Communication in Physical Sciences, 2026, 13(5):718-727

Assessment of Indoor and Outdoor Background Radiation \Levels in the Faculty of Veterinary Medicine and College of Medical Sciences, Ahmadu Bello University, Zaria, Nigeria

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Received: 26 February 2026/Accepted: 28 April 2026 /Published: 14 May 2026

https://dx.doi.org/10.4314/cps.v13i5.4

Abstract: Environmental radiation surveillance is a critical component in assessing radiological safety in institutions where ionizing radiation sources are routinely applied. This study evaluated indoor and outdoor background gamma radiation levels within selected locations in the College of Medical Sciences and the Faculty of Veterinary Medicine, Ahmadu Bello University, Zaria, Nigeria. Measurements were carried out at twenty (20) indoor and outdoor points using a portable gamma-ray spectrometer, while geographical coordinates were recorded with a handheld Global Positioning System (GPS) device. The acquired dose rates were subjected to statistical analysis and converted to annual effective dose rates for both indoor and outdoor environments using standard UNSCEAR conversion coefficients. The indoor absorbed dose rates ranged from 101.42 to 184.56 nGy/h, with an average value of 150.99 nGy/h. Outdoor dose rates varied from 96.50 to 173.00 nGy/h, with a mean value of 132.59 nGy/h. Correspondingly, the estimated annual effective dose ranged from 0.49 to 0.88 mSv/y for indoor environments, while outdoor values ranged from 0.12 to 0.27 mSv/y. The highest radiation level was observed at the Radiographic (Imaging) Facility. Nonetheless, all measured values were below the International Commission on Radiological Protection (ICRP) recommended public dose limit of 1 mSv/y. Spatial distribution analysis indicated moderate variability in radiation levels across the study area, with relatively elevated concentrations in laboratory and radiographic facilities. The findings suggest that current radiation levels within the investigated environment do not pose significant radiological health risks to students, staff, or visitors. However, continuous and periodic monitoring is recommended to ensure sustained compliance with international radiological protection standards.

Keywords: *Background radiation, gamma dose rate, environmental radiation monitoring, annual effective dose, radiological assessment.*

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1.0 Introduction

Background ionizing radiation is a naturally occurring environmental process originating from terrestrial radionuclides, cosmic rays, and internally deposited radioactive substances within living organisms. Human exposure to environmental radiation varies spatially due to geological formations, altitude, soil composition, climatic conditions, and anthropogenic activities (UNSCEAR 2020). Naturally occurring radionuclides such as uranium (^{238}U), thorium (^{232}Th), and potassium (^{40}K) contribute significantly to terrestrial gamma radiation exposure. In recent decades, the increasing use of ionizing radiation in medicine, industry, and scientific research has raised global concern regarding environmental radiation exposure and its associated health implications. Prolonged exposure to elevated ionizing radiation levels may increase the risk of stochastic health effects such as cancer induction, hereditary mutations, and cellular damage (ICRP, 2007: WHO, 2023, NCRP, 2009; Knoll, 2020; El-Taher, 2012). Consequently, environmental radiation monitoring has become an essential component of radiological protection and public health assessment.

Medical and veterinary institutions represent important environments for radiation assessment because of the routine use of diagnostic imaging systems, laboratory equipment, and radioactive materials. Several studies conducted in educational and healthcare institutions have demonstrated variations in environmental radiation levels associated with geological factors, building materials, and institutional activities (Baraya *et al*., 2019; Eddy *et al*., 2025a,b; Eke & Emelue, 2020). Previous investigations in Nigerian universities and healthcare facilities have reported indoor absorbed dose rates ranging between 80 and 190 nGy/h, with relatively higher values commonly observed in radiology laboratories, diagnostic imaging centres, and research facilities due to frequent radiation-related activities.

As one of the largest tertiary institutions in Nigeria, Ahmadu Bello University, Zaria, hosts numerous academic, medical, veterinary, and research facilities characterized by high human occupancy and extensive use of laboratory and imaging equipment. "Despite the growing application of ionizing radiation equipment and laboratory technologies within the university environment, comprehensive baseline radiological data for the College of Medical Sciences and Faculty of Veterinary Medicine remain scarce. "To the best of the authors' knowledge, no comprehensive comparative assessment of indoor and outdoor background radiation levels has previously been conducted within these faculties. Establishing baseline radiation information is therefore essential for environmental monitoring, radiological protection, and future epidemiological investigations. The generated data will provide useful information for radiation safety management, environmental health assessment, institutional policy formulation, and future radiological surveillance programmes within the university community.

This study was designed to evaluate indoor and outdoor background gamma radiation levels within selected locations in the College of Medical Sciences and Faculty of Veterinary Medicine, Ahmadu Bello University, Zaria. Specifically, the study evaluated absorbed dose rates and estimated annual effective dose rates for selected locations within the study area. In addition, spatial radiation distribution patterns were analyzed and the measured values were compared with international radiological safety standards recommended by the International Commission on Radiological Protection (ICRP) and the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR).

2.0 Materials and Methods

2.1 Study Area

The study was conducted within the College of Medical Sciences and Faculty of Veterinary Medicine, Ahmadu Bello University, Zaria, Nigeria. Ahmadu Bello University is located in Zaria, Kaduna State, northwestern Nigeria, between latitude 11°04′N and longitude 7°42′E.

The area lies within the Northern Guinea Savannah region and is characterized by tropical climatic conditions with distinct wet and dry seasons. The geology of the region consists predominantly of basement complex rocks which may contribute to natural background radiation levels.

The investigated sites comprised lecture theatres, laboratories, seminar rooms, libraries, radiographic facilities, offices, and multipurpose halls characterized by moderate to high human occupancy and frequent academic and medical activities."

2.2 Radiation Measurement

Environmental gamma radiation measurements were conducted using a portable gamma-ray spectrometer (Radcomm Syclone:RC2000) (Radcomm, 2020), calibrated against standard radiation sources before field deployment to ensure measurement accuracy and reliability. The instrument was used to measure ambient gamma dose equivalent rates at selected indoor and outdoor locations.

Geographic coordinates were obtained using a handheld Global Positioning System (GPS) receiver to facilitate spatial analysis. A total of twenty sampling points were selected based on accessibility, population occupancy, functional relevance, and representativeness of the study environment. Measurements were conducted at approximately 1 m above ground level in accordance with standard environmental radiation monitoring protocols in order to minimize ground surface effects and localized fluctuations. At each location, multiple readings were obtained and averaged to improve measurement reliability. Each measurement was recorded after allowing the instrument to stabilize for approximately 2–5 minutes.

2.3 Data Analysis

The measured dose rates were recorded in nanograys per hour (nGy/h). Descriptive statistical analyses including minimum, maximum, and mean values were computed for indoor and outdoor measurements. Standard deviation and coefficient of variation were also determined to evaluate the degree of variability in radiation levels across the study locations.

The annual indoor effective dose rate (AIEDR) and annual outdoor effective dose rate (AOEDR) were calculated using the UNSCEAR conversion model:

$$\mathrm{AIEDR} = \mathrm{D}(0.8)(8760) \times 0.7 \times 10^{-6} \quad (1)$$

$$\mathrm{AOEDR} = \mathrm{D}(0.2)(8760) \times 0.7 \times 10^{-6} \quad (2)$$

where D represents absorbed dose rate (nGy/h), 0.8 and 0.2 are indoor and outdoor occupancy factors, respectively, 8760 is the number of hours in a year, and 0.7 SvGy^{-1} represents the dose conversion coefficient recommended by UNSCEAR for converting absorbed dose in air to effective dose received by humans.

Partial radiation distribution maps were generated using Geographic Information System (GIS)-based interpolation techniques, specifically the Inverse Distance Weighting (IDW) method, based on the acquired GPS coordinates and measured dose rates. Statistical analyses and spatial mapping were performed using OriginPro, Microsoft Excel, and ArcGIS software packages.

The measured radiation parameters were compared with internationally recommended radiological safety limits established by the International Commission on Radiological Protection (ICRP) and the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR).

3.0 Results and Discussion

3.1 Indoor and Outdoor Radiation Levels

The measured indoor and outdoor gamma radiation dose rates exhibited noticeable spatial variability across the investigated locations, reflecting differences in building characteristics, laboratory activities, occupancy patterns, and environmental conditions. Indoor dose rates ranged from 101.42 to 184.56 nGy/h with an average value of 150.99 nGy/h, whereas outdoor dose rates ranged from 96.50 to 173.00 nGy/h with an average value of

132.59 nGy/h. Generally, indoor radiation levels were higher than outdoor values in most locations. The relatively higher indoor radiation levels may be attributed to the accumulation of naturally occurring radionuclides in construction materials such as concrete, tiles, granite, cement, and ceramics, which are known contributors to indoor terrestrial gamma radiation. Similar trends of elevated indoor radiation levels relative to outdoor values have been reported in environmental radiation studies conducted in universities, hospitals, and research facilities in Nigeria and other parts of the (Mehra & Singh, 2011; Usman *et al*., 2025a,b,c; Jibiri & Okeyede, 2012). The highest indoor radiation level was observed at the Radiographic (Imaging) Facility (184.56 nGy/h), followed by the Gross Anatomy Laboratory and the Multipurpose Hall. The elevated radiation levels observed in these facilities may be associated with the presence of diagnostic imaging equipment, increased laboratory-related activities, shielding materials, and dense structural components capable of enhancing gamma radiation accumulation.

3.2 Annual Effective Dose Assessment

The estimated annual indoor effective dose rates ranged from 0.49 to 0.88 mSv/y, while the annual outdoor effective dose rates varied between 0.12 and 0.27 mSv/y. The mean indoor and outdoor annual effective dose rates were estimated at 0.74 mSv/y and 0.16 mSv/y, respectively. The obtained annual effective dose values are comparable to those reported for similar academic and healthcare environments in developing countries, indicating that the radiation profile of the study area falls within the expected range for naturally influenced institutional environments. Although the measured mean absorbed dose rates were slightly higher than the worldwide average terrestrial background radiation values reported by UNSCEAR, the corresponding annual effective dose estimates remained below the recommended public exposure limit of 1 mSv/y established by ICRP. This suggests that the current radiological conditions within the investigated environment are unlikely to pose immediate significant radiological health hazards to students, staff, and visitors under normal occupancy conditions.

3.3 Statistical Analysis of Radiation Levels

The grouped bar chart (Fig. 1) compares indoor and outdoor radiation levels across the investigated locations. The grouped bar chart demonstrates a consistent pattern of higher indoor radiation levels across most sampling locations, supporting the influence of building materials and indoor radiation accumulation mechanisms."

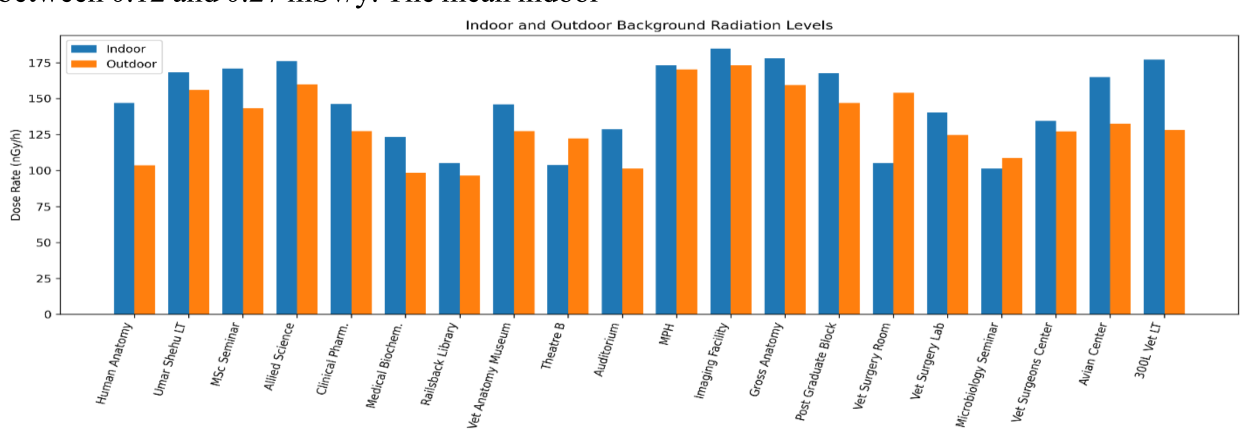

Fig. 1. Grouped bar chart showing indoor and outdoor gamma radiation dose rates across the investigated locations.

The boxplot analysis (Fig, 2) indicates that indoor radiation measurements exhibit greater variability and higher median values compared with outdoor measurements. The wider interquartile range and higher median observed for indoor measurements indicate greater dispersion and variability, suggesting stronger influence from localized indoor radiation sources and structural materials.

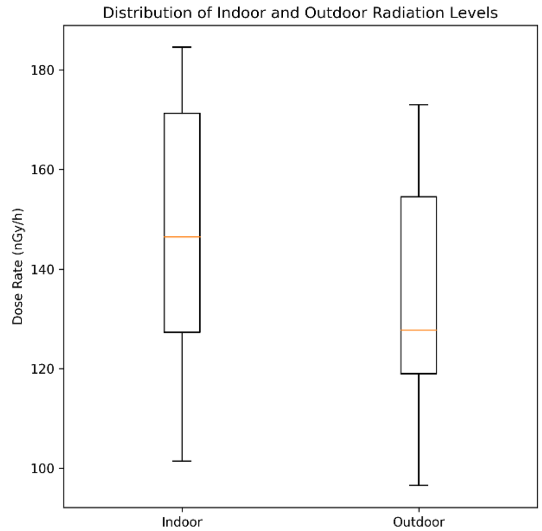

Fig. 2. Boxplot showing statistical distribution of indoor and outdoor radiation levels

The scatter plot with regression analysis (Fig/ demonstrates a positive linear correlation between indoor and outdoor dose rates, indicating that areas with elevated environmental background radiation generally exhibit correspondingly higher indoor radiation levels (Fig. 3).

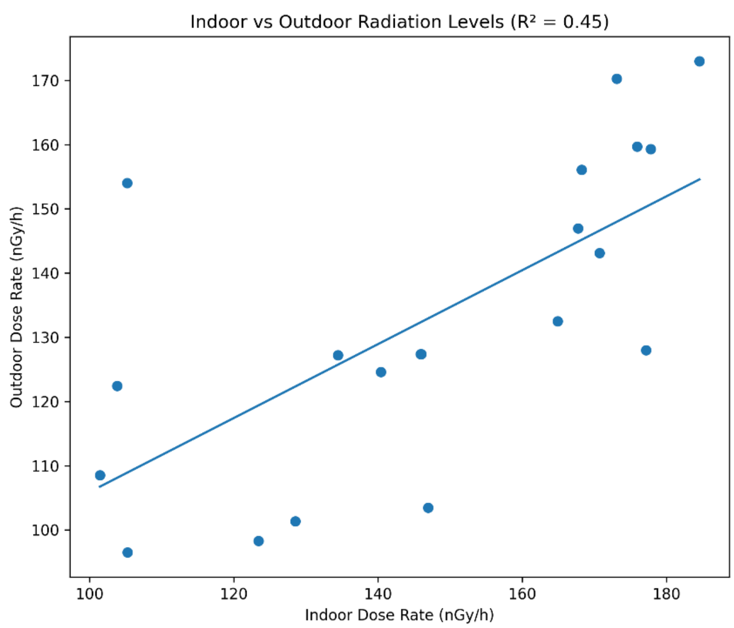

Fig. 3. Scatter plot with regression line illustrating the relationship between indoor and outdoor radiation levels.

The coefficient of determination (R^2) obtained from the regression analysis further confirms the degree of association between indoor and outdoor radiation levels. The error bar plot (Fig. 4) presents the mean dose rates and standard deviations for indoor and outdoor environments, illustrating the mean dose distribution, measurement variability, and statistical consistency of the acquired radiation data.

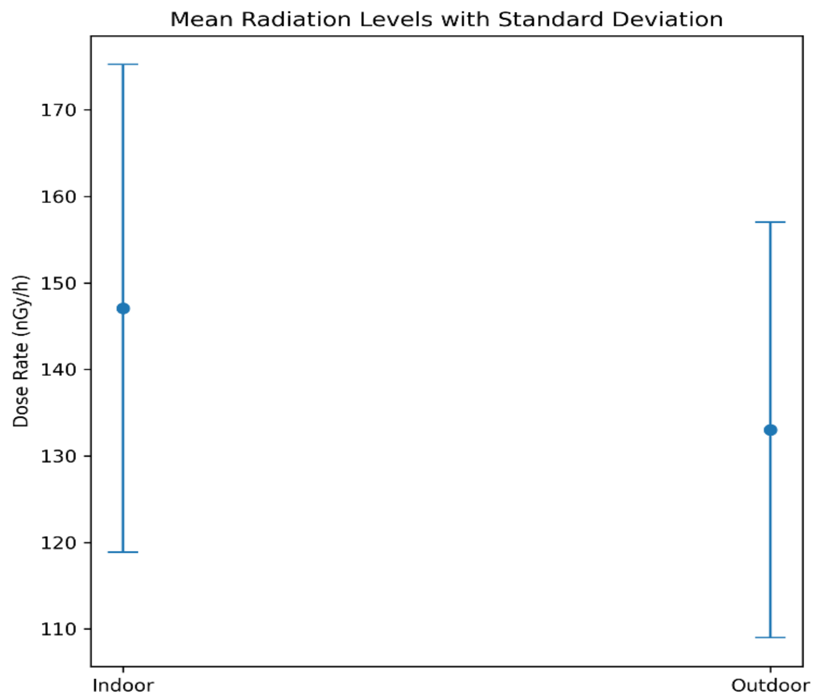

Fig. 4. Error bar plot showing mean indoor and outdoor dose rates with standard deviations

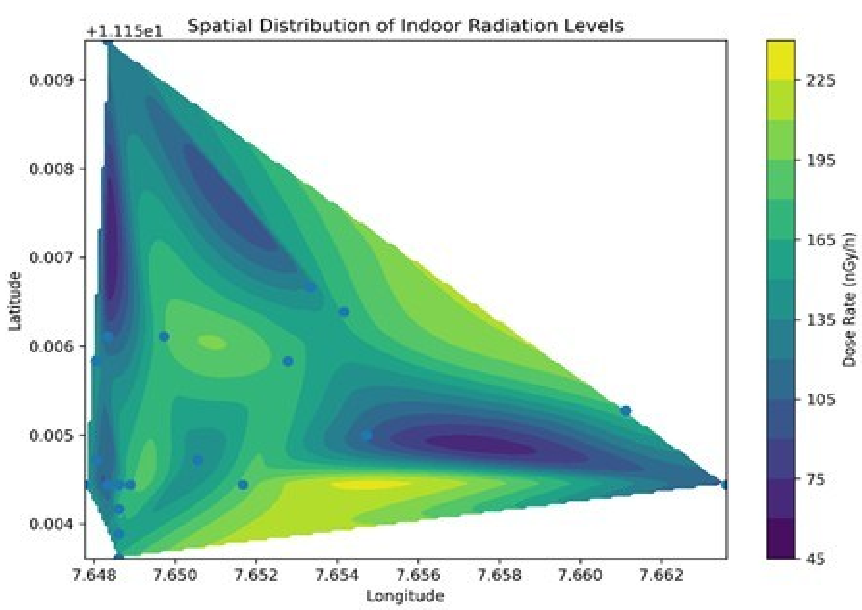

Fig. 5. Spatial distribution map of indoor radiation levels within the study area

3.4 Spatial Radiation Distribution

The spatial distribution maps (Figs. 5 and 6) reveal moderate spatial variation in radiation intensity within the study area. Relatively elevated radiation zones were predominantly observed around laboratory environments, radiographic facilities, and densely occupied buildings, indicating possible contributions from both structural materials and radiation-related institutional activities. The spatial interpolation maps reveal heterogeneous radiation distribution patterns across the study area, confirming that radiation intensity is influenced by localized environmental variables.

The indoor radiation bubble map (Fig. 7) provides visual confirmation of localized radiation hotspots, particularly around diagnostic and laboratory facilities where radiation-generating equipment are routinely utilized.

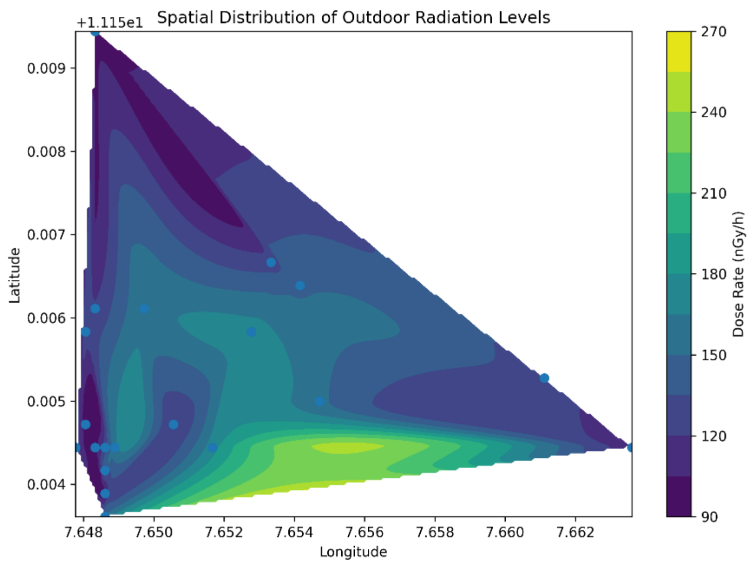

Fig. 6. Spatial distribution map of outdoor radiation levels within the study area.

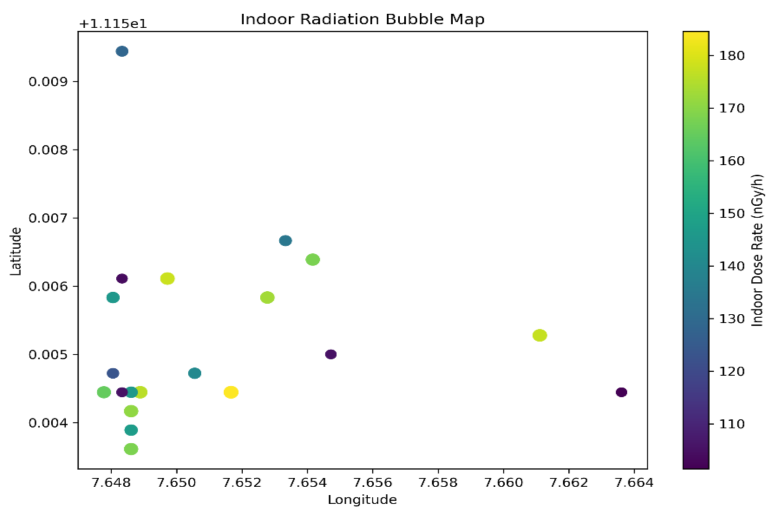

Fig. 7. Indoor radiation bubble map showing relative radiation intensity across measurement locations

These findings emphasize the importance of continuous environmental radiation surveillance in academic and healthcare environments where diagnostic imaging systems and laboratory equipment are routinely operated.

3.5 Comparison with International Standards

The comparison between the measured annual effective dose rates and the ICRP public exposure limit is presented in Fig. 8. Both the estimated mean indoor and outdoor annual effective dose rates remained below the ICRP recommended annual public exposure limit of 1 mSv/y.

This confirms that the radiological conditions within the College of Medical Sciences and Faculty of Veterinary Medicine are currently within internationally acceptable radiological safety limits and do not constitute significant environmental radiation concerns.

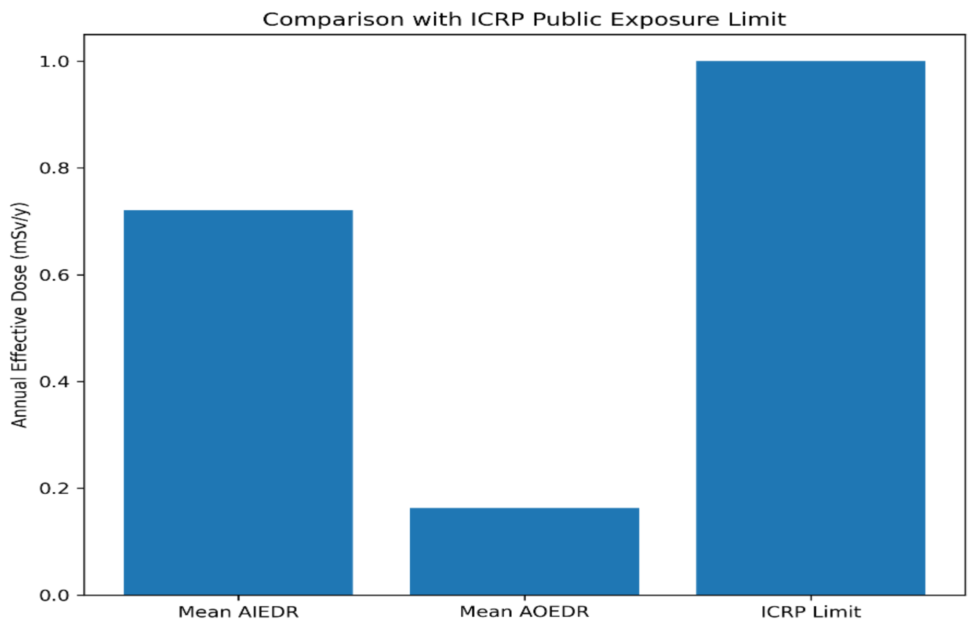

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Fig. 8. Comparison of annual effective dose rates with the ICRP recommended public exposure limit.

4.0 Conclusion

This study evaluated indoor and outdoor background gamma radiation levels within selected locations in the College of Medical Sciences and Faculty of Veterinary Medicine, Ahmadu Bello University, Zaria, Nigeria. The measured radiation levels exhibited moderate spatial variation across the study area, with indoor environments generally recording higher dose rates than outdoor environments. “The mean indoor and outdoor absorbed dose rates were 150.99 nGy/h and 132.59 nGy/h, respectively.

The relatively elevated radiation values observed in some laboratory and radiographic environments may be associated with the use of diagnostic equipment and building materials containing naturally occurring radionuclides. The estimated annual indoor and outdoor effective dose rates remained below the International Commission on Radiological Protection (ICRP) recommended public exposure limit of 1 mSv/y, indicating that the current environmental radiation levels do not pose significant radiological health risks to occupants of the study area. Nevertheless, periodic environmental radiation monitoring and strict adherence to radiation safety practices are recommended to ensure continuous compliance with international radiological protection standards.

Acknowledgment

The authors sincerely thank Alhaji Sani Ibrahim 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 and materials

The publisher has the right to make the data public

Ethical Considerations

Not applicable

Competing interest

The authors report no conflict or competing interest

Funding:

The authors declared no external source of funding

Authors' Contribution

Yahaya Aliyu conducted the field measurements, analyzed the data, interpreted the results, and drafted the manuscript (Manuscript editing). Ahmed Kehinde Usman supervised the study, validated the methodology, and critically reviewed the manuscript. Paul Peter Dawai assisted in radiation measurements (conducted the field measurement), data collection, literature review, and manuscript editing. All authors read, approved, and agreed to the final version of the manuscript.