



EVALUATION OF EXCESS LIFE CANCER RISK DUE TO RADON CONCENTRATION IN WATER SAMPLES OF ADELEKE UNIVERSITY EDE, OSUN STATE, NIGERIA

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Abstract

This study investigates the radiological impact of radon in drinking water from sources within the Adeleke University Community, with a specific focus on evaluating the Excess Lifetime Cancer Risk (ELCR) across different age demographics, including, infants, children, and adults. Radon, a naturally occurring radioactive gas, poses a significant health hazard when ingested or inhaled, especially at a significantly high concentration. In this research, water samples were collected from borehole sources within the university community and analyzed to determine the levels of radon concentration and the corresponding effective doses (AED) and excess lifetime cancer risk for each demographic group. Results of radon concentrations were found to be higher than 0.1 Bq/L limit set by the SON but appreciably lesser than 11.1 Bq/L allowed limit set by USEPA. Annual effective doses due to radon ingestion vary from 0.3854 $\mu\text{Sv/y}$ to 8.1667 $\mu\text{Sv/y}$, 0.1196 $\mu\text{Sv/y}$ to 8.9434 $\mu\text{Sv/y}$, and 0.0122 $\mu\text{Sv/y}$ to 0.8038 $\mu\text{Sv/y}$ for infants, children and adults respectively, and ELCR values among infants, children, and adults range respectively from 0.0135 to 8.0691 $\mu\text{Sv/y}$, 0.1651 to 0.5868 $\mu\text{Sv/y}$, and 0.0319 to 0.1680 $\mu\text{Sv/y}$. These variations reflect differing consumption rates, physiological sensitivities, and exposure durations among the population groups. This result showed that lower age group are more radiosensitive, indicating the importance of radiation monitoring among infants and children. Notably, evaluated values of AED and ELCR recorded in this study are significantly below the recommended global average of 100 $\mu\text{Sv/y}$ and 2.9×10^{-4} for AED and ELCR respectively, suggesting that the current levels of radon in the community's drinking water do not pose a significant radiological health threat. This study underscores the importance of radiological monitoring and risk assessment, especially in institutional environments, to ensure long-term health safety of workers. The findings provide public awareness with a valuable baseline for future comparative studies and support the need for maintaining water quality standards in line with international safety benchmarks.

Water is one of the most essential underground resources relevant to maintain healthy living among living organisms. Water is an important resource for environmental studies and for ensuring wellness and survival of individual human beings [1,2]. Notably, a substantial number of people depend on groundwater sources, like hand pump boreholes and wells, especially in civilized environment as against people in rural areas who largely depend on water from rivers and streams [3, 4]. However, studies have shown that groundwater contains radon, a radioactive inert gas from the uranium series which is present in rocks and

soil [4,6]. The concentration of radon present in drinking water varies from one region to the other based on the geological properties of that region, such as soil porosity, uranium mineralization and other anthropogenic activities [7, 8,9].

Forty percent (40%) of human radiation exposure has been associated with radon. Radon is reportedly the second leading cause of lung cancer after tobacco smoking [10,11,12]. At a significant amount, radon has been reported to pose a significant health risk to humans, notably, lung and stomach cancers [4,13]. Inhalation of decay products can lead to respiratory health concern while ingestion through contaminated water may contribute to internal organ cancers [14,15,16]. Consequently, community and regional health assessment due to radiological impact of radon in drinking water is imperative and awareness of radon levels in household and community water supplies cannot be overemphasized [17].

In Nigeria, studies have revealed varying radon concentrations in groundwater. For instance, research in the Ojo axis reported radon levels ranging from 3.09 to 32.03 Bq/L, with some samples exceeding the Nigerian standard of 0.10 Bq/L for drinking water [18]. Similarly, findings in Ogbomoso indicated a mean radon concentration of Bq/L in borehole water samples, with values between 0.60 ± 0.37 to 2.64 ± 0.80 Bq/L [14].

A comprehensive assessment of radon concentrations in water sources at Adeleke University, Ede, is essential to determine potential health risks to the

university community. This study aims to measure radon levels from various water supplies across the campus and evaluate the associated radiological risks. By establishing a localized dataset, the research seeks to inform safety guidelines and promote awareness regarding radon exposure. The outcomes are expected to contribute significantly to public health initiatives and environmental safety protocols within the university and surrounding regions.

2.0 MATERIALS AND METHODS

2.1 Study Area

The study area is Adeleke University situated in Ede, Osun State on geographical coordinates, 7.7530° N latitude and 4.5320° E longitude, on a relatively undulating landscape with relatively low hills, which are a result of the underlying crystalline rocks. The topography of Ede is shaped by outcrops of granite and gneiss, gold, clay and limestone as common minerals which are natural sources of radioactive elements. Adeleke University, being a fully residential institution, provides water supplies in boreholes for its immediate community, students and members of staff. Numerous boreholes are strategically dug within the university as water source necessary for the survival of children and adults in the community. Literature has revealed possible high radon concentration from boreholes[19], posing radiological health concern to the public. Therefore, this study investigated radiological impact of radon in drinking water consumed by Adeleke University community. Figure 1 shows the map of the study area.



Figure 1: Map of Ede showing the study area

2.2 Collection of Water Samples



A total of twenty-four (24) water samples from six (6) boreholes comprising of four (4) samples per borehole were collected at different locations within the study area. The samples were taken during dry (harmattan) season in January 2024. Water samples were carefully collected into airtight clean bottles (350ml), filled to the brim in order to avoid air pocket and sealed to prevent escape of radon gas. Bubble formation was avoided during water collection and collected water samples were labelled with appropriate sample code to avoid mix up and then transported to the laboratory at Ladoké Akintola University of Technology within 4 hours period for radon measurement. The GPS coordinates of sampling points were measured using Garmin GPS device and recorded as shown in Table 1.

Table 1: Sampling points showing GPS coordinates

Sampl ing Area	Sampl ing Coordinates Latitude Longitude	Sampl e Code	Water sour ce
Girls Hostel	7.7100°N 4.8200°E	GH1, GH2, GH3, GH4	Borehole
Admin	7.6924°N 4.4181°E	AD1, AD2, AD3, AD4	Borehole
Boy's Hostel	7.6899°N 4.42328° E	BH1, BH2, BH3, BH4	Borehole
Staff Quarte rs	7.6796°N 4.4197°E	SQ1, SQ2, SQ3, SQ4	Borehole
Health Centre	7.6895°N 4.4197°E	HC1, HC2, HC3, HC4	Borehole
Water Factor y	7.6934°N 4.4231°E	WF1, WF2, WF3, WF4	Borehole

2.3 Decay Correction

Equations 1 and 2 represent the decay correction formulae which were used to account for possible radon decay in water between the period of sampling and analysis.

$$C = C_0 e^{-\lambda t} \quad (1)$$

$$\lambda = \frac{0.693}{3.83 \text{ days}} \quad (2)$$



Where; C is the measured radon concentration; C_0 is the initial concentration to be calculated; $t = 4$ hours is the time elapsed between sampling and analysis; λ is the decay constant.

2.4 Radon Measurement

Radon (^{222}Rn) concentrations in water samples were measured with the use of RAD7, with results being generated after 30 minutes of counting with detector's sensitivity equal or greater than that of scintillation method. The RAD7, manufactured by DURRIDGE Company, is a sophisticated electronic radon detector designed for continuous measurement of radon and thoron concentrations in air, water, and soil gas. It operates by detecting the alpha decay of radon and thoron daughters, providing rapid and precise readings. Additionally, with the RAD H2O accessory, it can measure radon concentrations in water samples. Figure 2 shows the experimental set-up. The infant group showed higher radiosensitivity than the children and adult groups.

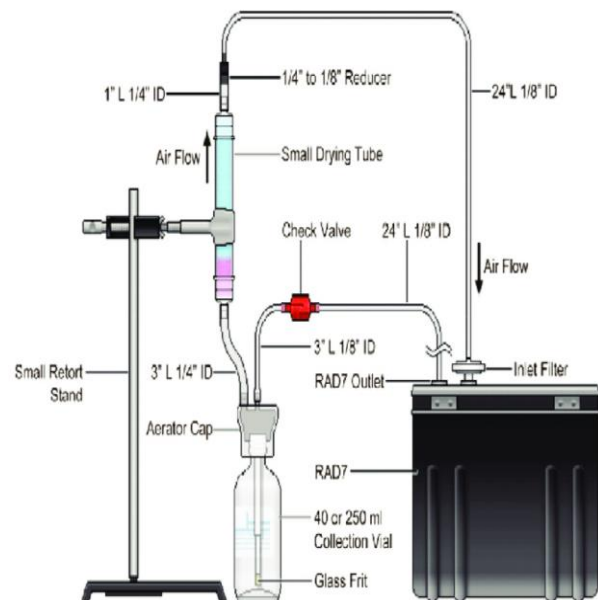


Figure 2: Experimental set-up for ^{222}Rn count in water using RAD7 [21]

2.4.1 Key operational features of RAD7

- Continuous monitoring:** The RAD7 offers real-time tracking of radon levels, capable of measuring concentrations as low as 0.2 Bq/m^3 with a standard deviation of 10% in under one hour [20].
- Sniffer mode:** This mode allows for the detection of radon entry points by sensing the 3-minute alpha decay of radon daughters without interference from other radiation [20].

- iii. **Rapid response and recovery:** The instrument quickly responds to changes in radon levels and recovers from high radon exposures within minutes, ensuring accurate and timely measurements [20].
- iv. **Data storage and analysis:** The RAD7 can store extensive radon data, which can be downloaded and analyzed using DURRIDGE's CAPTURE software. This software facilitates data graphing, analysis, and report generation, enhancing the user's ability to interpret measurement results effectively [20].

2.5 Annual Effective Dose Estimation

Measured radon concentrations were used to estimate annual effective dose (AED_{ing}) from ingestion of radon in water by infant, children and adult in the study area using Equation 3. Table 2 is a representative age grouping utilized in this study according to [22].

$$AED_{ing} \left(\frac{Sv}{y} \right) = C_{Rn} \times C_w \times DCF_{Rn} \quad (3)$$

Where, AED ($Sv \cdot y^{-1}$) is the annual effective dose, C_{Rn} ($Bq \cdot L^{-1}$) is the measured radon concentration and DCF_{Rn} is the dose conversion factor of radon, which equals 3.5 nSvBq^{-1} , 5 nSvBq^{-1} and 23 nSvBq^{-1} for adults, children and infants respectively [23].

The estimation of annual effective dose (AED_{inh}) of inhalation of radon from water is needful because the water under study is pumped through public water pipelines. Therefore Equation 4 was used to achieve this purpose [17].

$$AED_{inh} \left(\frac{Sv}{y} \right) = C_{Rn} \times R_w \times DCF_{Rn} \times EQ_F \times T \quad (4)$$

Where, C_{Rn} is the mean radon (^{222}Rn) activity concentration in water, R_w is the ratio of radon in air to radon in water (10^{-4}), DCF is the dose conversion factor of radon ($9 \text{ nSv/hr}(Bq/m^3))^{-1}$, EQ_F is the indoor equilibrium factor between radon and its progeny (0.4) and T is indoor time (7000 hr/y).

Table 2: Representative age grouping in the study area.

Age range (years)	Age Categories	Annual Consumption (Ly^{-1})	Water
1 – 2	Infants	230	
8 – 12	Children	330	
Greater than 17	Adults	730	

2.6 Excess Life Cancer Risk

The probability of an individual developing cancer over a lifetime due to exposure to a potential carcinogenic substance is a term known as excess lifetime cancer risk (ELCR). ELCR due to ingestion and inhalation of radon in water was calculated for infants, children and adults using Equation 5 [24].

$$ELCR \left(\frac{Sv}{y} \right) = AED_{total} \times RF \times DL \quad (5)$$

Where, AED_{total} is the addition of AED_{ing} and AED_{inh} due to radon; RF is the fatal cancer risk factor which equals 0.05 Sv^{-1} for the public, introduced by the International Commission on Radiological Protection, ICRP 60; and DL is the life expectancy which is assumed to be 70 years [1].

3.0 RESULTS AND DISCUSSION

3.1 Results

Table 3 presents the result of ^{222}Rn found in water which showed maximum mean concentration (10.1450 Bq/L) at Boy's Hostel (BH) while Girl's Hostel (GH) recorded minimum concentration (2.8550 Bq/L) in the study area. Figure 3 represents the graph of varying ^{222}Rn concentrations across the study area. Values of ^{222}Rn in drinking water present at Administrative Building (AD), 7.2475 Bq/L and Staff Quarters (SQ), 7.6700 Bq/L showed an appreciable increase compared to that of Health Centre (HC), 5.4203 Bq/L and Water Factory (WF), 4.7875 Bq/L . Radon ingestion doses, AED_{ing} ($\mu Sv/y$) due to borehole water intake range from 0.0122 in adults to 8.9434 in children at AD and BH respectively with Figure 4 showing the graphical representation of the distribution among different age groups. Also, the annual effective dose, AED_{inh} ($\mu Sv/y$) by exposure due to inhalation of radon in water showed values range from 0.0072 at GH to 0.2557 at BH. Excess life cancer risk (ELCR) estimated from total annual effective dose ($AED_{ing} + AED_{inh}$) showed values varying from $0.0135 \mu Sv/y$ at sampling point WF to $8.0691 \mu Sv/y$ at sampling point GH among infants; $0.1651 \mu Sv/y$ at GH to $0.5868 \mu Sv/y$ at BH among children, and $0.0281 \mu Sv/y$ at WF to $0.0596 \mu Sv/y$ at BH among adults. Figure 5 presents the graph of ELCR among different age groups in the study area.

Table 3: Annual effective doses and excess lifetime cancer risk in the study area

S/N	AED Ingestion ($\mu Sv/y$)	ELCR ($\mu Sv/y$)
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	Sampling Point	Mean ²²² Rn Conc. (Bq/L)	Infants	Children	Adult	AED Inhalation (μ Sv/y)	Infant	Children	Adults
1	GH	2.8550	2.2983	4.7108	0.4793	0.0072	8.0691	0.1651	0.1680
2	AD	7.2475	5.8342	0.1196	0.0122	0.0183	0.2048	0.4192	0.0426
3	BH	10.1450	8.1667	0.1674	0.0170	0.2557	0.2867	0.5868	0.0596
4	SQ	7.6700	6.1744	0.1266	0.0129	0.1933	0.2168	0.4436	0.0451
5	HC	5.4203	4.3633	8.9434	0.9101	0.1366	0.1531	0.3135	0.0319
6	WF	4.7875	0.3854	7.8993	0.8038	0.1206	0.0135	0.2769	0.0281

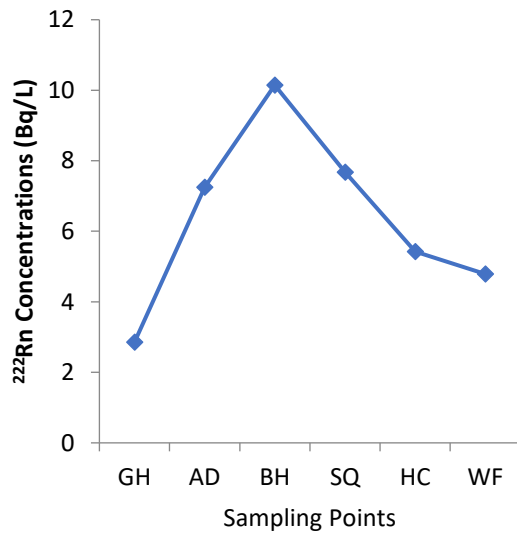


Figure 3: Graph showing varying radon concentration in the study area

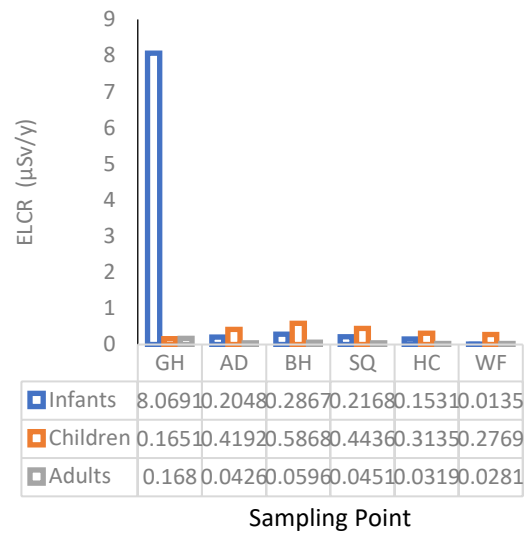


Figure 5: Graph showing cancer risk due to radon in drinking water of the study area

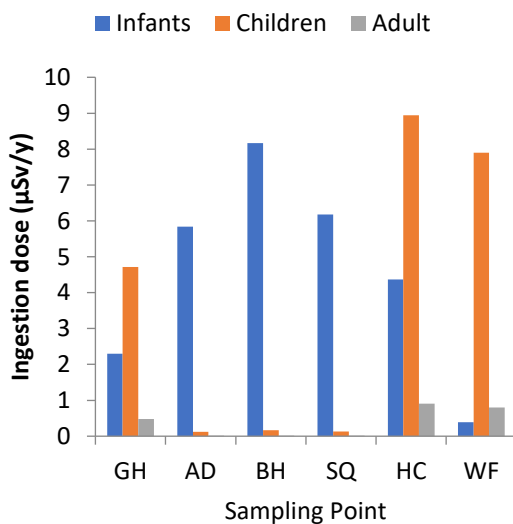


Figure 4: Graph of radon ingestion doses among different age categories in the study area

3.2 Discussion

Results of the mean ²²²Rn concentrations recorded for the six sampling points within the study area fall below action level of 11.1 Bq/L recommended by the United States Environmental Protection Agency (USEPA) [24, 25] but higher compared to the allowed limit of 0.1 Bq/L set for drinking water by Standard Organization of Nigeria, SON [26], and the Nigerian Industrial Standard, NIS[27]. The present study presents radon concentration range, varying from 2.8550 Bq/L at Girls's hostel (GH) to 10.1459 Bq/L at Boy's hostel (BH). The maximum radon concentration (10.1450 Bq/L) in water found in BH is appreciably less than 11.1 Bq/L action level of [24] and within the 4 Bq/L – 40 Bq/L benchmark of the [22] but higher than SON set limit of 0.1 Bq/L [26]. This is suggestive of a potential health risk due to radon exposure from drinking water among the members of Adeleke University community. Findings from the present study complement other research findings [1] and, in some cases, show disparity [18] as described in Table 4. Several factors, including geology, depth of boreholes, seasonal changes, permeability of



underlying rock and soil are associated to varying radon concentrations from one place to another.

Annual effective doses (AED_{ing}) due to radon ingestion vary from 0.3854 $\mu\text{Sv/y}$ to 8.1667 $\mu\text{Sv/y}$, 0.1196 $\mu\text{Sv/y}$ to 8.9434 $\mu\text{Sv/y}$, and 0.0122 $\mu\text{Sv/y}$ to 0.8038 $\mu\text{Sv/y}$ for infants, children and adults respectively shown in Figure 4. The obtained values of AED_{ing} in infants group showed multiples of that in adults which could be attributed to dose conversion coefficient which is twice in infants and children categories compared to adults. No relative significance was observed between children and adult groups. Even though, annual consumption rate in adults' group is significantly higher than that of infants and children, adults' group still recorded lowest AED_{ing} values. This emphasizes higher radiosensitivity in lower age groups.

This result is consistent with previous studies by [4, 15, 23]. However, the present study recorded outrageous AED_{ing} values at some sampling points (7.8993 $\mu\text{Sv/y}$ at WF and 8.9434 $\mu\text{Sv/y}$ at HC) in

children group compared to infant group of the same location. This tends to support the findings of [28] where adults group recorded highest effective dose followed by infants and children. This suggests the need for further radiation risk assessment among different age groups, especially in Adeleke University community and environs of which there is low awareness of radiological impact of radon. Also, estimated inhaled radon (AED_{inh}) from drinking water range from 0.0072 $\mu\text{Sv/y}$ at GH to 0.2557 $\mu\text{Sv/y}$ at BH. All values of annual effective doses due to radon ingestion and inhalation are well below ICRP recommended limit of 100 $\mu\text{Sv/y}$ [29] and the world limit of 300 $\mu\text{Sv/y}$. The excess lifetime cancer risk (ELCR) among infants, children and adults' groups varies from (0.0135, 0.1651 and 0.0319) $\mu\text{Sv/y}$ to (8.0691, 0.5868 and 0.1680) $\mu\text{Sv/y}$ respectively as shown in Table 3. ELCR values obtained in this study are well below the global average of 2.9×10^{-4} reported by United Nations Scientific Committee on Effects of Atomic Radiation.

Table 4: Results comparison with previous studies in Nigeria.

References	Region-Country	^{222}Rn concentration range (Bq/L)	Annual effective dose ($\mu\text{Sv/y}$)
Present study	Ede, Nigeria	2.8550 - 10.1459	Infants = 0.3854 - 8.1667; Children = 0.1196 - 8.9434; Adults = 0.0122-0.8038
[4]	Ondo, Nigeria	0.4100 – 5.5700	Infants = 2.200 – 295; Children = 0.8078 - 10.84; Adults = 1.0601 – 14.2314
[1]	Kano, Nigeria	4.19 - 45.24	Infants = 53.53 – 577.94; Children = 45.881 – 495.38; Adult = 30.59 - 330.25
[30]	Osun, Nigeria	8.6000 – 60.8000	Adults = 50 – 440
[15]	Jigawa, Nigeria	31.2300 – 273.2200	Infants = 430 – 1680; Children = 340 – 1440; Adult = 0.23 – 1.99

4.0 CONCLUSION

Radiological evaluation due to radon concentration levels from water supplies in Adeleke University Ede were carried out among different age demographic groups. The infant group showed higher radiosensitivity than the children and adult groups. Mean radon concentrations recorded in drinking water from various sampling points appear to be higher than 0.1 Bq/L limit set by SON and NIS but appreciably fall below 11.1 Bq/L limit of the USEPA. However, evaluation of excess life cancer risk is below global average of 2.9×10^{-4} among different age groups considered in the study, suggesting that the water supplies in the University Community is safe for drinking. Nevertheless, due to the significant increase in measured radon concentrations compared to allowed limit of the SON and NIS, and since no radon mitigation approach is considered in this study, it is

recommended that radon reduction plan should be employed in the University Community.

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