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Research Article

Assessment of Indoor and Outdoor Environments Ionizing Radiation Exposure Levels at Fourah Bay College Laboratories and Workshops, University of Sierra Leone

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Abstract
This study was an attempt to assess indoor and outdoor radiation equivalent dose rates in six laboratories and four workshops at Fourah Bay College, University of Sierra Leone in order to determine corresponding Annual Effective Dose Equivalent (AEDE) and assess the Excess Life-time Cancer Risk (ELCR) of students, staff and other users of the laboratories, workshops and their immediate neighborhood. The average values recorded for the indoor and outdoor equivalent dose rate, AEDE and ELCR are (0.20 μSv/h and 0.10 μSv/h), 1.40 mSv/y and 0.18 mSv/y) and (4.92 x 10^{-3} and 6.3 x 10^{-4}) respectively while the average ratio of indoor to outdoor equivalent dose rate observed was 1.97. These average values are lower when compared with the global average limits of 2.4 mSv/y for indoor exposure, and 1.0 mSv/y for outdoor exposure, established by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) and the International Commission on Radiological Protection (ICRP) respectively. The maximum values of Indoor Equivalent Dose Rates, AEDE and ELCR were recorded in the Nuclear Science and Physics laboratories, both significantly higher than the recommended limits by UNSCEAR and ICRP. This indicates potential health risks for staff and students spending prolonged periods in these environments. Generally, the study shows that Fourah Bay College is relatively safe radiologically with little contamination which could be attributed to the artificial radiation sources (radioactive isotopes, particle accelerators and nuclear reactors) found in the nuclear science and physics laboratories and also due to the poor ventilation system in the nuclear science laboratory. However, the contamination will not pose any immediate radiological health effect on students and staff in the college but there is tendency for long-term hazards in the future such as cancer due to doses accumulated. It is therefore recommended that regular radiation monitoring exercise should be conducted from time to time in order to checkmate both the workers and students from high radiation exposure.
Keywords: Indoor, Outdoor, Radiation Equivalent Dose, Effective Dose Equivalent, Excess Lifetime Cancer Risk.

Introduction

Radiation is the emission or transmission of energy in the form of waves or particles through space or material medium. Electromagnetic radiation consists with radio waves, microwaves, infrared, visible light, ultraviolet, x-rays, and gamma radiation (γ), particle radiation are found in the form of alpha radiation (α), beta radiation (β), proton radiation and neutron radiation, acoustic radiation can be exemplified as ultrasound, sound, and seismic waves and gravitational radiation is the radiation that takes the form of gravitational waves, or ripples in the curvature of space time (Ryan, 2012). Radiation can be both beneficial and harmful and is encountered in various forms and different intensities in everyday activities. Some of the harmful effects are: cancer, cataract, gene mutation, destruction of bones and blood cells and it can cause the death of an individual, encountered in everyday activities with varying forms and intensities (Rilwan *et al.,* 2021). Radiation can originate from natural sources, such as cosmic rays and terrestrial materials, as well as artificial sources like laboratory equipment and medical devices (UNSCEAR, 2008). Radiation exposure, whether indoor or outdoor, is a critical factor in assessing environmental and occupational health risks. The management of these risks becomes especially important in academic institutions where both students and staff may be exposed to varying levels of radiation, particularly in specialized areas such as laboratories. This study focuses on evaluating the radiation doses at Fourah Bay College, University of Sierra Leone, which encompasses a diverse range of facilities including laboratories and workshops. By employing appropriate measurement techniques and instruments, this assessment will provide valuable data on the radiation exposure levels experienced by individuals working within these facilities.

Baraya *et al.,* (2019) assessment of indoor background ionizing radiation level at School of Technology, Kano State Polytechnic, Nigeria was carried out using a digital radiation meter (Radiation Alert Inspector). A total of 49 areas were surveyed and the results obtained showed that the annual indoor reading were highest at Compounding Lab (2.368±0.35 mSv/y) and Old Chemistry Lab (2.169±0.35 mSv/y), and lowest at New Biology Lab (1.219±0.21) and Press Workshop (1.303±0.35 mSv/y). For the lecture venues, Auditorium has the highest indoor annual equivalent dose of 2.060±0.49 mSv/y, while H-Block ND I Textile Class recorded the lowest values of 1.275±0.27 mSv/y. Based on the aforementioned findings, it was deduced that radiation levels are within the permissible radiation limit as stipulated by the ICRP and UNSCEAR of 2.4 mSv/y and thus, SOT Kano is radiologically safe. Rilwan *et al.,* (2022) work aimed to check the environmental impact of radiation emitted from radionuclide across Southern Borno, Nigeria using Inspector Alert Nuclear Radiation Monitor. Finding of the study revealed that the mean values for the lungs, ovaries, bone marrow, testes, kidney, liver and whole body are 0.065, 0.059, 0.070, 0.083, 0.063, 0.046 and 0.069 mSv/y respectively. It can be concluded that background radiation in Southern Borno is not an issue of health concern in regards to sensitive organs and may not cause immediate health effect except on excessive exposure.

James *et al.,* (2015) measured the outdoor background ionizing radiation level at Kwali General Hospital Abuja, Nigeria was carried out using a well calibrated Geiger-Muller counter radiation monitor. The dose equivalent results obtained it ranges from 0.100±0.001 µSv/h to 0.122±0.003 µSv/h with an average of 0.108±0.003 µSv/h for outdoor measurement. The study also revealed that the average annual equivalent dose rate is 0.189±0.005 mSv/y for outdoor measurement. This result revealed that the dose levels in all of the locations (outdoor) were below the 1 mSv/y maximum permissible limit for the public set by International Commission on Radiation Protection (ICRP). Therefore, Kwali General Hospital is radiologically safe. Samaila *et al.,* (2020) carried a quantitative review on the background radiation levels in some parts of Nigeria. The overview result has revealed that the mean absorbed dose rate and the annual effective dose equivalent rate levels are within the standard permissible limits set by the International Commission on Radiation Protection (ICRP) except for excess life cancer risk which exceed the permissible limit set by UNSCEAR. Hence, the radiological assessment showed that the investigated areas do not constitute any immediate radiological health effect on the general public due to background radiation exposure but there exists the possibility of one developing cancer over a life time of exposure within the studied environments.

Ugbede and Echeweozo (2017) estimated the annual effective dose equivalent and excess lifetime cancer risk due to background ionizing radiation within and around Okpoto quarry site has been carry out, using a portable Geiger counter radiation detector. An in-situ measurement of absorbed dose rate in air at 1.0 meter above ground level was carried out at twenty different locations each for within and around the quarry site. It concluded that the values are observed to be slightly lower than the global average value and are within the permissible limit as recommended by the international bodies. Ademoh *et al.,* (2022) reported an assessment of ionizing radiation in some chosen dumpsites in Lafia local government area of Nasarawa State. Ionizing radiation measurement was conducted at four dumpsites. The survey was done using a radiation survey meter. Readings were taken by placing the detector at gonad level about 1 meter above the ground. Result showed that the average annual effective dose rate in the selected dumpsites were 0.22 mSv/y for Lafia modern market, 0.17 mSv/y for dumpsite opposite governor Isa house, 0.15 mSv/y for Timber shade Lafia and 0.20 mSv/y for Science School Lafia respectively with a mean value of 0.19 mSv/y for all location. Dumpsites yearly absorbed dose rate and their corresponding values did not exceed the 1.0 mSv/y basic safety standard set for the masses by International Council on Radiation Protection (ICRP, 2007). Based on these results there are no radiation consequence to the scavengers, dumpsite workers and residents living around the dumpsites. Ofomola *et al.,* (2023) investigated the environmental risk of natural radioactivity and some toxic elements in quarry site located in Nkalagu, Southeastern Nigeria. The mean concentration of the analyzed toxic elements in the rock and soil followed the order; Fe> Zn> Cr> Pb> Cd and Fe> Zn> Pb> Cr> Cd respectively. The analyzed metal concentration was within WHO permissible limits for soil samples. Findings from the study showed that the background radiation of the quarry environment is slightly elevated which may result to higher exposure dose of workers.

The problem addressed is the lack of comprehensive assessment of indoor and outdoor radiation levels at Fourah Bay College campus laboratories and workshops. While radiation monitoring is a standard practice in many scientific institutions worldwide, there is limited information available regarding the radiation levels specifically within the college's facilities. This knowledge gap poses potential risks to the health and safety of students, faculty members, and other individuals present on campus. The assessment of absorbed radiation dose rates in both indoor and outdoor environments is crucial for understanding the potential health risks associated with exposure to ionizing radiation.

Study Area

Fourah Bay College is a public university that sits on the beautiful Mount Aureol, a landscape etched in serene greenery affording it a panoramic and picturesque view of Freetown, the capital city of Sierra Leone. Mount Aureol is 300 meters above sea level with low carbon foot-print making the college ideal for learning and ecotourism. It is located between latitude 8° 28' 22.73" N and longitude -13° 13' 9.78" W.

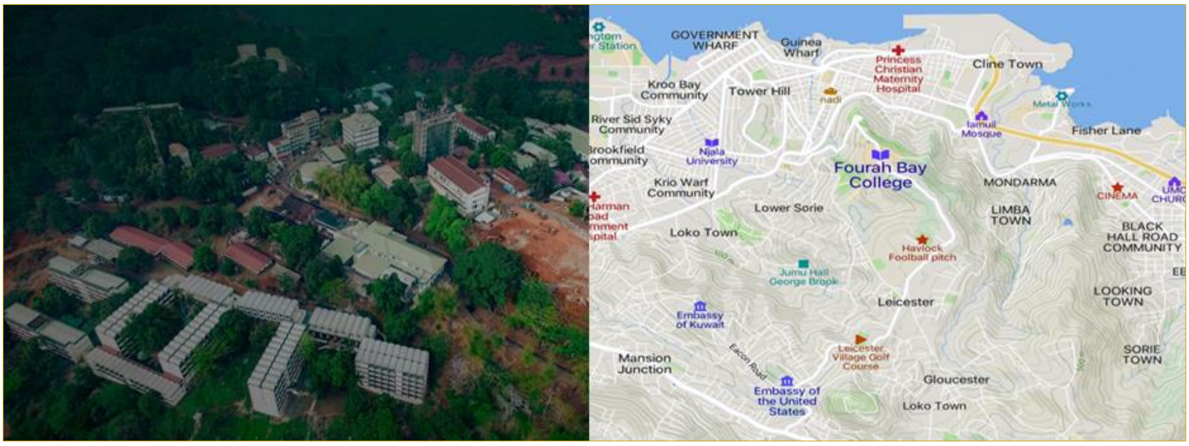

Figure 1. Pictorial view and map showing the location of Fourah Bay College, University of Sierra Leone.

Materials and Methods

All measurements were conducted using a calibrated RADIAGEM-2000 meter equipped with an integrated Geiger-Muller tube functioning in the dose rate mode. The radiation meter was positioned one meter above ground level in order to mitigate the influence of the ground on both indoor and outdoor readings. In addition, the detector was placed at least six meters away from any nearby building walls to prevent any interference from the materials used in those structures on the measurement results during outdoor assessments.

Figure 2. The calibrated RADIAGEM-2000 meter.

The equivalent dose measurements in micro-Sievert per hour (μSv/h) were directly recorded from the display screen of the radiation meter, compiled into a table and used to determine the annual effective doses and assess the excess lifetime cancer risks using well established radiological relations.

The annual effective dose equivalent (AEDE) was calculated using the following formula (UNSCEAR, 2008).

$$\text{Indoor AEDE}\left(\frac{\text{mSv}}{\text{y}}\right) = X\left(\frac{\mu\text{Sv}}{\text{h}}\right) \times 8760 \times 0.8 \times 0.001 \quad (1)$$

$$\text{Outdoor AEDE}\left(\frac{\text{mSv}}{\text{y}}\right) = Y\left(\frac{\mu\text{Sv}}{\text{h}}\right) \times 8760 \times 0.2 \times 0.001 \quad (2)$$

X= Mean indoor equivalent dose rate, Y= Mean outdoor equivalent dose rate, 8760 = the number of hours in one year, 0.8 = the indoor occupancy factor, 0.2 = the outdoor occupancy factor (UNSCEAR, 2000).

Excess Life Cancer Risk (ELCR): The calculated AEDE values were used to determine the ELCR values in each of the locations using appropriate equations, as noted by (Mokobia and Oyibo, 2017).

$$ELCR = AEDE \times ALD \times CRF \quad (3)$$

Where ALD is average life duration (70 years) and CRF is the cancer risk factor per sievert (Sv^{-1}). For low dose background radiation, which is considered to produce stochastic effects, ICRP 103 uses a fatal cancer risk factor value of 0.05 for public exposure (ICRP, 2007).

Results and Discussion

Table 1 displayed the results of the indoor and outdoor mean equivalent dose rates, annual effective dose equivalent (AEDE) and excess life-time cancer risk (ELCR) and ratio of mean equivalent dose rate (X/Y).

Table 1. Determined indoor and outdoor mean equivalent dose rates, annual effective dose equivalent (AEDE) and excess life-time cancer risk (ELCR) and ratio of mean equivalent dose rate (X/Y).

Location	Indoor			Outdoor			Ratio, R =X/Y
	Mean equivalent dose rate, X (µSv/h)	AEDE (mSv/y)	ELCR x 10^{-3}	Mean equivalent dose rate, Y (µSv/h)	AEDE (mSv/y)	ELCR x 10^{-3}	
Physics laboratory	0.41	2.85	9.96	0.16	0.29	1.01	2.48
Biology laboratory	0.09	0.64	2.26	0.07	0.12	0.43	1.31
Chemistry laboratory 1	0.12	0.83	2.89	0.09	0.15	0.54	1.34
Chemistry laboratory 2	0.06	0.42	1.47	0.04	0.06	0.22	1.67
Nuclear science laboratory	0.44	3.08	10.79	0.29	0.50	1.75	1.54
Physics workshop	0.09	0.6	2.11	0.05	0.08	0.29	1.79
Civil engineering laboratory	0.13	0.91	3.19	0.07	0.12	0.43	1.86
Electrical engineering workshop 1	0.28	1.95	6.82	0.11	0.19	0.65	2.62
Electrical engineering workshop 2	0.17	1.21	4.22	0.06	0.10	0.36	2.97
Mechanical engineering workshop	0.22	1.56	5.45	0.11	0.19	0.65	2.09
Maximum	**0.44**	**3.08**	**10.79**	**0.29**	**0.50**	**1.75**	**2.97**
Minimum	**0.06**	**0.42**	**1.47**	**0.04**	**0.06**	**0.22**	**1.31**
Average	**0.20**	**1.40**	**4.92**	**0.10**	**0.18**	**0.63**	**1.97**

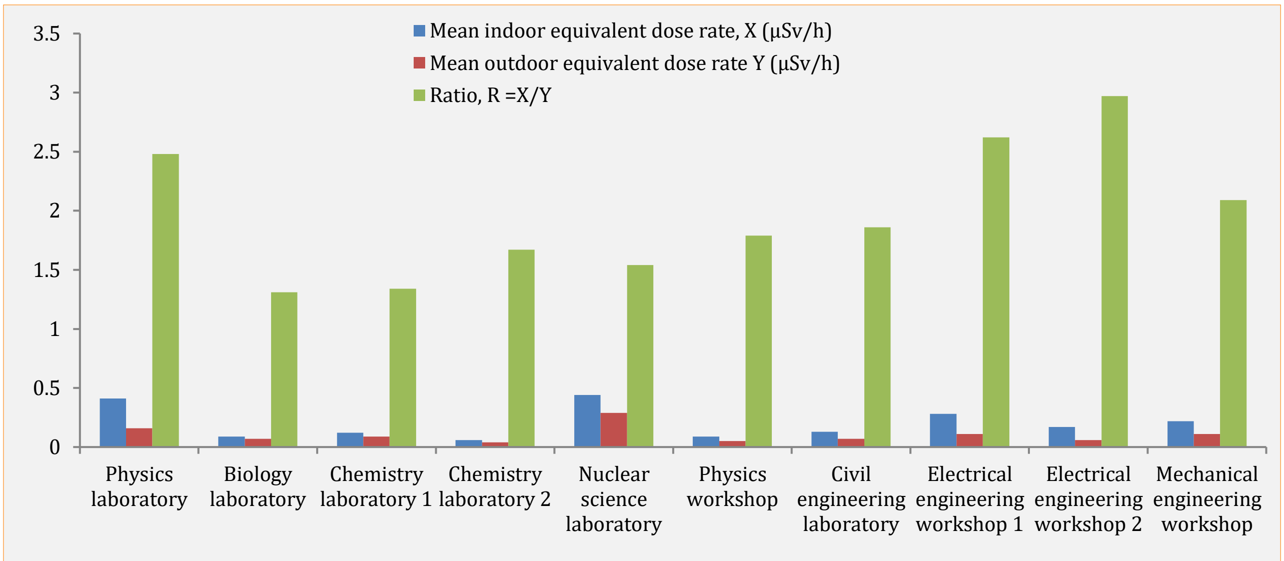

Figure 3. Graphical representation of mean equivalent dose rate in different locations at FBC campus.

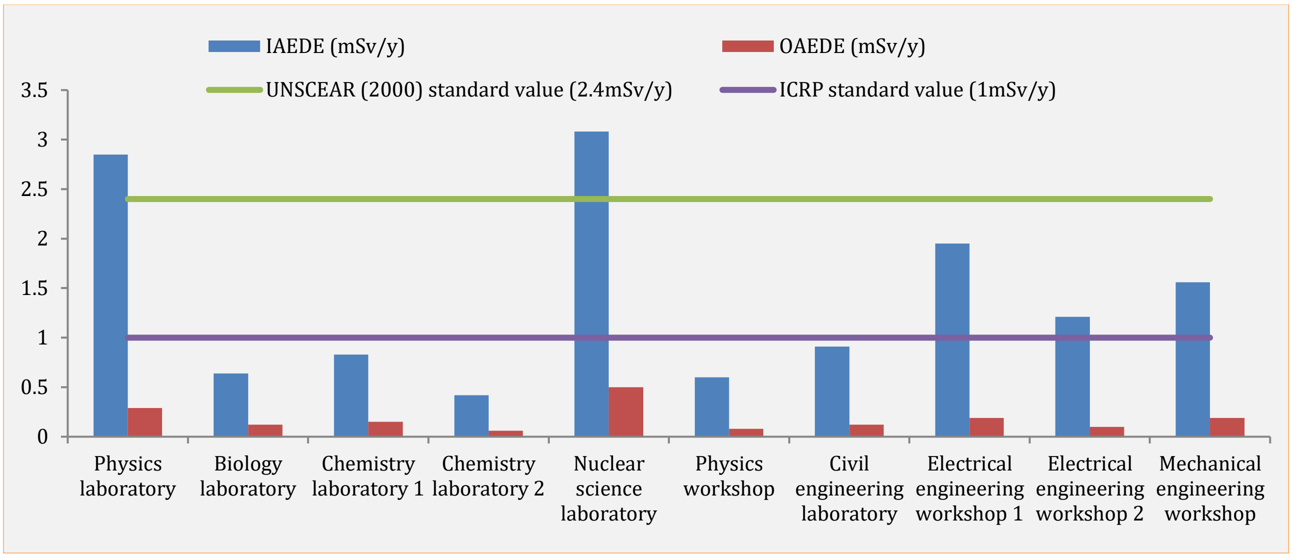

Figure 4. Graphical representation and comparison of AEDE in different locations with respect to ICRP and UNSCEAR standards.

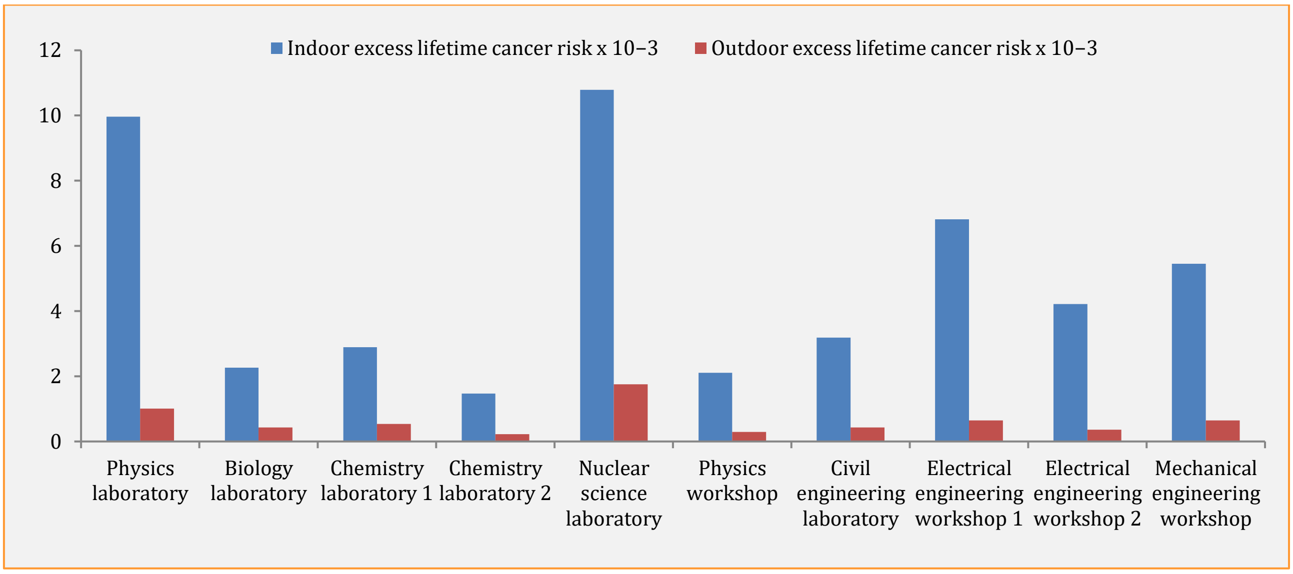

Figure 5. Graphical representation of ELCR at different locations at FBC.

Conclusion and Recommendation

It is concluded that the level of harmful ionizing radiation within the six laboratories and four workshops was higher than their outsides, around their immediate environs. However, staff, students and other users that use the laboratories, workshops and their immediate neighborhood are exposed to insignificant health risks as the values of the mean equivalent dose recorded in this study are consistently less than the worldwide average dose of 2.4 mSv/y (UNSCEAR, 2000) for a human being. We also observed that the average effective dose equivalent (AEDE) in the physics and nuclear science laboratories exceeds the established safety limits. This finding raises significant concerns regarding radiation exposure for individuals working in these environments. The data collected indicates that specific operational practices or equipment used within these labs may contribute to elevated radiation levels. It is essential to conduct a thorough investigation into the sources of radiation and implement appropriate safety measures to mitigate exposure. These measures may include enhancing shielding, improving ventilation systems, conducting regular monitoring of radiation levels, and providing comprehensive training for personnel on safe handling practices.

Declarations

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