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Measurement of Indoor Radon Concentration and Associated Health Risks in Selected Elementary Schools in Lafia, Nasarawa State, Nigeria

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Abstract

Indoor radon concentration was measured in selected elementary schools across Lafia, Nasarawa State, Nigeria, using passive diffusion cups fitted with CR-39 detectors. The rooms were selected based on varying natural ventilation conditions and height above ground level. Detectors were deployed in classrooms and offices for a period of 90 days. After exposure, the detectors were etched using sodium hydroxide (NaOH) at 90 °C for 3 hours. Alpha tracks were counted and photographed using a digital camera attached to a microscope and computer system. The arithmetic and geometric mean radon concentrations were 193.3 Bq m^{-3} and 182.4 Bq m^{-3}, respectively. The mean annual effective lung dose was 0.24 $mSv \cdot y^{-1}$, with an excess lifetime cancer risk of 1.0 MPY^{-1}. Factors such as ventilation rate, proximity to the ground, and construction materials of floors, walls, and ceilings were investigated. An inverse relationship ($R^2 = 0.6$) was observed between radon concentration and ventilation rate. Rooms situated closer to the ground exhibited higher radon levels. Concrete and asbestos materials were associated with higher radon concentrations, whereas painted and carpeted surfaces recorded lower values. The measured radon concentrations were below the International Commission on Radiological Protection recommended action level of 300 Bq m^{-3} for workplaces.

Keywords: Radon; radiation protection; ventilation; environmental radiation; radioactivity.

I. INTRODUCTION

Radon is a radioactive, colourless, and odourless gas formed from the decay of uranium naturally present in soils and rocks. Due to its gaseous nature, radon can migrate through soil and enter buildings, where it may accumulate in enclosed environments such as homes, schools, and workplaces [1].

Epidemiological studies have shown that prolonged exposure to ionising radiation from short-lived radon progeny increases the risk of lung cancer in humans [2]. Radon exposure is recognised as one of the leading causes of lung cancer deaths in the United States of America (USA), contributing to thousands of deaths annually. Similarly, in the United Kingdom (UK), radon exposure is the second leading cause of lung cancer, responsible for approximately 2,000 deaths per year [3]. Notably, radon is the leading cause of lung cancer among non-smokers [4].

In outdoor environments, radon is typically diluted to very low concentrations and poses minimal health risk. However, indoor environments facilitate its accumulation, particularly in areas with poor ventilation. Recent studies in Nigeria have reported elevated indoor radon concentrations in residential and public buildings, in some cases exceeding recommended limits and indicating potential long-term health risks [5]. Similar observations have been reported in other parts of Africa, particularly in poorly ventilated buildings [6]. Radon enters buildings through cracks and openings in foundations [7].

School buildings are important environments where students and teachers spend considerable time. On average, children spend between 30 and 50 hours per week in school, making it a significant exposure setting. Children are more vulnerable to environmental pollutants such as radon due to their developing tissues and higher respiration rates relative to body size. Consequently, prolonged exposure during childhood may increase the risk of lung cancer in later life [8 - 9].

II. MATERIALS AND METHODS

A. *Study Area*

Lafia is the headquarters of Lafia Local Government Area and the largest town in Nasarawa State, with a population of 330,712 according to the 2006 census. It shares boundaries with Wamba (north), Nasarawa Eggon (north-west), Obi (south), Doma (south-west), and Plateau State (east) (see Fig. 1). Lafia lies between latitudes 8.4012°N to 8.6100°N and longitudes 8.4212°E to 8.6510°E [10].

The geology of Nasarawa State consists of Basement Complex rocks such as granites and gneisses, as well as sedimentary rocks [11 - 12]. The rocks upon which Lafia and its surrounding areas are founded include the Agwu, Asu, and Lafia Formations.

The rock types that make up the Agwu Formation include limestone and shale. The limestone in this formation comprises sandy limestone, shaly limestone, coal seams, and siltstone, while the shale consists of calcareous shale and bluish-grey to dark, carbonaceous shale.

The Asu Formation is composed mainly of mudstone and shale. Other components of this formation include calcareous, micaceous, and clay-rich materials, as well as limestone. The youngest of all the formations is the Lafia Formation, which is also the most dominant. The Lafia Formation consists essentially of loose red sands and ferruginized sandstones. The Lafia area is underlain by rhythmic sequences of shale, siltstone, sandstone, and limestone with varying thicknesses of interbedded coal, indicating deposition under shallow marine conditions. The coal has high ash and moisture contents, suggesting good potential for use in the steel industry.

Areas underlain by the Lafia Formation are observed to have the highest groundwater yield. The availability of groundwater in these sedimentary rocks depends on factors such as fractures, porosity, permeability, and the degree of jointing in the rocks [13].

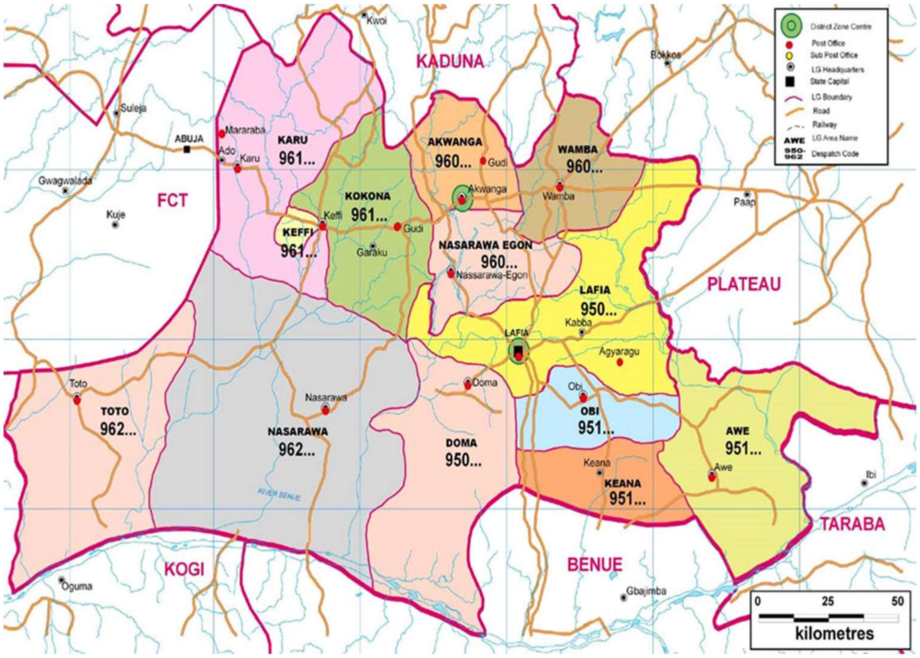

Fig. 1. Map of Nasarawa State showing Lafia Metropolis. Source: Field Work [14].

B. *Sampling and Detector Deployment*

In this study, sixty-two (62) Solid State Nuclear Track Detectors (SSNTDs), consisting of square and rectangular CR-39 detectors were randomly distributed across sixteen purposively selected elementary schools in Lafia metropolis, Nasarawa State, Nigeria. The table shows the schools selected, alongside their corresponding GPS coordinates.

Table I. Names of Schools Selected in Lafia Metropolis and their corresponding GPS coordinates.

S/N	School Code	No. of Detectors per Room	Name of School	GPS Location
1.	La-A	4	Melchizedek Academy, Ombi I, Opp. Nasarawa State Polytechnic, Lafia	Longitude: 8.5355675 Latitude: 8.5451195
2.	La- B	4	Lafia East Pilot Science Primary School, Beside Lafia Modern Market, Lafia	Longitude:8.5252343 Latitude:8.4911858
3.	La- C	4	Uyisa Model School, Gandun Sarki, Lafia	Longitude: 8.5607945 Latitude: 8.4868401
4.	La- D	4	Yumaco International Academy, Lafia	Longitude: 8.5387754 Latitude: 8.5151534
5.	La- E	4	Sandaji Elementary School, Shendam Way, Opp. Lafia Hotel, Lafia	Longitude: 8.5343875 Latitude: 8.5047803
6.	La- F	4	Basic Foundation Elementary School, Mararaba Akunza, Lafia	Longitude: 8.5768634 Latitude: 8.4719977
7.	La- G	4	L.G.E.A. Primary School, Bukan Kwato, Lafia	Longitude: 5.5506244 Latitude:8.4810277
8.	La- H	4	Sterling Academy, Workers Village, Tundun Amba, Lafia	Longitude: 8.5026125 Latitude: 8.4830206
9.	La- I	4	Essential International School, Govt. House by-pass, Lafia	Longitude: 8.541605 Latitude: 8.4960669
10.	La- J	4	Islamiyya Elementary School, Shabu, Lafia.	Longitude: 8.5569416 Latitude: 8.5910922
11.	La- K	4	ECWA Elementary School, Modern Market Road, Tudun Kauri, Lafia	Longitude: 8.5347404 Latitude: 8.4916344
12.	La- L	4	National Elementary School, Tudun Kauri, Lafia	Longitude: 8.5373772 Latitude: 8.4944464
13.	La- M	4	Ultimate Knowledge Academy, Lafia	Longitude: 8.533996 Latitude: 8.4893511
14.	La- N	4	Government Special School, Opposite College of School Agriculture, Lafia.	Longitude: 8.549195 Latitude: 8.5692387
15.	La- O	3	Primetime Royal Academy, Bukan Sidi, Lafia.	Longitude: 8.5318717 Latitude: 8.5236907
16.	La- P	3	San-Kinkilo Elementary School, Kurikio, Lafia	Longitude: 8.5571593 Latitude: 8.5724924

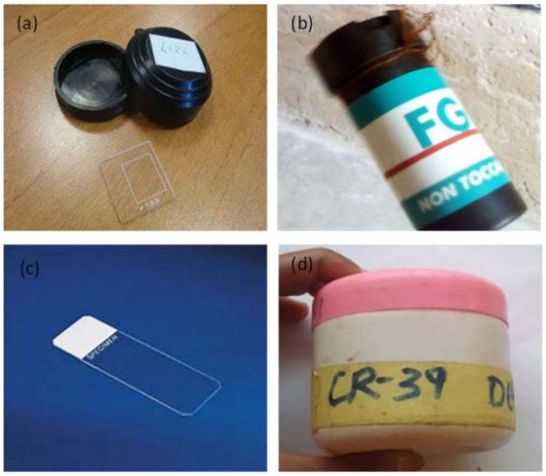

Fig. 2. CR-39 detectors and passive diffusion cups with varying dimensions used in the study.

Two (2) types of Solid-State Nuclear Track Detectors (SSNTDs), each with distinct dimensions were utilised.

(i) Square-shaped CR-39 detector of dimensions $1.0\ cm \times 1.0\ cm$, $1.0\ mm$ thick, which was contained in a passive diffusion cup of height $5.5\ cm$, and diameter $2.0\ cm$ as shown in Fig. 2(a)-(b), and

(ii) Rectangular-shaped CR-39 detector of dimensions $3.7\ cm \times 1.3\ cm$, 1.0 mm thick, which was contained in a passive diffusion cup of height $5.0\ cm$, and diameter $5.8\ cm$ as shown in Fig. 2(c)-(d).

The detectors were affixed to the base of passive diffusion cups using plasticine and sealed with adhesive tape to prevent air leakage and minimize background exposure before deployment.

C. *Measurement Procedure*

Indoor radon concentration was measured using CR-39 SSNTDs placed in selected classrooms and offices (see Fig. 3). Detectors were installed at a height of approximately $1.0\ m$ above the floor, corresponding to the human breathing zone. Care was taken to position detectors away from windows, doors, and direct airflow. Exposure lasted for 90 days. After exposure, detectors were etched in 6.25 M sodium hydroxide solution at 90 °C for 3 hours. They were then rinsed with distilled water and dried.

Alpha tracks were examined using an optical microscope connected to a digital camera and computer system. Track density was determined from multiple fields of view.

Fig. 3. Radon detector suspended at breathing height in a classroom.

D. Track Density (D_t)

Track density (D_t) was calculated using (1).

$$(D_t) = \frac{\sum_{i=1}^{n} N_i}{nS} \tag{1}$$

Where (N_i) is the number of tracks in the (i^{th}) field of view, (n) is the total number of fields of view analyzed, and (S) is the area of each field of view (mm^2) [15].

Background correction was applied using unexposed detectors.

E. Radon Concentration (R_n)

Radon concentration (R_n) was calculated using (2).

$$R_n = \frac{D}{CF \times \Delta t} \tag{2}$$

Where (R_n) is the radon concentration ($Bq\ m^{-3}$), D is the corrected track density (tracks mm^{-2}), CF is the calibration factor ($Bq\ m^{-3}$ per tracks $mm^{-2}\ day^{-1}$), and t is the exposure time (90 days).

The calibration factors (CF) were obtained from the detector manufacturers and inherently account for the detection efficiency of the CR-39 detectors under controlled calibration conditions. The values used in this study were 997.14 tracks per mm^{-2} per ($Bq\ m^{-3}\ day$) for detectors of dimensions $3.7\ cm \times 1.3\ cm \times 1.0\ mm$, and 1862.00 tracks per mm^{-2} per ($Bq\ m^{-3}\ day$) for detectors of dimensions $1.0\ cm \times 1.0\ cm \times 1.0\ mm$. Variations in these values are attributed to differences in detector geometry and effective sensitive area, consistent with previous studies on CR-39 detector response characteristics.

The uncertainty in radon concentration was estimated using standard error propagation techniques, taking into account uncertainties associated with track counting statistics, background correction, calibration factors, and exposure time. The combined relative uncertainty is given by (3).

$$\frac{\Delta R_n}{R_n} = \sqrt{\left(\frac{\Delta D}{D}\right)^2 + \left(\frac{\Delta CF}{CF}\right)^2 + \left(\frac{\Delta t}{t}\right)^2} \tag{3}$$

Where (ΔD), (ΔCF), and (Δt) represent uncertainties in corrected track density, calibration factor, and exposure time, respectively. The dominant sources of uncertainty were associated with track counting and calibration factor variability.

Based on the measured radon concentrations, additional radiological parameters, including working level (WL), working level month (WLM), annual effective dose (H), and excess lifetime cancer risk (ELCR), were calculated using standard models recommended by the United Nations Scientific Committee on the Effects of Atomic Radiation and the International Commission on Radiological Protection [16].

F. Working Level (WL)

Potential Alpha Energy Concentration in terms of Working Level was calculated using (4).

$$PAEC\ (WL) = \frac{F \times R_n}{3700} \tag{4}$$

Where R_n is the Radon concentration in Bqm^{-3}

F is the equilibrium factor, for schools and offices, $F = 0.4$ [8], [15].

G. Working Level Month (WLM)

Potential Alpha Energy Concentration in terms of Working Level Month was calculated using (5).

$$WLM = WL \times \frac{T}{170\ \text{hours}} \tag{5}$$

Where T is hours in a year, which is equal to 1825 hours [8].

H. Effective Dose

The effective dose to the lung was calculated using (6).

$$H = R_n \times F \times O \times T \times DCF \tag{6}$$

Where O is the Occupancy factor, which is equal to 0.2, and DCF is the dose conversion factor, which is equal to $9.0\ nSv\ (Bq\ m^{-3})$ [16].

I. Excess Lifetime Cancer Risk (ELCR)

Excess lifetime cancer risk (ELCR) was estimated using (7).

$$ELCR = H \times DL \times RF \tag{7}$$

Where H is the Effective dose, DL is the life expectancy (70 years), and RF is the risk factor ($0.055\ Sv^{-1}$) [8], [16].

J. Ventilation Rate

The change in natural ventilation rate in air per hour was calculated for each room using (8) and (9). The volume of each room was calculated using the measurements of length, width, and height, while the area of the openings in each room was determined by measuring the length and width of both the windows and doors. The velocity of air was measured using a digital anemometer placed about 2.0 meters from each opening. This process was repeated three times: once on the first day of exposing the detector, the second measurement was taken after 45 days of exposure, and the last measurement was taken when retrieving the detector. The average of these was used as the velocity of air.

$$Ventilation\ rate\ in\ ACH^{-1} = \frac{Q}{V} \times 60 \qquad (8)$$

Where Q is the airflow rate in cubic feet per minute (CFM), V is the volume of the room, and the 60 is used to convert per minute to per hour in the expression.

$$Q = Total\ area\ of\ opening \times velocity\ of\ air \qquad (9)$$

III. Results and Discussion

The respective mean values of indoor radon concentration, working level, working level months, effective dose, excess lifetime cancer risks, and ventilation rates as presented in Table II, are 193.3 $Bq.m^{-3}$, 20.90 mWL, 0.23 $mSv.y^{-1}$, 0.24 y^{-1}, 1.0 $(MPY)^{-1}$ and 1.42 ACH^{-1}, respectively. Among these schools, La-I (Essential International School, Govt. House by-pass, Lafia) exhibits the highest mean indoor radon concentration of 309.75 $Bq.m^{-3}$, while La-E (Sandaji Elementary School, Shendam Way, Opp. Lafia Hotel, Lafia) shows the lowest (78.50 $Bq.m^{-3}$).

These values indicate that several classrooms and offices may experience sustained indoor radon exposure at levels capable of contributing to long-term radiological risk, particularly in environments where occupancy duration is high, such as schools.

Table II. Variation of Radon Concentration, PAEC, Effective Dose, ELCR, and Ventilation Rate in the sixteen (16) Selected Elementary Schools in Lafia

S/N	School	Number of Detectors	Radon Concentration $(Bq.m^{-3})$	PAEC		Effective Dose $(mSvy^{-1})$	ELCR × 10^{-3} $(MPY)^{-1}$	Ventilation Rate ACH^{-1}
				WL (mWL)	WLM (y^{-1})			
1.	A	4	158.0	17.08	0.32	0.2	0.8	1.27
2.	B	4	144.8	15.65	0.17	0.19	0.7	2.07
3.	C	4	118.3	12.78	0.14	0.16	0.6	1.48
4.	D	4	118.3	12.78	0.14	0.16	0.6	1.77
5.	E	4	78.5	8.49	0.09	0.10	0.4	2.50
6.	F	4	131.5	14.22	0.15	0.17	0.7	1.40
7.	G	4	258.8	27.97	0.30	0.34	1.3	1.42
8.	H	4	236.3	25.54	0.27	0.31	1.2	1.41
9.	I	4	309.8	33.49	0.36	0.41	1.6	0.73
10.	J	4	237.0	25.62	0.28	0.31	1.2	0.68
11.	K	4	216.3	23.38	0.25	0.28	1.1	1.66
12.	L	4	207.8	22.46	0.24	0.27	1.1	1.79
13.	M	4	210.7	22.78	0.24	0.28	1.1	1.73
14.	N	4	260.0	28.11	0.30	0.16	1.3	0.96
15.	O	3	191.7	20.72	0.22	0.25	1.0	0.89
16.	P	3	214.3	23.35	0.25	0.28	1.1	1.03
Arithmetic Mean ± SD			193.3 ± 62.9	20.90 ± 6.81	0.23 ± 0.08	0.24 ± 0.08	1.0 ± 0.3	1.42 ± 0.50
Geometric Mean ± SD			182.4 ± 60.9	19.73 ± 6.59	0.22 ± 0.07	0.23 ± 0.08	0.9 ± 0.3	2.34 ± 0.48
Max			309.8	33.48	0.36	0.407	0.318	2.50
Min			78.5	8.48	0.09	0.103	0.397	0.68

A. Indoor Radon Concentration in Classrooms and Offices

The mean values of indoor Radon concentration, working level, working level months, effective dose, and excess lifetime cancer risks in all classrooms, offices, ground floors, and first floors are presented in Table III.

The average value of indoor Radon concentration in classrooms is 205.6 $Bq.m^{-3}$, slightly higher than

($198.8\ Bq.m^{-3}$) in offices, possibly due to differences in shielding, occupancy patterns, and interior surface characteristics. This finding aligns with [8], indicating higher Radon levels in classrooms.

Although the independent t-test analysis presented in Table IV suggests that the difference between indoor Radon concentration in offices and classrooms is not statistically significant (p = 0.071) at 95% confidence level with equal variance assumed, the radiological implication remains important. Radon risk is strongly dependent on duration of exposure rather than only statistical differences in concentration.

This is particularly critical in school environments, where children are the most exposed population group. Children breathe faster than adults relative to body size, and their lung tissues are still developing, making them more sensitive to ionizing radiation damage. Consequently, even moderate radon concentrations in classrooms may contribute to cumulative lifetime radiation dose, increasing the probability of developing lung cancer later in life.

Table III. Mean radon concentration in all classrooms, offices, ground floors, and first floors.

S/N	Radon Conc. ($Bq.m^{-3}$)	PAEC		Effective Dose ($mSvy^{-1}$)	ELCR x 10^{-3} $(MPY)^{-1}$
		WL (mWL)	WLM (y^{-1})		
Mean for Classrooms	205.6	23.06	0.26	0.27	1.08
Mean for offices	198.8	21.78	0.23	0.22	1.02
Mean for Ground Floor	206.1	21.65	0.24	0.25	1.01
Mean for the First floor	98.4	10.56	0.18	0.12	0.45

Table IV. Summary of t-test analysis of the difference between the mean Radon concentration levels in offices and classrooms

	Levene's Test for Equality of Variances		t-test for Equality of Means			
	F	T	df	p-values	Mean Difference	Std. Error Difference
Equal variances assumed	3.829	-2.833	57	0.071	-80.71	28.59
Equal variances not assumed		-3.571	51.6	0.061	-80.71	22.60

B. *Effect of Soil Proximity on Indoor Radon Concentrations*

The average indoor Radon concentration on the first floor, as presented in Table III, was estimated to be $98.4\ Bq.m^{-3}$, while that of the ground floor was $206.1\ Bq.m^{-3}$.

According to the independent t-test analysis presented in Table V, there is a significant difference in indoor Radon concentration between the ground and first floors ($p = 0.01, 95\%$ confidence). This finding supports the soil proximity effect reported by [17], suggesting that indoor Radon concentrations are higher on ground floors due to direct emanation from soil and foundation materials.

From a risk perspective, this is particularly relevant in school buildings where younger pupils may spend more time on ground floors. Therefore, continuous exposure at the ground floor level may result in higher cumulative radiation dose during childhood development, increasing long-term stochastic health risks such as lung cancer in adulthood.

Table V. Summary of t-test analysis of the difference between the mean Radon concentration levels in the ground floor and first floor

	Levene's Test for Equality of Variances	t-test for Equality of Means				
	F	T	df	p-values	Mean Difference	Std. Error Difference
Equal variances assumed	2.74	-2.40	57	.020	-113.69	47.41
Equal variances not assumed		-4.83	9.64	.001	-113.69	23.53

C. *Effect of Ventilation Rates on Indoor Radon Concentration*

To investigate the relationship between ventilation rates and indoor Radon concentration, statistical analysis of the data was carried out using a simple linear regression technique of the model.

$$Y = \beta_0 + \beta_1 x \qquad (10)$$

Where Y is the dependent variable, i.e., indoor Radon concentration, x is the independent variable, i.e., ventilation rates, β_0 and β_1 are the respective intercept and slope regression coefficient.

Fig. 4 displays a simple linear regression analysis between indoor Radon concentration and ventilation rates. Statistically, the graph in Fig. 4 depicts a moderate negative linear relationship (Correlation Coefficient, $R^2 = 0.60$) between indoor Radon concentration and ventilation rates.

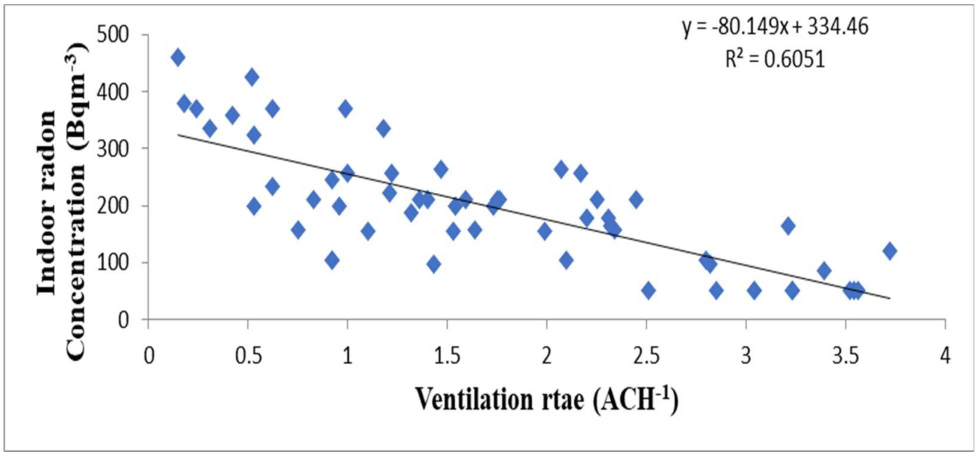

Fig. 4. Regression analysis between Indoor radon Concentration and Ventilation Rates.

The regression analysis suggests that ventilation rate is an important factor influencing indoor radon concentration, with poorer ventilation associated with higher radon accumulation. The inverse relationship indicates that improved ventilation facilitates Radon dilution and removal, while poor ventilation allows accumulation.

Beyond statistical interpretation, this finding has important health implications. In school environments where ventilation is inadequate, children may be subjected to continuous low-dose radiation exposure over long periods of time (30–50 hours weekly). Over several years of schooling, this may lead to a significant cumulative radiation dose, increasing long-term lung cancer risk in adulthood.

D. *Effect of Covering Material on Indoor Radon Concentration*

This study examined the impact of various covering materials on indoor Radon concentrations in all selected classrooms and offices. The available covering materials as presented in Table VI were categorized into five distinct combinations: Combination A (paint, concrete, and asbestos), Combination B (concrete, concrete, and asbestos), Combination C (paint, concrete, and concrete), Combination D (paint, rug/carpet, and asbestos), and Combination E (paint, tile/terrazzo, and concrete).

The most common covering for walls, floors, and ceilings is Combination A (38.9%), while Combination C (8.5%) is the least common. The highest indoor Radon concentration ($233.3\ Bq.m^{-3}$) was observed in rooms with Combination B, while the lowest ($117.3\ Bq.m^{-3}$) was observed in Combination D.

This variation suggests that building materials influence Radon ingress and accumulation. However, from a health standpoint, what is most important is that children and school occupants may still experience prolonged exposure regardless of material type if ventilation and structural sealing are inadequate. Over time, this may contribute to incremental radiation dose accumulation during critical developmental years.

Table VI. Statistical Distribution of Indoor Radon Concentration among the Five Combinations of Covering for Wall, Floor, and Ceilings in the Selected Schools

	Combination A: Paint, concrete, and asbestos	Combination B: Concrete, concrete, and asbestos	Combination C: Paint, concrete, and concrete	Combination D: Paint, rug/carpet, and concrete	Combination E: Paint, tile/terrazzo, and concrete
Number of Rooms	23 (38.9 %)	22 (37.3%)	5 (8.5 %)	5 (8.5 %)	4 (6.8 %)
Mean (Bq m^{-3})	171.5	233.3	201.0	117.3	134.0
Min (Bq m^{-3})	52.0	52.0	52.0	86.0	52.0
Max (Bq m^{-3})	426.0	380.0	460.0	211.0	158.0
SD (Bq m^{-3})	107.4	93.2	135.4	67.4	49.7

E. Comparison of Recent Results with Other Existing Research Works in Schools

Table VII compares the present result of indoor radon measurement with other available research works in schools. It could be observed that the mean values of indoor radon concentration vary from place to place due to geological formation, ventilation conditions, and building materials.

Table VII. Comparison of Radon Concentrations in Schools of Some Countries

Workplace	Location	Average Radon Conc. (Bq.m^{-3})	Exposure time (Days)	Reference
Classrooms	Fairfax County, Virginia	148.0	90	[18]
	Republic of Ireland	338.0	90	[19]
	Xanthi, Northern Greece	231.0	90	[20]
	Tularm Province, Palestine	40.43	90	[21]
	Oke-Ogun, Nigeria	45.0	90	[22]
	Ibadan, Nigeria	197.0	90	[8]
	Korea	300.0	2-3	[23]
	Luka city, Srpska	400.0	90	[24]
	Kremikovtsi, Bulgaria	339.0	90	[25]
	Lafia, Nigeria	210.07	90	Present Study
Offices	Hong Kong	37.0	90	[26]
	Turkey	76.0	75	[27]
	Jenin, Suadi Arabia	76.6	90	[28]
	Ibadan, Nigeria	65.0	90	[29]
	Ile-Ife, Nigeria	196.0	2	[3]
	Ibadan, Nigeria	155.0	90	[8]
	Ogbomoso, Nigeria	26.3	2	[30]
	Lafia, Nigeria	175.13	90	Present Study

Apart from spatial variation, the key concern is that school environments consistently represent long-term exposure settings, where occupants (especially children) spend significant portions of their developmental years. This makes even moderate radon levels relevant in terms of lifetime risk accumulation, rather than short-term exposure effects.

IV. CONCLUSION

This study investigated the radiation hazard associated with indoor Radon in Lafia metropolis, Nasarawa State, Nigeria. Radon measurements were taken in 16 selected elementary schools using CR-39 Solid State Nuclear Track Detectors. The study found that the arithmetic mean, geometric mean, and geometric standard deviation of indoor Radon concentrations were 193.3 Bqm^{-3}, 182.4 Bqm^{-3}, and 60.9 Bqm^{-3}, respectively. The effective dose to occupants was estimated to be 0.24 mSv.y^{-1}, and the excess lifetime cancer risk was 1.0 (MPY)$^{-1}$. This research work also established that ventilation rates, proximity of the rooms to the soil, and covering materials for floor, wall, and ceiling have a significant impact on radon concentration in indoor buildings.

The mean indoor radon concentration obtained in this study is below the workplace reference level of 300 Bq·m^{-3} recommended by the International Commission on Radiological Protection (ICRP), but exceeds the 100 Bq·m^{-3} guideline level set by the World Health Organization (WHO). This apparent discrepancy arises from the different protection philosophies underlying the two limits. The ICRP level is an upper bound for occupational settings, where exposures are time-restricted, monitored, and subject to regulatory control; it represents a level at which remedial action is strongly advised rather than an optimal target. In contrast, the WHO reference level is risk-based and more conservative, derived from epidemiological evidence of lung cancer at relatively low radon concentrations, and is intended for prolonged, largely uncontrolled exposures typical of dwellings and dwelling-like environments. Given that classrooms involve repeated, long-term occupancy by a sensitive population (students), their exposure scenario is closer to residential conditions than strictly controlled workplaces. Therefore, while the measured values comply with the ICRP limit, they still indicate a potential health concern when assessed against the WHO benchmark. Furthermore, the annual effective dose estimated in this study assumes an occupancy factor of 0.2, which likely underrepresents total exposure, as students and staff receive additional radon doses in their homes. These findings are preliminary, and more extensive measurements across schools in Nasarawa State and nationwide are recommended.

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AUTHOR CONTRIBUTION

Emmanuel A. Oyelade: Conceptualization, Investigation, Formal analysis, Project administration, Writing – original draft, Writing – review & editing.

Rachel I. Obed: Conceptualization, Investigation, Formal analysis, Supervision, Writing – review & editing.

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DATA AVAILABILITY

Data supporting the findings of this study are available from the corresponding author upon reasonable request.

CONFLICT OF INTEREST

The authors declare no conflict of interest

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