *to* $2.36\ mSv\ y^{-1}$ *which is below the recommended ICRP intervention level of*$3 - 10\ mSv\ y^{-1}$. *Hence, there is low risk of adverse health effect and lung cancer induction to the staff of Abia State University.*

KEYWORDS*:* indoor radon, lung cancer, effective dose, Nigeria, exposure.

INTRODUCTION

It has been established that radiation monitoring remains a viable way of protecting humans from harmful ionizing radiation. This is because exposure to ionizing radiation can easily result to serious deleterious effects on humans (Jwanbot *et al* 2013). According to the review by Morunke *et al* (2017), cancer incidence and mortality are on the increase on yearly bases in NIgeria. As part of the recommendation by many authors, constant monitoring of cancer causing substances and improvement of lifestyle such as reduced tobacco smoking have been introduced as a way of reducing this sudden surge.

Natural radiation remains the largest contributor to the collective radiation dose to the world population. Such include sources from cosmic, medical, gamma radiation and terrestrial

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radionuclides. The terrestrial radionuclides or primordial radionuclides consist majorly of isotopes of radioactive elements, which include ^{238}U, ^{232}Th, ^{40}K, ^{235}U and their progenies. These radionuclides are ubiquitous in the earth crust and tissues of living tissues. They occur in food, water and in aerosols (Sohrabi 1998, Ajiboye *et al* 2016) Of the primary contributors to natural background ionizing radiation, radon (^{222}Rn) a radioactive gas derived from the decay series of the primordial radioactive element ^{238}U, remains the largest contributor to naturally ionizing radiation (WHO, 2009). Radon has long been recognized as a cause of lung cancer and it was identified as a human lung carcinogen. It is the second largest cause of lung cancer after smoking (WHO, 2009; UNSCEAR 2000).

Radon-222 is a naturally occurring odourless, colourless, tasteless and chemically inert gas with a half-life of 3.8 days. Inhaling radon gas does not actually pose any health risk; the real danger comes from its progenies, Po-218 and Po-214 that are high alpha emitter (Oni *et al* 2012). Alpha particles become more dangerous if it gets into the body in any way. The viable ways by which they can have access into the tissues of the body are if they are ingested through eating, drinking or inhaled. High-energy deposition of this particle (alpha) in lungs tissue can lead to DNA damage (Oni *et al* 2012; Obed *et al* 2012).

Radon is particularly ubiquitous in an environment with high content of granitic and sedimentary rocks (Eisenbud *et al* 1997). The concentration of radon is dependent on three main factors; they are the geological, geophysical and atmospheric conditions of the environment. Specifically, the concentration of radon in any soil is contingent on the Uranium content of such soil (Ajiboye *et al* 2016, Sumner *et al* 1991).

Radon can exist indoor, outdoor (in the atmosphere), in water and in the soil. Indoor radon consists of radon that exists inside enclosed spaces such as living rooms, offices, mines, quarries and caves. In the rainy season, the concentration of indoor radon tends to be high because common practice will include the closure of doors and windows. This is not the case with dry season as the doors and windows are normally open to aid ventilation. The attendant effect being, decrease in the concentration of indoor radon gas (Obed *et al* 2011, Durrani *et al* 1997, Ushie *et al* 2016).Other factors that can influence the concentration of indoor radon include; building materials, building age and air pressure (Obed *et al* 2011). Extensive work has been carried out to estimate indoor radon. Table 1, shows the radon level as determined for various cities in some developed and developing countries. The table also contains the upper limit as determined by various agencies that sets rules for radiation protection. International Commission for Radiological Protection (ICRP) an independent, international, non-governmental organization, which has the mission to provide recommendations and guidance on radiation protection, set the upper limit of 222-Rn to be 200-600 Bq/m^3.

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Table 1: National and international environmental values for 222Rn concentration indoors and recommended upper limits

Environmental values	222Rn concentration (Bq/m^3)
El-Minia City, Egypt	123
Cairo, Egypt	24-55
Belgium	48
Czech Republic	140
Cyprus	7
Finland	120
Kazakhstan	10
Poland	41
Romania	45
United States	46
Upper limit	
EPA	148
ICRP	200-400
Sweden	400
CNSC occupational	148
CNSC public exposure	600-1000

Source: El-Gamal and Hosny (2008); EPA: US Environmental Protection Agency; ICRP: International Commission on Radiological Protection; CNSC: Canadian Nuclear Safety Commission

Few studies have measured the indoor radon levels in Nigeria (Obed et al 2011; Ushie et al 2016, Ademola 2012) and they were all carried out in South-Western states of Nigeria. The main reason for this may be due to the high granitic and sedimentary content of rocks in the region. In all research, none reported indoor radon level that exceeded the upper limit of 10 mSv/y set by ICRP (ICRP 2009). The recommended ICRP intervention level for the effective dose is 3-10 mSv/y. Indoor radon assessment in the South-Eastern Nigeria is scarce. The aim of this work therefore is to fill in the gap and provide dependable data on the concentration of radon in the region.

MATERIALS AND METHOD

Study area

Abia State University, Uturu is located on latitudes $latitudes\ 5^0 46.742^I N\ and\ 5^0 46.742^I N\ and\ longitude\ 7^o 23.159' E\ and\ 7^o 23.159' E$ within Isuikwuato area of southeastern Nigeria (Igboekwe *et al* 2011). It is bounded by Ihube and Leru on the North, Umuahia and Bende on the South, Uturu on the east and Okigwe by the West. The rock component of Abia State University and Uturu as a whole is hugely made up of granitic and sedimentary rocks. In the area surrounding the University, there are many quarry sites where rocks are mined for building construction and other purposes.

Sampling

Indoor radon was measured in 55 offices located within Abia State University, Uturu. Offices were chosen to vary between those that are furnished with air conditioning systems and those that are without such facility. Measurements were taken between December 2017 to June 2018. The offices measured were located in different buildings in the University with wide age difference that range between 10 – 20 years. The offices are of relatively same dimension (2.4 m X 3.6 m). The windows of the offices were usually kept closed especially after work hour. Common ventilation condition involving opening of doors and windows during office hours were maintained.

Instrumentation

An active Corentium Digital Radon Monitor (model QRI: dimensions 120mm x 69mm x 25.5mm) was used. The detector is a battery-operated device, which comes in a small box with 3 AAA batteries. It is also popularly used in developed countries like Canada, Norway, USA. The detector was normally placed in the office at a location that is representative of the air that is breathed in the office. The monitor was not exposed to direct sunlight or electromagnetic radiation. The monitor was positioned lying flat at least 25 cm from the nearest wall, at least 50 cm above the floor and at least 150cm from the nearest door, window or ventilation device. The monitor was normally left untouched for the duration of the measurement.

The detector can be used to measure both long term and short-term averages of indoor radon. In contrast with other available radon gas detectors, the CORENTIUM detector has a large Liquid Crystal Display (LCD), it uses advanced technology, quite portable, and takes only 24 hours to give an exact and safe reading for indoor Radon. The instrument is a handheld device with an indicator that reads in picocurie per liter (pCi/L). This value is thereafter converted to Bqm^{-3} by multiplying by 37, a constant. Before the detector starts to record a radon value, it takes 48 hours to calibrate (This value may vary depending on the concentration of radon in such environment). A RESET button was used to return the monitor to default settings before it is used in a new office or new environment. New values of radon are displayed if the values differ for the previous hour.

Radon measurement in offices

For this work, the short-term average was used. Short term averages show radon reading for one day (updated every hour). For each office, readings were taken for the occupancy duration, which spans from (9am – 4pm).

Estimation of annual effective dose

The unit of the indoor radon gas concentration value obtained with the monitor is in pCi/L. The average value of the radon is then converted to the required to unit of Bqm^{-3}. This can be done by multiplying the average value by 37.
The dose of radon in mSv/y is then obtained using the formular

$$annual\ dose\ of\ radon\ (mSv/y) = \sum (C_{Rn} \times D \times F \times T)$$

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$\boldsymbol{C_{Rn}}$ is the effective dose received by adult per 222Rnper unit of air volume. It is a constant with value $9.0 \times 10^{-6}\ mSvh^{-1}perBqm^{-3}$
$\boldsymbol{T}$ is indoor radon occupancy factor given as

$$0.4 \times 24\ (hrs) \times 365\ (days) = 3504$$

$$where\ 0.4\ is\ from\ {}^{9hrs}/_{24hrs}$$

$\boldsymbol{F}$ is the equilibrium factor for radon. It is constant value 0.8
$\boldsymbol{D_A}$ is the average dose measured in Bqm^{-3}
The Annual effective dose is calculated from the annual effective dose with the formula

$$annual\ Effective\ dose = \sum W_T Q_{TR}$$

$$where \qquad Q_{TR} = W_R \times D_A$$

$$annual\ Effective\ dose = W_T \times W_R \times D_A$$

$$W_R\ \ is\ the\ radiation\ weighting\ factor. For\ alpha\ particles = 20$$
$$W_T\ is\ the\ tissues\ wieghting\ factor. W_T\ \ for\ lung = 0.12$$ (Bushberg et al 2002)

The values obtained were then compared with the intervention level recommended by International Commission on Radiological Protection (ICRP). The formulars as shown here where used to analyze the raw data obtained from measurement for each office.

RESULTS AND DISCUSSIONS

Indoor Radon concentrations were measured for 55 offices. Readings were taken hourly and then the mean of the days was used for calculation. The value of the effective dose represents the average value for each office from all the daily measurement. The effective dose was estimated from the mean of the indoor radon dose for each office
Summary of the effective radon dose in 55 offices investigated are presented in tables 2 – 8.

Table 1: Annual Effective radon dose for offices in New Science block

Offices	Mean radon concentration (Bq m^{-3})	Annual Effective dose (mSv y^{-1})	Offices	Mean radon concentration (Bq m^{-3})	Annual Effective dose (mSv y^{-1})
DOWNSTAIRS			***UPSTAIRS***		
OFFICE 16	18.82±1.19	1.14	OFFICE 21	39.04±1.61	2.36
OFFICE 17	16.79±2.61	1.02	OFFICE 22	18.59±1.54	1.13
OFFICE 18	19.29±1.61	1.17	OFFICE 23	8.04±0.51	0.49
OFFICE 19	11.01±3.19	0.67	OFFICE 24	12.58±1.14	0.76
OFFICE 20	16.51±1.76	0.20	OFFICE 25	17.76±0.00	1.08

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The highest value was measured at the 'New science block upstairs' (Table 1) where the value of $39.04 \pm 1.61\, Bqm^{-3}$ was obtained. This is equivalent to the annual effective dose of $2.36\, mSvy^{-1}$. The lowest value was obtained at the medical block (Table 2), where the value of $0.00\, Bqm^{-3}$ was measured. In all, the highest mean indoor radon was measured at the new science block (upstairs and downstairs) as compared with other offices at other office blocks. The lowest mean indoor radon was measured at the medical block.

Table 2: Annual Effective radon dose for offices in Medicine and Surgery block

Offices	Mean radon concentration (Bq m^{-3})	Annual Effective dose (mSv y^{-1})
	UPSTAIRS	
OFFICE 46	0.74±0.00	0.04
OFFICE 47	1.85±0.00	0.11
OFFICE 48	1.85±0.00	0.11
OFFICE 49	0.37±0.00	0.00
OFFICE 50	1.85±0.00	0.11

Table 3: Annual Effective radon dose for offices in Medical Laboratory Science block

Offices	Mean radon concentration (Bq m^{-3})	Annual Effective dose (mSv y^{-1})	Offices	Mean radon concentration (Bq m^{-3})	Annual Effective dose (mSv y^{-1})
	DOWNSTAIRS			***UPSTAIRS***	
OFFICE 26	10.73±0.00	0.65	OFFICE 31	1.85±0.00	0.11
OFFICE 27	10.73±0.00	0.65	OFFICE 32	3.70±0.00	0.22
OFFICE 28	11.29±0.59	0.68	OFFICE 33	2.45±0.86	0.15
OFFICE 29	11.70±0.71	0.71	OFFICE 34	2.82±0.39	0.17
OFFICE 30	10.73±0.00	0.65	OFFICE 35	3.19±0.65	0.19

Table 4: Annual effective radon dose for offices in Faculty of Biological Science (FBS) block

Offices	Mean radon concentration (Bq m^{-3})	Annual Effective dose (mSv y^{-1})	Offices	Mean radon concentration (Bq m^{-3})	Annual Effective dose (mSv y^{-1})
	DOWNSTAIRS			***UPSTAIRS***	
OFFICE 1	7.77±0.00	0.47	OFFICE 11	4.53±0.51	0.27
OFFICE 2	8.42±1.59	0.51	OFFICE 12	0.74±0.00	0.04
OFFICE 3	6.98±1.04	0.42	OFFICE 13	8.33±0.59	0.50
OFFICE 4	10.08±0.80	0.61	OFFICE 14	5.04±1.31	0.31
OFFICE 5	11.38±0.86	0.69	OFFICE 15	6.38±2.40	0.39
OFFICE 6	6.66±0.00	0.40			
OFFICE 7	5.97±0.96	0.36			
OFFICE 8	4.49±1.04	0.27			
OFFICE 9	4.82±0.00	0.29			
OFFICE 10	4.07±0.93	0.25			

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It is evident from the Table 2 - 8 that there are different factors that affect the concentration of radon at a particular region or office. Such factors, which include building materials for construction, age of building. The indoor radon measured at offices downstairs were mostly higher than that measured downstairs for offices at FBS block (Table 4). This confirms that as we go lower to the earth, the indoor level increases. This was also evident in Med. Lab. science block (Table 3). The indoor radon measured at new science block (Table 1) seems to be higher than that measured at other offices. This may be because of the building materials used in constructing the office building. Visual inspection showed that there were so many cracks at the building of new science block. Gases such radon can emanate from such cracks.

Table 5: Annual Effective radon dose for offices in Olu Obasanjo block

Offices	Mean radon concentration (Bq m^{-3})	Annual Effective dose (mSv y^{-1})
DOWNSTAIRS		
OFFICE 36	12.3±2.35	0.77
OFFICE 37	3.70±0.00	0.60
OFFICE 38	2.45±0.65	0.64
OFFICE 39	2.82±1.38	0.10
OFFICE 40	3.19±1.27	0.69

Table 6: Annual Effective radon dose for offices in <u>Mathematics and Statistics</u> block

Offices	Mean radon concentration (Bq m^{-3})	Annual Effective dose (mSv y^{-1})
UPSTAIRS		
OFFICE 41	6.01±0.26	0.36
OFFICE 42	6.57±0.00	0.38
OFFICE 43	6.66±0.00	0.40
OFFICE 44	5.92±0.00	0.36
OFFICE 45	6.66±0.00	0.40

Table 8: Annual Effective radon dose for offices in <u>Political Science</u> block

Offices	Mean radon concentration (Bq m^{-3})	Annual Effective dose (mSv y^{-1})
UPSTAIRS		
OFFICE 51	7.77±0.00	0.47
OFFICE 52	8.14±0.00	0.49
OFFICE 53	9.39±1.12	0.57
OFFICE 54	14.11±0.57	0.85
OFFICE 55	2.96±0.07	0.18

Offices that have air-conditioning facilities have lower indoor radon when compared with offices that do not have such facility. This was quite conspicuous for offices at New science block as office 17, 19, 20 and 24 had air-conditioning facilities, while, office 16, 18 and 21 (Table 1) do not have such facility. This was also evident at the political science block (Table 8) where Office 55 was the only one with an air conditioning facility.

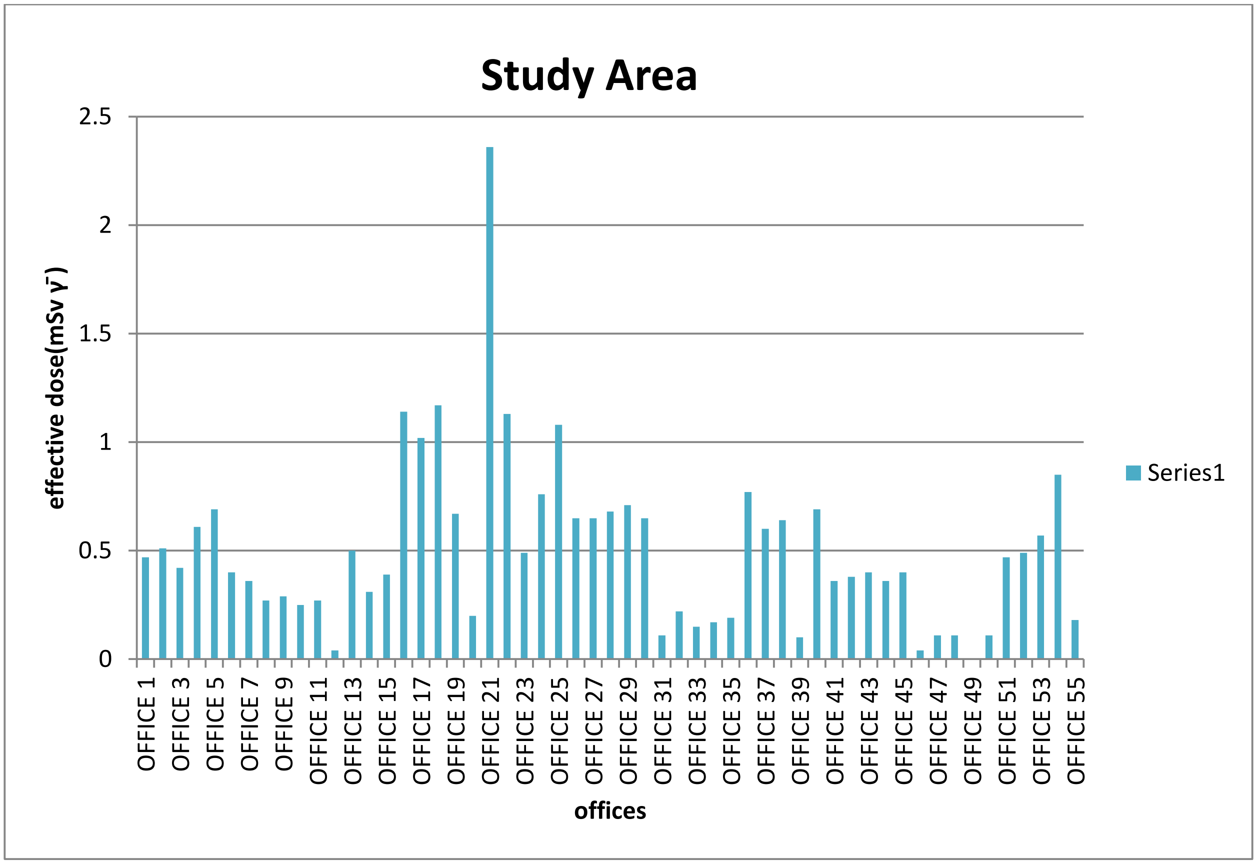

Fig 1: Graph of effective radon dose for all the offfices

For all the offices, the mean radon concentration of $10.09 \pm 0.79\ Bqm^{-3}$ was measured. This represents the average mean indoor radon for the offices measured at Abia State University. This value $10.09 \pm 0.79\ Bqm^{-3}$ was found to be lower than the intervention level $200 - 600\ Bqm^{-3}$ as recommended by International Commission on Radiological Protection (ICRP, 1993). The values of the effective dose for the offices are as summarized in Fig 1. The plot shows that the radon for the offices varied between $0.04 - 2.36\ mSvy^{-1}$. This value is below the range of action level $3 - 10\ mSvy^{-1}$ recommended by ICRP.

Prototype of this work has been carried out in some tertiary institutions in the Southwestern region of Nigeria. Results show that the average radon dose value obtained for all the offices at Abia state university $10.09 \pm 0.79\ Bqm^{-3}$ was low when compared with the measurement obtained at Ladoke Akintola University of Technology, Ogbomosho Nigeria LAUTECH ($26.30 \pm 4.17\ Bqm^{-3}$) (Oni *et al* 2012).

In all, the annual effective dose of indoor radon measured for all the offices was below the intervention range as recommended by ICRP. This shows that the lung cancer risk due to indoor radon from offices of the University is very low.

CONCLUSIONS

The result of this work shows that measurable naturally occurring ionizing radiation that is within the range of $0.74 \pm 0.01\ Bq\ m^{-3}\ \ to\ \ 39.04 \pm 1.61\ Bq\ m^{-3}$ exists in Abia State University. The effective dose of radon in offices investigated was lower than the intervention range set by ICRP. This implies that that the staff of Abia State University are in no way facing a threat of lung cancer disease, which is one of the stochastic effects of exposure to ionizing radiation such as alpha particle.

However, if the Linear-no-threshold model (LNT model) which says that – no matter how small the dose is there is a probable effect – is considered, then there is need to put in measures to further mitigate the concentration of radon in offices at Abia State University Uturu. Such measures can include: Installation of air-conditioning equipment in all the offices, Using stronger building materials in the building of structures to reduce cracks in walls (radon gas is easily released from openings in buildings), and ensuring that offices are well ventilated.

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