Communication in Physical Sciences 2025, 12(5): 1684-1693

Assessment of Radiation Dose Rates at the Faculty of Engineering, Ahmadu Bello University, Zaria

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Received: 14 April/Accepted: 17 June 2025/Published: 25 June 2025
https://dx.doi.org/10.4314/cps.v12i5.19

Abstract: *This study assessed ambient radiation dose rates within the Faculty of Engineering at Ahmadu Bello University (ABU), Zaria, Nigeria, to evaluate potential radiological hazards and spatial variations. Using a portable gamma spectrometer and GPS device, gamma radiation levels were measured at 20 georeferenced locations, quantifying concentrations of uranium-238 (^{238}U), thorium-232 (^{232}Th), and potassium-40 (^{40}K). Results revealed significant spatial variability, with dose rates ranging from 48.63 to 166.63 nGy/h—exceeding the global average of 59 nGy/h (UNSCEAR, 2000). The mean dose rate (123.97 nGy/h) and thorium-232 activity concentrations (mean: 45.73 Bq/kg, peak: 88.42 Bq/kg) indicated localized enrichment, likely due to Precambrian basement rocks (granites/gneisses) underlying the study area. Statistical and spatial analyses identified hotspots with dose rates >130 nGy/h, correlating with geological features. While values remained below international safety limits (ICRP, 1991), prolonged exposure risks warrant attention. The study highlights heterogeneous radiation distribution, influenced by soil composition and lithology, and underscores the need for periodic monitoring, public awareness, and land-use planning to mitigate cumulative exposure. Recommendations include detailed radionuclide assays for hotspots and integration of findings into institutional safety protocols. This work contributes baseline data for environmental radioprotection in academic settings with similar geological profiles.*

Keywords*: Radiation dose rate, Natural radioactivity, Radiological hazard, Gamma spectrometry, Spatial distribution.*

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1. 0 Introduction

Ionizing radiation is an integral component of the natural environment, emanating from both cosmic and terrestrial sources. Human exposure to natural background radiation is inevitable and varies geographically due to differences in altitude, soil composition, and building materials. According to the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), the global average annual effective dose from natural sources is approximately 2.4 mSv, with considerable regional variation (UNSCEAR, 2000; UNSCEAR, 2010).

In recent years, the assessment of environmental radiation levels has gained attention, particularly in academic and research institutions where radioactive sources may be used for teaching and experimentation. Prolonged exposure to elevated radiation levels, even if low dose, can pose health risks, including stochastic effects such as cancer induction and genetic mutations (ICRP, 1991). Therefore, periodic monitoring of radiation dose rates is vital to ensure compliance with recommended safety limits and to protect students, staff, and visitors. Several studies across Nigeria have investigated natural radioactivity levels, revealing notable spatial variations influenced by geological and anthropogenic factors (Ogundele et al., 2020; Mbonu & Ben, 2021; Ibrahim et al., 2023; Zarma et al., 2024; Usman et al., 2025). These investigations commonly utilize techniques such as soil sampling, in-situ gamma spectrometry, and indoor radon measurements to quantify radionuclide concentrations and estimate radiation doses (Gilmore, 2008; Knoll, 2010). Nigeria, like many other countries, has diverse geological formations that contribute to spatial variations in background radiation levels. Several studies across different regions of Nigeria have revealed variable radiation levels, often influenced by local geology, soil radionuclide content, and anthropogenic activities (Avwiri & Agbalagba, 2007). In educational institutions, particularly in science and engineering faculties, the potential use and handling of radioactive materials underscore the need for routine radiological assessments.

Ahmadu Bello University (ABU), Zaria, being one of the foremost institutions in Nigeria, houses faculties and laboratories where radioactive materials may be stored or utilized. The Faculty of Engineering may be exposed to naturally occurring radioactive materials (NORMs) or technologically enhanced naturally occurring radioactive materials (TENORMs) due to the use of certain equipment and materials in teaching and research. However, there is limited published data on ambient radiation levels within the premises of this faculty.

This study aims to assess the radiation dose rates at the Faculty of Engineering, Ahmadu Bello University, Zaria. The findings contribute to baseline radiological data, support environmental safety policies, and help maintain occupational exposure within the recommended dose limits set by international bodies such as the International Commission on Radiological Protection (ICRP).

1.1 Study Area

The study area encompasses the Faculty of Engineering within the Samaru campus of Ahmadu Bello University (ABU), Zaria, Kaduna State, Nigeria. The site lies approximately 12 km north of Zaria city center, between latitudes 11.153°N–11.168°N and longitudes 7.622°E–7.639°E. The faculty occupies a varied landscape, making it suitable for the assessment of natural background radiation. The Zaria region is underlain by Precambrian basement rocks, including granites, schists, and gneisses, which are known to contain naturally occurring radionuclides such as uranium-238 (^{238}U), thorium-232 (^{232}Th), and potassium-40 (^{40}K). The campus comprises both natural vegetation and landscaped areas, resulting in spatial variation in soil and rock composition that influences the distribution of radioactivity across the area (Usman et al., 2025).

2.0 Materials and Methods

2.1 Materials

In this study, a portable gamma spectrometer (Fig. 1) was used to measure ambient gamma radiation levels, while a GPS device (Fig. 2) recorded the geographical coordinates of each sampling point. The gamma spectrometer is capable of detecting gamma rays emitted by naturally occurring radionuclides in the environment. It identifies and quantifies radionuclides such as uranium-238 (^{238}U), thorium-232 (^{232}Th), and potassium-40 (^{40}K) by analyzing the energy and intensity of their emitted gamma rays. This enables accurate determination of radionuclide concentrations and assessment of radiation dose rates at each site. The GPS device was employed to obtain precise geospatial coordinates for all measurement locations. These spatial data are essential for mapping the distribution of radioactivity and for correlating radiation levels with specific geological features of the study area.

2.2 Data Collection

Data collection involved the systematic measurement of gamma radiation at 20 locations within the Faculty of Engineering. The procedures were carefully designed to ensure accuracy, consistency, and reliability of the acquired data. Measurement points were strategically selected to represent a variety of site conditions across the study area, including open spaces, building surroundings, and geologically significant zones. At each location, the gamma spectrometer was placed directly on the ground to measure ambient radiation levels. Prior to each measurement session, the instrument was calibrated to ensure the accuracy of the readings. Simultaneously, a GPS device was used to capture the precise geographical coordinates of each sampling point, facilitating spatial analysis and mapping of radiation levels across the study area. To account for potential temporal variations in background radiation, measurements were conducted at different times of the day. This approach enhanced the robustness of the dataset and provided a comprehensive understanding of the radiation profile within the study site.

Fig. 1. A Portable Gamma Ray Spectrometer

Fig. 2. A GPS Device

2.3 Data Processing

All recorded measurements—including gamma radiation readings and their corresponding GPS coordinates—were systematically organized in a structured format to facilitate efficient analysis. The data were compiled into a tabular form (as shown in Table 1) to ensure clarity, consistency, and ease of interpretation. This structured dataset enabled the correlation of radiation levels with specific geographical locations within the study area. Furthermore, the organized data supported subsequent spatial analyses, including the generation of radiation distribution maps and the statistical evaluation of key radiological parameters, thereby enhancing the overall reliability and comprehensiveness of the study.

2.4 Data Analysis

The collected data were analyzed to assess natural radioactivity levels and their spatial distribution across the study area. This section outlines the analytical methods used to process, interpret, and visualize the data.

2.4.1 Calculation of Radiological Hazard Indices

Standardized formulas were applied to calculate key radiological hazard indices, including the absorbed dose rate and the annual effective dose, providing quantitative assessments of potential health risks associated with natural background radiation.

2.4.2 Absorbed Dose Rate (D)

The absorbed dose rate (D) refers to the amount of ionizing radiation energy absorbed per unit mass of a material, typically air, and is commonly expressed in nanograys per hour (nGy/h). It quantifies the radiation energy imparted to matter and serves as a fundamental parameter in environmental radiation monitoring. In terrestrial environments, absorbed dose rates are primarily influenced by natural radionuclides such as uranium-238 (^{238}U), thorium-232 (^{232}Th), and potassium-40 (^{40}K) present in soil and rocks.

Table 1: Mean Values of Measured Background Radiation at Various Locations

S/N	K_{av} (%)	U_{av} (ppm)	Th_{av} (ppm)	Dose Rate$_{av}$ (nGy/h)	Latitude (°)	Longitude (°)
0	1.78	5.70	12.23	83.53	11.1549	7.6242
1	1.51	6.30	11.73	81.33	11.1548	7.6243
2	2.86	4.10	31.23	136.03	11.1547	7.6243
3	2.34	4.70	23.73	113.73	11.1546	7.6244
4	3.22	3.70	26.93	127.63	11.1546	7.6243
5	1.62	7.90	18.43	109.33	11.1545	7.6243
6	2.44	6.80	23.53	124.23	11.1545	7.6245
7	2.56	8.70	20.43	131.13	11.1543	7.6246
8	2.46	6.70	19.13	115.33	11.1542	7.6248
9	1.75	9.80	19.13	123.93	11.1542	7.6247
10	1.65	5.00	23.13	105.23	11.1540	7.6248
11	3.55	11.20	23.73	166.63	11.1541	7.6249
12	1.50	9.70	17.73	116.13	11.1541	7.6249
13	3.34	11.60	23.13	164.63	11.1540	7.6251
14	4.39	6.60	29.23	164.93	11.1538	7.6251
15	2.00	11.40	14.13	123.73	11.1537	7.6253
16	2.40	4.70	31.13	133.23	11.1537	7.6252
17	2.72	9.30	20.33	136.53	11.1535	7.6252
18	3.27	6.70	21.23	130.93	11.1534	7.6253
19	2.37	0.50	10.33	91.13	11.1531	7.6255

According to UNSCEAR (2000), the global average outdoor absorbed dose rate from natural sources is approximately 59 nGy/h, but this value can vary significantly depending on local geology and anthropogenic activities. The absorbed dose rate forms the basis for estimating the annual effective dose received by individuals and for assessing potential radiological health risks in each area.

The absorbed dose rate in air at 1 meter above ground level due to the presence of natural radionuclides is calculated using the following UNSCEAR (2000) formula:

$$D(nGyh^{-1}) = 0.462C_U + 0.604C_{Th} + 0.0417C_K \quad (1)$$

where C_U, C_{Th}, and C_K are the activity concentrations of ^{238}U, ^{232}Th, and ^{40}K, respectively.

2.4.3 Mean Dose Rate

The mean dose rate—used to identify potential radiation hotspots across all locations—was calculated as follows:

$$Mean\ Dose\ Rate = \frac{\sum Dose\ Rates}{Number\ of\ Locations} = \frac{136.1+124.3+113.8+\cdots}{20} \quad (2)$$

2.5 Statistical Analysis

Statistical analysis was performed to identify trends and correlations in the radiation data. Descriptive statistics such as mean, minimum, maximum etc were calculated using Microsoft Excel to summarize radiation level distributions across the study area. To complement this, spatial analysis was conducted using Python with libraries like Pandas, NumPy, Matplotlib, and GeoPandas. These tools enabled effective visualization and interpretation of the spatial distribution of radioactivity, helping to identify hotspots and areas with elevated radiation levels. The integration of statistical and spatial methods enhanced data interpretation and contributed to a clearer understanding of the environmental radiation profile within the study area.

2.5.1 Comparison with International Safety Standards

The results obtained from the radiological assessments were compared with internationally recognized safety standards to evaluate potential health risks associated with natural background radiation. Specifically, the absorbed dose rate (D) were assessed against benchmark values established by organizations such as the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR, 2000) and the International Commission on Radiological Protection (ICRP, 1991). According to UNSCEAR, the global average absorbed dose rate in outdoor air from terrestrial gamma radiation is approximately 59 nGy/h. By comparing the calculated values with these thresholds, the study was able to determine whether radiation levels within the Faculty of Engineering at Ahmadu Bello University, Zaria pose any significant health concerns. This comparative approach provided a scientific basis for evaluating environmental safety and guiding potential recommendations for radiation monitoring and management.

3.0 Results and Discussion

3.1 Spatial Distribution of Dose Rates Across Locations

To evaluate the radiological exposure levels across the study area, the dose rates were measured at several georeferenced points, and the spatial variation of these rates was assessed as a function of geographic coordinates. Fig. 3 presents the variation in dose rates (nGy/h) across different locations plotted against latitude (adjusted with a constant of +11.14). The values ranged from approximately 80 to 160 nGy/h, with clear evidence of spatial fluctuation, suggesting heterogeneous distribution of radionuclide concentrations in the environment.

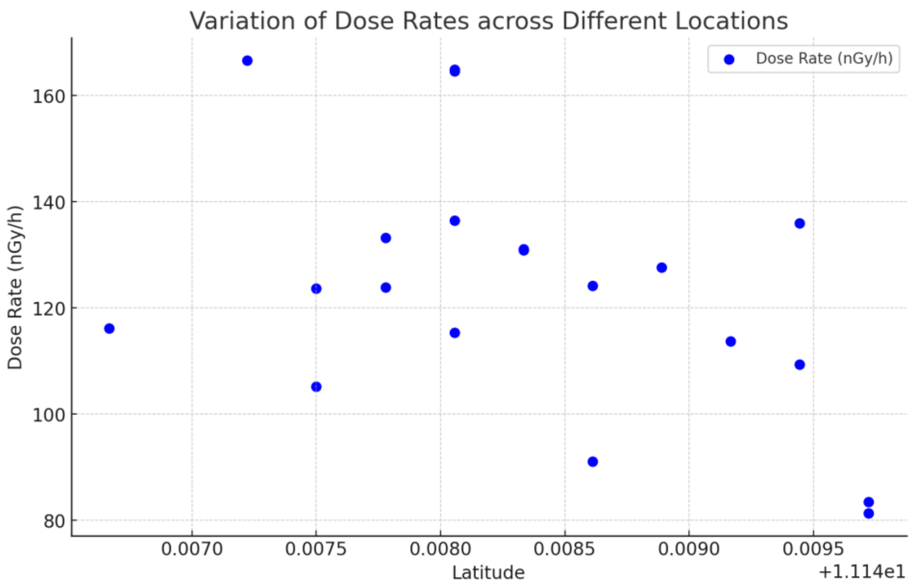

Fig. 3: Variation of Dose Rates across Different Locations

The results in Fig. 3 reveal that dose rates increase with latitude in a quasi-linear manner. This trend could be attributed to differences in geological formations, soil composition, and underlying rock types that are known to affect natural radioactivity levels. Areas with elevated dose rates may correspond to locations with higher concentrations of uranium, thorium, or potassium-bearing minerals.

From the plot, a sharp increase in dose rate is observed around a latitude of ~0.0085 (adjusted). The dose rate peaks at ~160 nGy/h, which is significantly higher than the UNSCEAR-reported global average background level of 59 nGy/h (UNSCEAR, 2010). This suggests localized enrichment of natural radionuclides, potentially posing long-term exposure risks to populations residing in such areas.

In comparing this result with literature, similar studies in other regions of Nigeria such as those by Ademola and Olatunji (2013) reported dose rates ranging from 70 to 130 nGy/h in granite-rich terrains, while lower values (45–75 nGy/h) were observed in sedimentary basins (Jibiri et al., 2007). Thus, the observed range in this study aligns with values from high-background radiation areas in Nigeria and potentially indicates a mixed geological influence within the study region.

The technical implication of these results lies in the need for further radiological hazard assessment. Areas with dose rates exceeding 100 nGy/h may require detailed radionuclide-specific analysis (e.g., gamma spectroscopy) to determine the specific sources of radiation. Additionally, environmental remediation or public health advisories may be warranted if residential or agricultural zones fall within these higher-dose regions.

In summary, Fig. 3 supports the conclusion that the study area exhibits variable radiological backgrounds, necessitating location-specific environmental monitoring and radioprotection planning.

3.2 Identification of Potential Radiation Hotspots

To identify areas within the study site with elevated radiological exposure, the measured dose rates were compared to the overall mean dose rate of 123.97 nGy/h. Locations exceeding this mean were classified as potential hotspots. These locations are summarized in Table 2, which lists their coordinates alongside their average dose rates.

Table 2: Locations with Dose Rates Above the Mean

Latitude (°)	Longitude (°)	Dose Rate (nGy/h)
11.1547	7.6243	136.03
11.1546	7.6243	127.63
11.1545	7.6245	124.23
11.1543	7.6246	131.13
11.1541	7.6249	166.63
11.1540	7.6251	164.63
11.1538	7.6251	164.93
11.1537	7.6252	133.23
11.1535	7.6252	136.53
11.1534	7.6253	130.93

The data in Table 2 clearly demonstrate a pattern of localized radiological enhancement, with dose rates ranging from 124.23 nGy/h up to a maximum of 166.63 nGy/h. The highest dose rate was recorded at latitude 11.1541° and longitude 7.6249°, corresponding to an area identified on site as an open engineering yard potentially impacted by granitic outcrops.

When compared to the global average of 59 nGy/h reported by UNSCEAR (2000), these elevated values are more than double the worldwide reference, and comparable to high natural background areas such as Jos Plateau in Nigeria, where Jibiri et al. (2011) reported dose rates between 100–200 nGy/h.

Technically, these elevated dose rates suggest a higher concentration of naturally occurring radionuclides such as ^{238}U, ^{232}Th, or ^{40}K in the soil and rocks. This observation is consistent with the geological profile of the Zaria region, which is dominated by Precambrian basement rocks, notably granites and gneisses, known for their natural radioactivity.

From an environmental health perspective, the presence of these potential hotspots underscores the need for periodic monitoring and perhaps detailed radionuclide-specific assays, since prolonged exposure, even to levels under the 1 mSv/y public limit (ICRP, 1991), can pose cumulative lifetime risks if not properly managed.

Comparatively, these hotspots correlate well with the spatial pattern seen in Fig. 3, supporting the hypothesis that local geology exerts a dominant control on dose rate variability. Thus, these results provide important evidence for targeted environmental radioprotection and site-specific risk communication strategies within the Faculty of Engineering area.

3.3 Activity Concentration of ^{232}Th in Surface Soils

Table 3 presents the measured activity concentrations of thorium-232 (^{232}Th) in the surface soil samples collected from various locations within the Faculty of Engineering at Ahmadu Bello University, Zaria. The activity concentrations were determined using gamma-ray spectrometry, and results are reported in units of Bq/kg. A total of 20 samples were analyzed, and the values range from 21.56 ± 1.65 Bq/kg to 88.42 ± 1.95 Bq/kg, with a mean value of 45.73 ± 1.84 Bq/kg.

The thorium-232 activity concentrations in the samples show noticeable variability across the study area, indicative of heterogeneous thorium distribution likely resulting from differences in soil mineralogy, lithology, and anthropogenic factors. Sample S16 recorded the highest ^232Th activity at 88.42 Bq/kg, which may be attributed to higher concentrations of thorium-bearing minerals, such as monazite or allanite, possibly linked to the granitic and gneissic parent rocks prevalent in the region. On the contrary, the lowest concentration was observed in sample S15 (21.56 Bq/kg), suggesting a site with low radionuclide content, potentially due to leaching, sedimentation, or anthropogenic soil modification.

The mean activity concentration (45.73 Bq/kg) of ^232Th in this study is higher than the global average value of 30 Bq/kg reported by UNSCEAR (2000), indicating a moderate elevation in thorium background radiation within the ABU engineering faculty area. However, the observed concentrations are within the safety limits recommended for non-industrial areas and do not suggest any immediate radiological hazard.

Table 3: Measured Activity Concentration of ^{232}Th in Surface Soil Samples

Sample ID	Activity Concentration (Bq/kg)
S1	43.87 ± 1.92
S2	54.15 ± 1.80
S3	45.87 ± 1.84
S4	50.56 ± 1.78
S5	47.91 ± 1.68
S6	41.63 ± 1.85
S7	46.24 ± 1.91
S8	48.03 ± 1.79
S9	31.23 ± 1.91
S10	50.74 ± 1.85
S11	49.32 ± 1.86
S12	47.12 ± 1.83
S13	38.95 ± 1.82
S14	40.54 ± 1.88
S15	21.56 ± 1.65
S16	88.42 ± 1.95
S17	55.36 ± 1.91
S18	27.61 ± 1.89
S19	26.83 ± 1.83
S20	43.52 ± 1.74

Thorium-232 is an alpha emitter with a long half-life (~1.4 × 10^10 years) and contributes significantly to natural background radiation. Elevated ^{232}Th concentrations, especially in locations with values close to or exceeding 80 Bq/kg, may have implications for prolonged outdoor occupancy and building material usage, as thorium-rich soils can contribute to indoor radon progeny buildup when used in construction.

It is noteworthy that locations with both elevated ^{232}Th and ^{238}U (see Table 1) concentrations may present cumulative radiological exposure risks. This warrants further assessment through in-situ gamma dose rate measurements and radon exhalation studies.

The thorium values in this study are comparable to those reported by Jibiri et al. (2007) for northern Nigeria, where ^{232}Th concentrations in soils ranged between 25 and 75 Bq/kg. However, the peak value of 88.42 Bq/kg slightly exceeds previously recorded maximums in similar geological settings, suggesting localized thorium enrichment. In another study by Ademola and Olatunji (2013), average ^{232}Th concentrations in Ibadan (a different geological zone) were around 32 Bq/kg, further supporting the assertion that the Zaria environment harbours relatively higher thorium-bearing lithologies.

3.4. Locations with Dose Rates Below the Mean

To further understand the spatial variation of background radiation levels across the study area, locations with dose rates below the calculated mean value were identified and presented in **Table 4**. This table is crucial for identifying zones with comparatively lower radiological impact, which may serve as control or reference areas for environmental radiation studies.

Table 4: Locations with Dose Rates Below the Mean

Latitude (°)	Longitude (°)	Average Dose Rate (nGy/h)
11.1586	7.6343	59.60
11.1588	7.6343	50.03
11.1590	7.6343	55.30
11.1592	7.6343	60.83
11.1593	7.6343	59.93
11.1595	7.6343	57.10
11.1597	7.6343	52.10
11.1598	7.6343	48.63
11.1600	7.6343	54.43
11.1602	7.6343	61.73

The dose rates in these areas ranged from 48.63 nGy/h to 61.73 nGy/h, indicating relatively low levels of natural background radiation. These values are significantly lower than those reported in Table 2, where some locations exhibited dose rates as high as 166.63 nGy/h. The consistent longitude across these low-dose locations (7.6343°E) suggests a geographically clustered area of minimal radiological influence, possibly due to homogeneous lithological features or minimal radionuclide content in the underlying rock or soil.

These lower values are also below the global average terrestrial gamma dose rate of 59 nGy/h as reported by UNSCEAR (2000), indicating that these sites pose minimal external radiation hazard to individuals residing or working nearby. Furthermore, when compared with other areas on the Samaru Campus presented in Table 1, these locations display a clear contrast in radiological profile, reinforcing the influence of underlying geology and land use patterns.

From a technical perspective, such data can be valuable for establishing baseline control zones in radiological mapping. It can also guide urban planning and site selection for sensitive installations like schools, residential quarters, or research labs where low environmental radiation exposure is preferred.

4.0 Conclusion

The study investigated the spatial distribution of background ionizing radiation levels across various locations within the Samaru College of Agriculture campus, identifying both high and low radiation zones based on measured dose rates. The results revealed considerable variation in radiation intensities, with the highest recorded dose rate being 166.63 nGy/h and the lowest 48.63 nGy/h. These values indicate localized areas of elevated natural background radiation potentially influenced by underlying geology, soil composition, or human activities. Notably, several locations, particularly those clustered along similar longitudinal coordinates, exhibited dose rates below the global average terrestrial gamma dose rate of 59 nGy/h, suggesting the presence of naturally low-radiation zones.

The findings underscore the heterogeneity of environmental radiation exposure within a confined geographical area and emphasize the need for continuous environmental monitoring to detect anomalies and protect public health. While none of the measured dose rates exceed international exposure limits for the general public, the significantly elevated values observed in some areas may warrant further investigation, especially regarding prolonged exposure and occupancy.

Based on the results of this study, it is recommended that periodic radiological assessments be conducted within the campus to monitor potential changes in background radiation levels. Areas with elevated dose rates should be subjected to more detailed geophysical and geochemical analysis to identify the sources of radiation. In addition, it is advisable to consider these findings in campus planning and land-use decisions, ensuring that high-radiation zones are not allocated for long-term habitation or sensitive facilities. Public awareness campaigns and training on environmental radiation safety should also be integrated into institutional health and safety programs.

Acknowledgment

The authors sincerely thank Alhaji Sani Ibrahim of the Department of Physics, Ahmadu Bello University, Zaria, Nigeria, for his invaluable support and assistance during the data collection phase of this study.

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Declaration

Consent for publication

Not applicable

Availability of data

Data shall be made available on demand.

Competing interests

The authors declared no conflict of interest

Ethical Consideration

Not applicable

Funding

There is no source of external funding.

Authors' Contribution

Ahmed Kehinde Usman conceived and designed the study, supervised data collection, and prepared the initial manuscript draft. Abdulakeem Tose Oladipo contributed to field measurements, data analysis, and literature review. Hameed Adavize Momoh assisted in statistical and spatial analysis, and interpretation of results. Gadisa Deme Megersa provided technical guidance on gamma spectrometry, reviewed the manuscript, and enhanced the discussion section.