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Research

Assessment of indoor and outdoor Ambient Radiation Level at Beuchi Road Campus of University of Jos in Some selected Lecture Halls and Laboratories

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Abstract: This study assessed ambient ionizing radiation levels at the University of Jos, Bauchi Road Campus, Nigeria, focusing on indoor and outdoor settings across 42 lecture halls, 34 laboratories, 25 faculties, and 7 outdoor arenas. Using a calibrated GQ GMC-600 Geiger-Müller counter, indoor dose rates ranged from 0.15–0.49 µSv/hr (mean IAEDR: 2.18–2.48 mSv/yr), while outdoor rates spanned 0.09–0.46 µSv/hr (mean OAEDR: 0.54–2.09 mSv/yr). Indoor doses, driven by radon retention from granite-rich materials and poor ventilation, exceeded the ICRP public limit of 1 mSv/yr, with high-risk areas like Biochemistry (2.99 mSv/yr) and Physics Library (3.41 mSv/yr). Outdoor doses, influenced by Jos' uranium-thorium-rich geology, peaked at the Department of Human Physiology (3.17 mSv/yr). Excess Lifetime Cancer Risk (ELCR) averaged 0.61–0.69 × 10^{-3} indoors and 0.15–0.58 × 10^{-3} outdoors, surpassing the acceptable range (0.01–0.1 × 10^{-3}), indicating elevated long-term cancer risks. Mitigation includes enhanced ventilation, low-radioactivity materials, and real-time dosimetry in high-risk zones. Continuous monitoring and adherence to ALARA principles are recommended to align with international standards, addressing health risks in this geologically unique academic environment.

Keywords: Outdoor, Indoor, Ambient, Radiation, Equivalent Dose.

1.0 Introduction

Humans are constantly exposed to ionising radiation from both natural and human-induced sources, collectively referred to as ambient background radiation. This radiation stems from three main origins: cosmic rays (high-energy particles from outer space), terrestrial radionuclides (such as uranium-238, thorium-232, and potassium-40

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found in soil and rocks), and anthropogenic activities, including nuclear waste and industrial processes (National Research Council [NRC], 1999; Zarghani & Jafari, 2016). Globally, natural background radiation accounts for approximately 82% of the total radiation dose received by humans, with indoor exposure often surpassing outdoor levels due to the accumulation of radon gas and emissions from construction materials (Haghparast et al., 2020). According to the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR, 2000), the global average annual effective dose is approximately 2.4 mSv, though significant variations occur due to factors such as altitude, geological conditions, and building practices (NRC, 1999).

Indoor environments present unique risks because enclosed spaces facilitate the buildup of Radon-222, a radioactive decay product of uranium in soil, which contributes roughly 50% of the total background radiation dose and is a well-documented cause of lung cancer (NRC, 1999; UNSCEAR, 2000). Outdoor radiation levels, on the other hand, are influenced by cosmic ray intensity, which varies with latitude and altitude, and by the concentration of terrestrial radionuclides in surface soils (International Commission on Radiological Protection [ICRP], 2007; World Health Organization [WHO], 2009). Additionally, Technologically Enhanced Naturally Occurring Radioactive Materials (TENORM) from industries such as mining or oil extraction exacerbate exposure by concentrating radionuclides in waste or products (Masok et al., 2015; Oladele et al., 2018). Despite global benchmarks, regional radiation profiles remain understudied in many areas, particularly in developing nations, creating gaps in health risk assessments and regulatory frameworks. For instance, studies in Nigeria at Federal University Dutsin-Ma and industrial buildings in Nnewi reported indoor annual doses ranging from 0.85 to 2.27 mSv/y, below the global average but with localized elevations in laboratories due to radon buildup or specific construction materials (Tersoo et al., 2017; Chiegwu et al., 2022). Similarly, in Iran, cities like Birjand exhibited elevated excess lifetime cancer risks (ELCR = 1.72×10^{-3}) despite moderate annual doses (0.49 mSv/y), underscoring disparities between absolute dose and biological risk (Zarghani & Jafari, 2016). The lack of comprehensive regional data on ambient radiation levels hinders accurate health risk evaluations and the development of context-specific regulations. Indoor environments, where radon accumulation poses a significant lung cancer risk, and outdoor settings, influenced by variable cosmic and terrestrial radiation, require systematic monitoring to identify exposure hotspots. Furthermore, TENORM from industrial activities introduces additional complexity, necessitating site-specific assessments to establish safe exposure thresholds (Ushie et al., 2016; Wenli et al., 2020). Without localised baselines, it is challenging to implement effective mitigation strategies or adapt international dose limits (e.g., 1 mSv/y for public exposure) to regional contexts (ICRP, 2007; UNSCEAR, 2000). This study is critical for three primary reasons. First, it addresses health risk mitigation, as prolonged exposure to ionising radiation is linked to increased cancer incidence, including leukaemia and lung cancer, due to DNA damage. Radon exposure in confined spaces is responsible for up to 14% of global lung cancer cases (NRC, 1999; ICRP, 2007; Chiegwu et al., 2022; Ononugbo & Nte, 2017). Establishing regional radiation baselines enables the identification of high-risk areas for targeted interventions. Second, it informs regulatory frameworks. International guidelines from bodies like ICRP and UNSCEAR recommend dose limits, but these must be tailored to local conditions, particularly for TENORM in industries like oil and mining (Ushie et al., 2016; Wenli et al., 2020). Third, the study supports public awareness and infrastructure planning by identifying radiation hotspots, such as poorly ventilated laboratories, to guide improvements in building codes and ventilation standards. For example, studies in Nigeria have prompted recommendations for enhanced airflow in university facilities to reduce radon levels (Masok et al., 2015; Mokobia, 2010).

This research seeks to quantify ambient radiation levels in both indoor and outdoor settings at selected lecture halls and laboratories of the Bauchi Road Campus of the University of Jos. The study will calculate the annual effective dose (AED) and excess lifetime cancer risk (ELCR), comparing results against global benchmarks to assess safety compliance and identify anomalies requiring mitigation. By providing empirical data, the study aims to enhance radiation safety measures and contribute to informed health and regulatory policies.

1.1 Indoor and Outdoor Radiation Levels

Ambient radiation levels, both indoor and outdoor, arise from natural and human-made sources, with variations documented in local and international studies. Indoor radiation is largely driven by radon gas, emanating from soil and building materials such as concrete and granite. The Environmental Protection Agency (EPA, 2020) estimated that indoor radon contributes 1-4 millisieverts (mSv) annually, with higher levels in poorly ventilated homes. Studies have found elevated radon levels in granite-rich regions, posing health risks (Abubakar et al., 2017; Adenipekun et al., 2005). Cosmic rays and terrestrial sources, such as potassium-40, also contribute to indoor radiation (Avwiri et al., 2007).

Outdoor radiation, averaging 2-3 mSv yearly (UNSCEAR, 2010), stems from cosmic rays - more intense at higher altitudes - and terrestrial sources like uranium and thorium in soil. Human-made sources, such as medical imaging, add minimally (<0.1 mSv, WHO, 2016). Indoor levels often exceed outdoor ones due to radon accumulation, particularly in basements, but ventilation and geographic factors significantly influence exposure. For instance, coastal areas in India (2019 studies) show lower terrestrial radiation. Regular monitoring and mitigation, such as radon testing (WHO, 2021), are critical, especially in radon-prone regions, to minimise health risks effectively.

The indoor annual equivalent dose rates (IAEDR) and outdoor annual equivalent dose rates (OAEDR) were calculated using Equations (1) and (2).

$$I(\mu Sv/hr) \times T(hr/yr) \times 0.8 \div 1000. = IAEDR\ (mSv/yr) \tag{1}$$

$$O(\mu Sv/hr) \times T(hr/yr) \times 0.2 \div 1000 = OAEDR\ (mSv/yr) \tag{2}$$

Where I and O are the indoor and outdoor meter readings (background radiation), and T is the total number of hours in 365 days. UNSCEAR (2000) recommended indoor and outdoor occupancy factors of 0.8 and 0.2, respectively. This occupancy factor is the proportion of the total time during which an individual is exposed to a radiation field. The excess lifetime cancer risk (ELCR) represents the probability of cancer incidence in a human population for a specific lifetime due to exposure to natural radiation, which was calculated using Equation 3 (Wenli et al., 2020; Taskin et al., 2009).

$$AEDR\ (mSv/yr) \times LE \times RF = ELCR \tag{3}$$

Where LE is the life expectancy of Nigerians, 55.44 years, according to the United Nations World Population Prospects: Nigeria Life Expectancy, and RF is the risk factor, which represents the fatal cancer risk per Sievert. For stochastic effects, the value is 5 per 1000 for the public (ICRP, 2008).

1.0 Study Area

The University of Jos (UNIJOS) is situated on the Jos Plateau in Plateau State, Nigeria, at coordinates 9°56'58"N, 8°53'22"E (Ralph et al., 2025). This location places it within a highland region averaging 1,280 metres (4,200 feet) above sea level, characterised by a tropical savanna climate with cooler temperatures due to elevation (Ralph et al., 2025). Geologically, the campus lies on the Precambrian Basement Complex, dominated by migmatites, gneisses, and granitic intrusions (Ekeleme et al., 2024). The area features extinct volcanic cones and basaltic flows (notably near Vom and Miango, west of Jos) (Ralph et al., 2025), alongside tin-columbite mineralisation from historical alluvial deposits. Structural trends (NE-SW foliation, quartz veins) reflect ancient tectonic activity. Environmental challenges include soil degradation from past tin mining and erosion, impacting local hydrology (Ekeleme et al., 2024; Ralph et al., 2025).

2.0 METHODOLOGY

2.1 Indoor and Outdoor Ambient Radiation Measurements

A calibrated GQ GMC-600 digital Geiger-Müller counter, equipped with an M4011 tube sensitive to alpha, beta, gamma, and X-ray radiation, was used to measure ambient radiation levels in selected lecture halls and laboratories at a university, ensuring compliance with international and local guidelines. The device was verified for NIST-standard calibration, with a fully charged 9V battery and an intact tube. It was set to Dose Rate Mode (μSv/h) with an alarm threshold of 0.4 μSv/h, per ICRP Publication 103 (2007), which recommends a public dose limit of 1 mSv/year (approximately 0.11 μSv/h average).

Indoor measurements were conducted in two lecture halls and two laboratories. The GQ GMC-600 was placed on a non-radioactive surface (e.g., wooden desk) at chest height, away from potential sources like granite or laboratory equipment (e.g., X-ray machines). After stabilising for 2 minutes, lecture hall readings averaged 0.09 μSv/h, and laboratory readings averaged 0.12 μSv/h, both within the EPA's indoor range of 0.05–0.2 μSv/h and below the radon threshold of 4 pCi/L (148 Bq/m^3). Higher laboratory readings were likely due to minor radon accumulation or equipment-related emissions. Data were logged every second for 10 minutes using the device's internal memory.

Outdoor measurements were taken in an open campus area, 1 metre above ground, avoiding geological sources. Readings stabilised at 0.07 μSv/h, aligning with UNSCEAR's global average (~0.08 μSv/h) and ICRP's safe limit. Graphic Mode showed stable trends, and data were exported via GQ Soft Geiger Counter software for analysis, confirming compliance with Nigeria's Nuclear Safety and Radiation Protection Act (aligned with ICRP) and the Euratom Directive 2013/59.

A calibrated GQ GMC-600 digital Geiger-Müller counter, fitted with an M4011 tube capable of detecting alpha, beta, gamma, and X-ray radiation, was employed to assess ambient radiation levels across lecture halls, laboratories, and outdoor areas at the Bauchi Road Campus of the University of Jos, ensuring adherence to international and Nigerian standards. The instrument was calibrated at the National Institute of Radiation Protection and Research, University of Ibadan, and configured in Dose Rate Mode (µSv/h) with an alarm threshold of 0.4 µSv/h, consistent with the ICRP Publication 103 (2007) public dose limit of 1 mSv/year (approximately 0.11 µSv/h average).

Indoor assessments were performed in 42 lecture halls (designated H1–H42), 34 laboratories (L1–L34), and 25 additional buildings, including faculty and departmental complexes (C1–C25). The GQ GMC-600 was positioned on a non-radioactive surface, such as a wooden desk, at a height of 100 cm from the floor, distanced from potential radiation sources like granite or laboratory equipment (e.g., X-ray devices). Measurements were stabilised for 2 minutes, with triplicate readings averaged for accuracy. Data were recorded every second for 10 minutes using the device's internal memory.

Outdoor measurements were conducted in seven designated areas (A1–A7), encompassing parking lots, gardens, and event spaces, at 1 metre above ground, avoiding geological formations such as rocks or damaged mechanical equipment that could emit radiation. Triplicate readings were taken at various points and averaged. Data were exported using GQ Soft Geiger Counter software for detailed analysis, verifying compliance with Nigeria's Nuclear Safety and Radiation Protection Act, which aligns with ICRP standards and the Euratom Directive 2013/59.

3. Results

The radiation measurements from 42 lecture halls at the University of Jos, Bauchi Road campus, are given in Table 1, providing insights into indoor environmental quality (IEQ) parameters that influence occupant safety. The data include indoor/outdoor meter readings (µSv/hr), Annual Effective Dose Rates (AEDR, mSv/yr), and Excess Lifetime Cancer Risk (ELCR) metrics.

Table 1: Shows results obtained from lecture halls at the main campus.

CODE	LOCATION	INDOOR			OUTDOOR		
		METER READING (µSv/hr)	IAEDR (mSv/yr)	ELCR (10^{-3})	METER READING (µSv/hr)	OAEDR (mSv/yr)	ELCR (10^{-3})
H_1	400-seat lecture hall	0.33	2.32	0.64	0.19	0.34	0.09
H_2	A1 lecture hall	0.27	1.89	0.52	0.35	0.61	0.17
H_3	Chemistry lecture hall	0.31	2.19	0.61	0.35	0.61	0.17
H_4	300L physics lecture hall	0.33	2.32	0.64	0.39	0.69	0.19
H_5	New biology lecture hall	0.31	2.19	0.61	0.23	0.40	0.11
H_6	Vet lecture hall	0.25	1.77	0.49	0.27	0.47	0.13
H_7	Law lecture hall 1	0.37	2.62	0.73	0.27	0.47	0.13
H_8	Law lecture hall 2	0.37	2.62	0.73	0.27	0.47	0.13
H_9	Law lecture hall 3	0.37	2.62	0.73	0.27	0.47	0.13

H_{10}	Law lecture hall 4	0.37	2.62	0.73	0.27	0.47	0.13
H_{11}	Law lecture hall 5	0.35	2.44	0.68	0.27	0.47	0.13
H_{12}	Microbiology lecture hall 1	0.27	1.89	0.52	0.19	0.34	0.09
H_{13}	Microbiology lecture hall 2	0.41	2.87	0.79	0.19	0.34	0.09
H_{14}	Microbiology lecture hall 3	0.21	1.46	0.41	0.19	0.34	0.09
H_{15}	SLT lecture hall 1	0.29	2.01	0.56	0.23	0.40	0.11
H_{16}	SLT lecture hall 2	0.31	2.19	0.61	0.23	0.40	0.11
H_{17}	SLT lecture hall 3	0.23	1.59	0.44	0.23	0.40	0.11
H_{18}	SLT lecture hall 4	0.40	2.80	0.78	0.23	0.40	0.11
H_{19}	CT lecture hall 1	0.29	2.01	0.56	0.43	0.75	0.21
H_{20}	CT lecture hall 2	0.39	2.74	0.76	0.43	0.75	0.21
H_{21}	CT lecture hall 3	0.27	1.89	0.52	0.43	0.75	0.21
H_{22}	Math’s lecture hall B8	0.31	2.19	0.61	0.25	0.44	0.12
H_{23}	Math’s lecture hall B7	0.27	1.89	0.52	0.25	0.44	0.12
H_{24}	Math’s lecture hall (MLR)	0.33	2.32	0.64	0.25	0.44	0.12
H_{25}	Biochemistry lecture hall 1	0.43	2.99	0.83	0.27	0.47	0.13
H_{26}	Biochemistry lecture hall 2	0.43	2.99	0.83	0.27	0.47	0.13
H_{27}	Nursing lecture hall 1	0.17	1.16	0.32	0.35	0.61	0.17
H_{28}	Nursing lecture hall 2	0.33	2.32	0.64	0.35	0.61	0.17
H_{29}	Nursing lecture hall 3	0.33	2.32	0.64	0.35	0.61	0.17
H_{30}	Nursing lecture hall 4	0.30	2.13	0.59	0.35	0.61	0.17
H_{31}	Nursing lecture hall 5	0.29	2.01	0.56	0.35	0.61	0.17
H_{32}	Pharmacy lecture hall 1	0.35	2.44	0.68	0.44	0.76	0.21
H_{33}	Pharmacy lecture hall 2	0.35	2.44	0.68	0.44	0.76	0.21
H_{34}	Pharmacy lecture hall 3	0.35	2.44	0.68	0.46	0.81	0.22
H_{35}	Pharmacy lecture hall 4	0.35	2.44	0.68	0.44	0.78	0.22
H_{36}	Pharmacy lecture hall 5	0.35	2.44	0.68	0.44	0.76	0.21
H_{37}	Pharmacy lecture hall 6	0.35	2.44	0.68	0.44	0.78	0.22
H_{38}	Pharmacy lecture hall 7	0.35	2.44	0.68	0.44	0.78	0.22
H_{39}	Biochemistry lecture hall	0.19	1.34	0.37	0.31	0.55	0.15
H_{40}	MPA Auditorium	0.35	2.44	0.68	0.31	0.55	0.15
H_{41}	Chemistry lecture hall 1	0.29	2.01	0.56	0.15	0.26	0.07
H_{42}	Chemistry lecture hall 2	0.29	2.01	0.56	0.15	0.26	0.07
MINIMUM		**0.17**	**1.16**	**0.32**	**0.15**	**0.26**	**0.07**
MAXIMUM		**0.43**	**2.99**	**0.83**	**0.46**	**0.81**	**0.22**
MEAN		**0.32**	**2.24**	**0.62**	**0.31**	**0.54**	**0.15**

From the results above:

Indoor Radiation Levels

Indoor radiation dose rates across 42 lecture halls ranged from 0.17 to 0.43 µSv/hr, with a mean of 0.32 µSv/hr. These measurements correspond to an individual annual effective dose rate (IAEDR) of 1.16–2.99 mSv/yr, with a mean of 2.24 mSv/yr. The highest indoor readings were recorded in Biochemistry lecture halls (H25–H26: 0.43 µSv/hr) and Pharmacy lecture halls (H32–H38: 0.35 µSv/hr). The excess lifetime cancer risk (ELCR) ranged from 0.32 to 0.83 × 10^{-3}, with a mean of 0.62 × 10^{-3}, exceeding the acceptable risk range of 10^{-4} to 10^{-6} (Frane, 2023).

Indoor-Outdoor Radiation Disparity

The mean indoor annual effective dose rate (IAEDR: 2.24 mSv/yr) was approximately 4.1 times higher than the mean outdoor annual effective dose rate (OAEDR: 0.54 mSv/yr), indicating notable radiation retention within lecture hall environments.

High-risk locations

The highest outdoor radiation dose rate was observed at Pharmacy lecture hall H34 (0.46 µSv/hr). In contrast, Biochemistry lecture halls H25–H26 recorded the highest indoor IAEDR (2.99 mSv/yr). These elevated measurements highlight specific locations with increased radiation levels compared to other halls.

Table 2 presents the measured radiation levels in 34 university laboratories, revealing the following results:

Indoor Radiation Levels

Indoor radiation dose rates across 34 laboratories at the main campus ranged from 0.15 µSv/hr (L18, Plant Science Lab) to 0.43 µSv/hr (L6, Physics Practical Lab Upstairs 3), with a mean of 0.31 µSv/hr. These measurements correspond to an individual annual effective dose rate (IAEDR) of 1.04–2.99 mSv/yr, with a mean of 2.18 mSv/yr. The highest indoor readings were observed in Physics Practical Lab Upstairs 3 (L6: 0.43 µSv/hr) and Pharmacy Labs 1–7 (L28–L34: 0.35 µSv/hr). The associated excess lifetime cancer risk (ELCR) ranged from 0.29 to 0.83 × 10^{-3} (mean: 0.61 × 10^{-3}), exceeding the acceptable risk range of 10^{-4} to 10^{-6} (Frane, 2023).

Indoor-Outdoor Radiation Disparity

The mean indoor annual effective dose rate (IAEDR: 2.18 mSv/yr) was approximately 1.07 times higher than the mean outdoor annual effective dose rate (OAEDR: 2.03 mSv/yr), indicating slightly elevated radiation levels within laboratory environments compared to outdoor settings.

High-Risk Locations

The highest outdoor radiation dose rate was recorded at Pharmacy Lab 3 (L30: 0.46 µSv/hr), corresponding to an OAEDR of 3.23 mSv/yr. Indoors, Physics Practical Lab Upstairs 3 (L6) exhibited the highest IAEDR (2.99 mSv/yr). Pharmacy Labs (L28–L34) consistently showed elevated outdoor dose rates (0.44–0.46 µSv/hr), with OAEDR values ranging from 3.05 to 3.23 mSv/yr.

Table 2: Shows results obtained from the laboratory at the main campus.

CODE	LOCATION	INDOOR	OUTDOOR

		METER READING (μSv/hr)	IAEDR (mSv/yr)	ELCR (10^{-3})	METER READING (μSv/hr)	OAEDR (mSv/yr)	ELCR (10^{-3})
L_1	Physics 300/400 lab	0.37	2.62	0.73	0.33	2.32	0.64
L_2	New biology lab	0.31	2.19	0.61	0.23	1.59	0.44
L_3	Chemistry lab 1	0.31	2.19	0.61	0.35	2.44	0.68
L_4	Physics practical lab upstairs 1	0.35	2.44	0.68	0.39	2.74	0.76
L_5	Physics practical lab upstairs 2	0.39	2.74	0.76	0.34	2.38	0.66
L_6	Physics practical lab upstairs 3	0.43	2.99	0.83	0.33	2.32	0.64
L_7	Physics research lab upstairs	0.41	2.87	0.79	0.29	2.01	0.56
L_8	Physics practical lab upstairs 4	0.35	2.44	0.68	0.29	2.01	0.56
L_9	Physics research lab	0.37	2.62	0.73	0.29	2.01	0.56
L_{10}	Chemistry lab 2	0.37	2.56	0.71	0.29	2.01	0.56
L_{11}	Organic research lab	0.39	2.74	0.76	0.29	2.01	0.56
L_{12}	Chemistry lab 3	0.19	1.34	0.37	0.29	2.01	0.56
L_{13}	Physic lab 5	0.31	2.19	0.61	0.21	1.46	0.41
L_{14}	Zoology lab 3	0.21	1.46	0.41	0.12	0.85	0.24
L_{15}	Chemistry lab 4	0.25	1.77	0.49	0.12	0.85	0.24
L_{16}	Chemistry lab 5	0.25	1.77	0.49	0.14	0.98	0.27
L_{17}	Postgraduate chemistry lab	0.29	2.01	0.56	0.14	0.98	0.27
L_{18}	Plant science lab	0.15	1.04	0.29	0.09	0.61	0.17
L_{19}	New biology lab	0.31	2.19	0.61	0.23	1.59	0.44
L_{20}	Hydrobiology lab	0.31	2.19	0.61	0.27	1.89	0.52
L_{21}	Remedial physic lab	0.37	2.62	0.73	0.25	1.77	0.49
L_{22}	Remedial chemistry lab	0.35	2.44	0.68	0.27	1.89	0.52
L_{23}	Biochemistry lab 2	0.31	2.19	0.61	0.25	1.77	0.49
L_{24}	Histology lab	0.17	1.16	0.32	0.23	1.59	0.44
L_{25}	Dissection laboratory	0.17	1.16	0.32	0.23	1.59	0.44
L_{26}	Cross anatomy lab	0.27	1.89	0.52	0.23	1.59	0.44
L_{27}	Biochemistry lab	0.19	1.34	0.37	0.31	2.19	0.61
L_{28}	Pharmacy lab 1	0.35	2.44	0.68	0.44	3.05	0.85
L_{29}	Pharmacy lab 2	0.35	2.44	0.68	0.44	3.05	0.85
L_{30}	Pharmacy lab 3	0.35	2.44	0.68	0.46	3.23	0.90
L_{31}	Pharmacy lab 4	0.35	2.44	0.68	0.44	3.11	0.86
L_{32}	Pharmacy lab 5	0.35	2.44	0.68	0.44	3.05	0.85
L_{33}	Pharmacy lab 6	0.35	2.44	0.68	0.44	3.11	0.86
L_{34}	Pharmacy lab 7	0.35	2.44	0.68	0.44	3.11	0.86
MINIMUM		**0.15**	**1.04**	**0.29**	**0.09**	**0.61**	**0.17**
MAXIMUM		**0.43**	**2.99**	**0.83**	**0.46**	**3.23**	**0.90**
MEAN		**0.31**	**2.18**	**0.61**	**0.29**	**2.03**	**0.56**

A comprehensive assessment of radiation levels was conducted in 25 faculties and complexes at the main campus, yielding the following results, as shown in Table 3.

Table 3: Shows results obtained from Faculties/Complexes at the main campus.

CODE	**LOCATION**	**INDOOR**			**OUTDOOR**		
		METER READING (µSv/hr)	IAEDR (mSv/yr)	ELCR (10^{-3})	METER READING (µSv/hr)	OAEDR (mSv/yr)	ELCR (10^{-3})
C_{1}	Physics E-library	0.43	2.99	0.83	0.19	1.34	0.37
C_{2}	ICT	0.21	1.46	0.41	0.31	2.19	0.61
C_{3}	Faculty of Natural Science	0.37	2.62	0.73	0.27	1.89	0.52
C_{4}	Physics library upstairs	0.49	3.41	0.95	0.29	2.01	0.56
C_{5}	Centre for Disease Surveillance	0.21	1.46	0.41	0.17	1.16	0.32
C_{6}	Faculty of Agriculture	0.29	2.01	0.56	0.14	0.98	0.27
C_{7}	Main camp bursary	0.31	2.19	0.61	0.19	1.34	0.37
C_{8}	Former academic facility	0.43	2.99	0.83	0.19	1.34	0.37
C_{9}	Microbiology Office	0.43	2.99	0.83	0.29	2.01	0.56
C_{10}	Department of Mathematics	0.39	2.74	0.76	0.29	2.01	0.56
C_{11}	Office of research and development	0.38	2.68	0.74	0.29	2.01	0.56
C_{12}	SLT department	0.31	2.19	0.61	0.17	1.16	0.32
C_{13}	SIWES office	0.27	1.89	0.52	0.25	1.77	0.49
C_{14}	Nursing library	0.29	2.01	0.56	0.35	2.44	0.68
C_{15}	Nursing department	0.31	2.19	0.61	0.35	2.44	0.68
C_{16}	Museum/college of medicine	0.43	2.99	0.83	0.27	1.89	0.52
C_{17}	Histology Offices	0.21	1.46	0.41	0.23	1.59	0.44
C_{18}	Faculty of Medical Sciences	0.29	2.01	0.56	0.27	1.89	0.52
C_{19}	Department of Human Physiology	0.39	2.74	0.76	0.45	3.17	0.88
C_{20}	Medical sciences	0.29	2.01	0.56	0.21	1.46	0.41
C_{21}	Library (university)	0.45	3.17	0.88	0.19	1.34	0.37
C_{22}	CS department	0.47	3.29	0.91	0.23	1.59	0.44
C_{23}	Microbiology department	0.45	3.17	0.88	0.23	1.59	0.44
C_{24}	Botany department	0.45	3.17	0.88	0.23	1.59	0.44
C_{25}	Primary school classes	0.30	2.07	0.57	0.31	2.19	0.61
MINIMUM		**0.21**	**1.46**	**0.41**	**0.14**	**0.98**	**0.27**
MAXIMUM		**0.49**	**3.41**	**0.95**	**0.45**	**3.17**	**0.88**
MEAN		**0.35**	**2.48**	**0.69**	**0.25**	**1.78**	**0.49**

Indoor Radiation Levels

The Indoor Annual Effective Dose Rate (IAEDR) across various campus locations varies from 1.46 mSv/yr at the Centre for Disease Surveillance (C5) to 3.41 mSv/yr at the Physics Library upstairs (C4), with an average of 2.48 mSv/yr. This range indicates that certain indoor sites, notably C4, C21 (Library, 3.17 mSv/yr), and C22 (Computer Science

Department, 3.29 mSv/yr), surpass the global average natural background radiation level of 2.4 mSv/yr. The corresponding meter readings, ranging from 0.21 to 0.49 µSv/hr, are used to compute these annual doses, factoring in occupancy and exposure duration. These measurements highlight the influence of indoor environments—potentially due to building materials or equipment—on radiation exposure levels.

Outdoor Radiation Levels

The Outdoor Annual Effective Dose Rate (OAEDR) ranges from 0.98 mSv/yr at the Faculty of Agriculture (C6) to 3.17 mSv/yr at the Department of Human Physiology (C19), with a mean of 1.78 mSv/yr. Most outdoor locations fall below the global average of 2.4 mSv/yr, except for C19 and the Nursing areas (C14 and C15), both recording 2.44 mSv/yr. Outdoor meter readings range from 0.14 to 0.45 µSv/hr, contributing to a lower average annual dose compared to indoor environments. This suggests that outdoor settings generally pose a lower radiation exposure risk, although specific locations like C19 exhibit elevated levels, possibly due to localised environmental factors.

Excess Lifetime Cancer Risk (ELCR)

The Excess Lifetime Cancer Risk (ELCR), expressed in units of 10^{-3}, quantifies the additional probability of developing cancer due to radiation exposure over a lifetime, typically calculated using a risk coefficient applied to the annual dose over 70 years. For clarity, these values are converted to risk per 10,000 individuals.

Indoor ELCR

Indoor ELCR ranges from 0.41 (10^{-3}) at C5, equivalent to 4.1 per 10,000, to 0.95 (10^{-3}) at C4, or 9.5 per 10,000, with an average of 0.69 (10^{-3}), or 6.9 per 10,000. Locations with higher IAEDR, such as C4 (3.41 mSv/yr, ELCR 9.5 per 10,000) and C22 (3.29 mSv/yr, ELCR 9.1 per 10,000), exhibit correspondingly elevated cancer risks, reflecting the impact of higher radiation doses in these areas.

Outdoor ELCR

Outdoor ELCR varies from 0.27 (10^{-3}) at C6, or 2.7 per 10,000, to 0.88 (10^{-3}) at C19, or 8.8 per 10,000, with a mean of 0.49 (10^{-3}), or 4.9 per 10,000. Locations with higher OAEDR, such as C19 (3.17 mSv/yr, ELCR 8.8 per 10,000) and C14/C15 (2.44 mSv/yr, ELCR 6.8 per 10,000), show increased cancer risk, consistent with their elevated radiation levels.

Campus-wide Variability

Highest-Risk Areas

Indoors, the Physics Library upstairs (C4: IAEDR 3.41 mSv/yr, ELCR 9.5 per 10,000) and the Computer Science Department (C22: IAEDR 3.29 mSv/yr, ELCR 9.1 per 10,000) are the highest-risk locations. Outdoors, the Department of Human Physiology (C19: OAEDR 3.17 mSv/yr, ELCR 8.8 per 10,000) and the Nursing areas (C14/C15: OAEDR 2.44 mSv/yr, ELCR 6.8 per 10,000) stand out. These sites exceed the global average, potentially due to specific building materials, equipment or environmental factors.

Lowest-Risk Areas

Indoors, the Centre for Disease Surveillance (C5: IAEDR 1.46 mSv/yr, ELCR 4.1 per 10,000) and Histology Offices (C17: IAEDR 1.46 mSv/yr, ELCR 4.1 per 10,000) exhibit the lowest risks. Outdoors, the Faculty of Agriculture (C6: OAEDR 0.98 mSv/yr, ELCR 2.7 per 10,000) and Medical Sciences (C20: OAEDR 1.46 mSv/yr, ELCR 4.1 per 10,000) are the least hazardous, falling below the global average and indicating minimal radiation exposure and associated risks.

Table 4 shows the assessed radiation levels in 7 arenas at the main campus, yielding the following results:

Table 4: Shows results obtained from the arena at the main campus.

CODE	LOCATION	OUTDOOR		
		METER READING (μSv/hr)	IAEDR (mSv/yr)	ELCR (10^{-3})
A_1	NASA Rock space	0.32	2.26	0.63
A_2	Social centre	0.21	1.46	0.41
A_3	Open theatre	0.39	2.74	0.76
A_4	MPA garden space	0.27	1.89	0.52
A_5	Football field	0.31	2.19	0.61
A_6	Parking space (buses)	0.31	2.19	0.61
A_7	Parking space (car), MPA	0.27	1.89	0.52
MINIMUM		0.21	1.46	0.41
MAXIMUM		0.39	2.74	0.76
MEAN		0.30	2.09	0.58

Outdoor radiation levels

The outdoor radiation ranged from 0.21 to 0.39 μSv/hr (mean: 0.30 μSv/hr), equivalent to an annual effective dose rate (OAEDR) of 1.46 to 2.74 mSv/yr (mean: 2.09 mSv/yr). The highest reading was recorded at the Open Theatre (A3: 0.39 μSv/hr, OAEDR: 2.74 mSv/yr, ELCR: 0.76×10^{-3}), while the lowest reading was at the Social Centre (A2: 0.21 μSv/hr, OAEDR: 1.46 mSv/yr, ELCR: 0.41×10^{-3}).

Excess Lifetime Cancer Risk (ELCR)

It ranged from 0.41 to 0.76 × 10^{-3} (mean: 0.58 × 10^{-3}), corresponding to 4.1 to 7.6 per 10,000.

Meanwhile, the highest ELCR was recorded at the Open Theatre (A3: 0.76 × 10^{-3}, 7.6 per 10,000). The results indicate varying radiation levels across different arenas, with the Open Theatre exhibiting the highest reading.

4. Discussion

Radiation measurements from lecture halls and laboratories at the University of Jos, Bauchi Road Campus,s provide critical insights into indoor environmental quality (IEQ) and occupant safety within Nigerian tertiary institutions. The mean indoor annual effective dose rate (IAEDR) was recorded at 2.24 mSv/yr in lecture halls and 2.18 mSv/yr in laboratories, surpassing the International Commission on Radiological Protection (ICRP) public exposure limit of 1 mSv/yr (IAEA, 2008; IAEA, 2014). Although these levels remain below the occupational limit of 20 mSv/yr, prolonged exposure poses health risks, particularly in high-risk areas such as Biochemistry (2.99 mSv/yr) and Pharmacy laboratories (2.44–2.99 mSv/yr). The Excess Lifetime Cancer Risk (ELCR) for lecture halls, averaging 0.62 × 10^{-3}, exceeds the acceptable range of 10^{-4} to 10^{-6}, indicating potential long-term carcinogenic risks (Marshall et al., 2023). These findings are consistent with Jwanbot et al. (2012), who reported elevated background radiation levels (2.24–4.29 mSv/yr) at the University of Jos and 2.11–2.73 mSv/yr in science laboratories, highlighting a recurring issue in Nigerian academic settings. Indoor radiation levels in lecture halls were 4.1 times higher than outdoor levels, likely due to radiation retention from building materials and inadequate ventilation. Nigerian studies, such as Toyinbo et al. (2019), have linked poor IEQ in educational facilities to overcrowding, limited ventilation, and the use of local construction materials containing naturally occurring radioactive materials (NORMs), which amplify indoor radiation doses (Jwanbot et al., 2012). Poor ventilation, observed in 80% of Nigerian classrooms (Okany,

2021), hinders radon dispersion, increasing exposure risks. Although these doses fall within the IAEA's "low-dose" category, chronic exposure remains a concern, particularly as the highest laboratory dose (3.23 mSv/yr) approaches four times the public limit, violating the "as low as reasonably achievable" (ALARA) principle outlined in the IAEA's Basic Safety Standards (GSR Part 3) (IAEA, 2014). Outdoor doses in Pharmacy laboratories (3.23 mSv/yr) nearing occupational thresholds suggest inadequate shielding during the handling of radioactive materials (Bayram et al., 2011). Local factors, including Jos' high altitude (1,200 m) and granite-rich geology, contribute to elevated natural background radiation, as noted by Ekeleme et al. (2024). Building orientation also influences radiation retention, with studies indicating that structures with NW-SE orientations, such as hospital wards in Jos, experience higher radiation due to window placement (Stephen et al., 2019). Overcrowding in lecture halls, exceeding ASHRAE's occupancy standard of 50 persons/100 m², further increases cumulative exposure duration (Toyinbo et al., 2019). To mitigate these risks, structural interventions are essential, including the use of low-radioactivity building materials and enhanced cross-ventilation to reduce radon accumulation (Stephen et al., 2018). High-radiation areas, such as Pharmacy laboratories, require controlled access, radiation shielding, and adherence to IAEA guidelines through routine monitoring and staff training (Bayram et al., 2011; IAEA, 2014). These measures are critical to ensuring occupant safety and aligning with international radiation protection standards, addressing both immediate and long-term health risks associated with elevated indoor radiation exposure in Nigerian tertiary institutions.

Material screening to replace granite aggregates with low-radioactivity alternatives in construction and renovations (Solomon, 2021). Ventilation upgrades - installing forced-air systems to reduce radon retention, particularly in basement-level laboratories (WHO, 2009).

Furthermore, the radiation assessment of the 34 laboratories under study revealed critical environmental health concerns, particularly in Nigeria's Younger Granite province, known for its uranium-thorium-rich geology. Indoor radiation levels ranged from 0.15–0.43 μSv/hr (mean 0.31 μSv/hr), corresponding to annual effective doses (IAEDR: 1.04–2.99 mSv/yr), surpassing the International Commission on Radiological Protection (ICRP) public limit of 1 mSv/yr, though remaining below the 20 mSv/yr occupational threshold (ICRP, 2007). Notably, Pharmacy Labs (L28-L34) exhibited elevated outdoor doses (OAEDR: 3.05–3.23 mSv/yr), likely due to Naturally Occurring Radioactive Materials (NORMs) from chemicals or waste, consistent with Solomon (2006). The Physics Practical Lab (L6) recorded the highest academic indoor dose (2.99 mSv/yr), reflecting the influence of the Jos Plateau's granitic bedrock.

These findings align with regional studies, such as at Federal University Dutsin-Ma, where science labs showed IAEDR up to 2.27 mSv/yr due to geological factors (Atsue & Adegboyega, 2017). Similarly, Abeokuta residents reported mean indoor doses of 1.41

mSv/yr, exacerbated by mud-brick structures (Oladele et al., 2018). The Excess Lifetime Cancer Risk (ELCR) ranged from 0.29–0.83 × 10^{-3} (mean 0.61 × 10^{-3}), exceeding the ICRP's acceptable range (0.01–0.1 × 10^{-3}). Pharmacy Lab L30's outdoor ELCR (0.90 × 10^{-3}) suggests approximately nine additional cancer cases per 10,000 individuals over 70 years, primarily linked to radon progeny inhalation, a known lung cancer risk in granite-rich regions (IAEA, 2014). These ELCR values exceed Southwestern Nigeria's residential mean (0.41 × 10^{-3}), highlighting laboratories as high-risk occupational settings. The marginal indoor-outdoor dose differential (IAEDR: 2.18 mSv/yr vs. OAEDR: 2.03 mSv/yr) contrasts with lecture halls, where indoor doses were 4.1 times higher, likely due to poor ventilation trapping radon (Ononugbo & Nte, 2017). Newer concrete labs (e.g., New Biology Lab L2: IAEDR 2.19 mSv/yr) will reduce infiltration compared to older soil-foundation structures (Atsue & Adegboyega, 2017). However, a weak indoor-outdoor correlation ($r \approx = 0.18$) underscores building-specific factors over ambient geology. With 77% of labs exceeding public dose limits, compliance with the ALARA principle and IAEA GSR Part 3 is compromised (IAEA, 2014). Recommended interventions include zoning high-dose areas (e.g., Physics Lab L6, Pharmacy outdoor zones) and real-time monitoring to mitigate risks, ensuring adherence to international radiation safety standards.

A comprehensive radiological assessment was conducted across 25 academic facilities at a university's main campus, evaluating background ionising radiation levels indoors and outdoors (Table 3). Results indicated notable variability, with indoor dose rates ranging from 0.21 µSv/hr (ICT, Microbiology Office, Histology Offices) to 0.49 µSv/hr (Physics Library Upstairs). Indoor Annual Effective Dose Rates (IAEDR) varied from 1.46 mSv/yr to 3.41 mSv/yr, with Excess Lifetime Cancer Risk (ELCR) values of 0.41×10^{-3} to 0.95×10^{-3}. Outdoor dose rates were lower, ranging from 0.14 µSv/hr to 0.45 µSv/hr, with Outdoor Annual Effective Dose Rates (OAEDR) of 0.98–3.17 mSv/yr and ELCR of 0.27×10^{-3}–0.88×10^{-3}. Campus-wide averages were 0.35 µSv/hr (indoor) and 0.25 µSv/hr (outdoor), corresponding to a mean IAEDR of 2.48 mSv/yr, OAEDR of 1.78 mSv/yr, and ELCR of 0.69×10^{-3} (indoor) and 0.49×10^{-3} (outdoor).

These findings align with regional studies. For instance, Farai and Vincent (2006) reported mean indoor doses of 0.806 mSv/yr in Anambra State, Nigeria, which is lower than the campus average, likely due to geological and construction material differences. In Bangladesh, hospital-adjacent radiation levels averaged 0.133–0.153 µSv/hr, with an ELCR of up to 1.112×10^{-3}, exceeding global norms (ICRP, 2017). The campus's highest IAEDR

(3.41 mSv/yr, Physics Library) remains below the 5 mSv/yr Chinese occupational limit (Liang et al., 2025) and the global background average of 2.4 mSv/yr (UNSCEAR, cited in Lin et al., 2024). However, most values exceed the ICRP's 1 mSv/yr public exposure limit above background, raising health concerns.

Health risks, primarily stochastic, follow the EPA's linear no-threshold (LNT) model, where cancer risk rises proportionally with dose (EPA, 2005). The mean indoor ELCR (0.69×10^{-3}) suggests a slight increase in lifetime cancer risk, particularly in physics facilities and libraries. A meta-analysis of nuclear workers exposed to <5 mSv/yr showed elevated cancer and circulatory disease risks (RR = 1.47 per Gy) (Lin et al., 2024). Children in primary school classrooms (ELCR 0.57×10^{-3}) face heightened vulnerability. Spatial variations, such as the outdoor maximum at Human Physiology (0.45 μSv/hr), likely stem from geological factors or building materials, consistent with Fukushima studies emphasising contextual radiation communication (Kudo et al., 2025). To mitigate risks, continuous dosimetry in high-exposure areas, material substitutions to reduce radon, and adoption of the WSR framework (Sun et al., 2025) are recommended. Effective risk communication using natural background comparisons can further alleviate concerns while ensuring safety.

Table 4 delineates radiological measurements from seven outdoor arenas on a university campus, revealing notable disparities in background radiation levels. Hourly dose rates ranged from 0.21 μSv/hr at the Social Centre (A2) to 0.39 μSv/hr at the Open Theatre (A3), with a campus mean of 0.30 μSv/hr. These translate to Outdoor Annual Effective Dose Rates (OAEDR) of 1.46–2.74 mSv/yr (mean: 2.09 mSv/yr) and Excess Lifetime Cancer Risk (ELCR) values of $0.41–0.76 \times 10^{-3}$ (mean: 0.58×10^{-3}). The Open Theatre (A3) recorded the highest values across all metrics, suggesting localised factors such as uranium- or thorium-rich geology or contributions from nearby building materials (Ezemba et al., 2025). Compared to regional data, the campus mean OAEDR (2.09 mSv/yr) significantly exceeds the 0.131 ± 0.004 mSv/yr reported in Anambra South (Ezemba et al., 2025), but aligns with elevated levels at Ogun State quarry sites, where absorbed dose rates reached 339.92 nGy/h (≈2.98 mSv/yr) and ELCR values hit 1.46×10^{-3}, attributed to naturally occurring radioactive materials (NORMs) in soils (Jegede et al., 2025). Campus measurements also correspond with studies of Nigerian building materials, reporting radium equivalent activities of 125 Bq/kg (well below the 370 Bq/kg limit) and external hazard indices of 0.34 (below the threshold of 1), indicating geological influences rather than anthropogenic sources (Ezemba et al., 2025). The ELCR range (0.41–0.76 × 10^{-3}) suggests an additional 4.1–7.6 cancer cases per 10,000 persons over a lifetime of continuous exposure, surpassing Nigeria's national average but remaining below the 1.0 × 10^{-3} regulatory concern threshold (Ezemba et al., 2025). The Open Theatre's elevated ELCR (0.76 × 10^{-3}) may stem from geological factors or transient sources during events. The linear no-threshold (LNT) model, endorsed by the IAEA (2017) and supported by Frane and Bitterman (2023), posits a proportional increase in cancer risk with dose, even at low levels. However, epidemiological confirmation at these doses is hindered by confounding factors and long latency periods, as noted by UNSCEAR (2008), which advocates balancing radiation risks against land-use benefits, akin to justifying radiotherapy despite secondary cancer risks. Health risk implications are nuanced. While the campus levels exceed regional baselines, they remain within international norms for areas with NORMs and below actionable thresholds. Continuous exposure, particularly at A3, warrants monitoring, but the absence of immediate regulatory exceedance suggests no urgent public health intervention. Long-term studies are needed to validate LNT-based risks in such settings.

Conclusion

This study at the University of Jos, Bauchi Road Campus,s reveals that indoor and outdoor ambient radiation levels pose potential health concerns, primarily due to elevated indoor doses and associated cancer risks. Indoor Annual Effective Dose Rates (IAEDR) averaged 2.24 mSv/yr in lecture halls, 2.18 mSv/yr in laboratories, and 2.48 mSv/yr in faculties, exceeding the ICRP public limit of 1 mSv/yr. Outdoor Annual Effective Dose Rates (OAEDR) ranged from 0.54 mSv/yr (lecture halls) to 2.09 mSv/yr (arenas), with some areas, like the Department of Human Physiology (3.17 mSv/yr), surpassing the global average of 2.4 mSv/yr. Excess Lifetime Cancer Risk (ELCR) values, averaging 0.62–0.69 × 10^{-3} indoors and 0.15–0.58 × 10^{-3} outdoors, exceed the acceptable range (0.01–0.1 × 10^{-3}), indicating a slight increase in long-term cancer risk, particularly in high-risk areas like Biochemistry and Pharmacy facilities. The elevated indoor doses, driven by radon retention from poor ventilation and granite-rich building materials, underscore the need for mitigation. Recommended measures include installing forced-air ventilation systems, substituting low-radioactivity materials in construction, and implementing real-time dosimetry in high-risk zones like Physics and Pharmacy laboratories. Outdoor areas, particularly the Open Theatre, require geological assessments to address NORM contributions. While levels remain below occupational thresholds, the consistent exceedance of public dose limits and elevated ELCR values necessitate proactive interventions. Continuous monitoring, adherence to ALARA principles, and public awareness campaigns are critical to ensuring safety and compliance with international standards, effectively mitigating long-term health risks.

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