Assessment of Outdoor Radiation Exposure in an Academic Environment: A Case Study of Lead City University

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Abstract

This study presents an assessment of outdoor gamma background ionizing radiation across selected locations within Lead City University, Ibadan, South-western Nigeria, using a Gamma-Scout survey meter. Five radiological parameters were evaluated: equivalent dose rate (EDR), absorbed dose rate (ADR), annual effective dose equivalent (AEDE), excess lifetime cancer risk (ELCR), and effective dose rate to organs (Dorgan). All surveyed sites recorded EDR values exceeding the International Commission on Radiological Protection (ICRP) recommended limit of 0.133 µSv/h, with the lowest value observed at CPG (0.17 µSv/h) and the highest at SFB1 (0.25 µSv/h). ADR values also surpassed the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) global average of 55 nGy/h, ranging from 170 nGy/h at CPT1 and CPG to 250 nGy/h at SFB2. Although background radiation levels were elevated, AEDE values remained below the ICRP annual threshold of 1 mSv/y, averaging 0.25 mSv/y. The lowest AEDE was recorded at CPT1 and CPG (0.21 mSv/y), while SFB2 showed the highest (0.31 mSv/y). ELCR values ranged from 0.73 × 10⁻³ to 1.07 × 10⁻³, exceeding the global average of 0.293 × 10⁻³, indicating a slightly increased lifetime cancer risk. In contrast, Dorgan values were significantly lower than the global average of 1 mSv/y, with a mean of 0.07 mSv/y across all locations. Overall, the findings suggest localized elevation in environmental radiation, potentially influenced by geological or material-specific factors. While short-term exposure levels exceed global norms, the relatively low AEDE and Dorgan values imply that immediate health risks such as acute radiation effects or organ damage are unlikely. These results emphasize the importance of continuous environmental monitoring and localized radiological risk evaluation to safeguard public health.

Keywords: Outdoor exposure, survey meter, equivalent dose rate, background radiation.

1.0 Introduction

Radiation often known as radiant energy, is energy that travels through space in the form of waves or particles [1]. Radiation is continually being emitted into the atmosphere. Radiation encompasses visible light, heat, radio waves, alpha, beta, and gamma rays [2]. People actually absorb the sun's radiant energy when they feel its warmth [3]. Electromagnetic radiation manifests as electromagnetic waves, such as beta and alpha particles [4]. Ionizing radiations have the capacity to disrupt bonds between atoms or molecules without the use of heat by ejecting one or more electrons from their orbit, resulting in ionized or radical ion states [5]. Ionizing radiation deposits specific energy in living matter. The absorbed dose, a metric quantity used to calculate dose intake in living tissue, is frequently estimated and standardized for comparison with world-recommended limits.

According to UNSCEAR [6], the world recommended limit for the annual effective dose (AED) is 2.4 mSv, while those of ICRP [7] for the annual effective dose equivalent (AEDE) recommended limits for occupationally exposed workers from natural sources are estimated to be 1.0 mSv/y for the public. Background radiation is the exposure to ionizing radiation in everyday life, excluding occupational exposures [8]. Background radiation is caused by cosmic radiation (primary and secondary), terrestrial radiation (from natural radium, uranium, and thorium and their decay products; radon gas, which is the most common natural source of radiation exposure to humans), internal radiation (radioactivity in the body), and artificial or man-made sources such as medical exposure, weapon testing, nuclear technologies, and office equipment use [9,10].

Natural radionuclides of terrestrial and cosmogenic origin account for approximately 85% of a person's annual total radiation dosage [11]. Natural background radiation is found everywhere on earth, and it is constantly present in the daily lives of human beings, including public activity, work settings, and medical settings. This means that radiation exposure throughout life was either safe or resulted in radiation adaptation, ensuring survival, reproduction, and evolution [12, 13, 14].

Many scientific organizations throughout the world have conducted research on human exposure to ionizing background radiation. Nuclear physicists, medical physicists, and radiation experts have collaborated to study natural background radiation both indoors and outdoors in Nigeria [15].

Human daily living routines are inextricably linked to radiation exposure, particularly natural radiation exposure. The earth's crust contains radionuclides, which are the primary source of naturally occurring radioactive materials (NORMs) in the environment [16, 17].

[18] presented the data extracted based on indoor and outdoor locations, revealing that Plateau, Oyo, River, Delta, Ondo, Sokoto, Kano, and Niger have the highest dosage rate value compared to the global average value. The highest outdoor and indoor yearly effective doses were found in OYO, Sokoto, Ondo, Delta, Akwanga, Plateau, and River. The results were far higher than the world-acceptable level of 1.0 mSv/year.

[19] investigated the natural radioactivity levels in popular construction materials (structural and ornamental) used in Bangladeshi dwellings with the goal of determining ionizing radiation levels using HPGe gamma-ray spectrometry. The observed activity levels of 226Ra, 232Th, and 40K in the examined materials were 7.33 ± 3.49 and 157.13 ± 13.03 Bq kg^{-1}, 4.08 ± 1.84 and 131.65 ± 6.87 Bq kg^{-1}, and 128.38 ± 170.27 and 1234.5 ± 39.77 Bq kg^{-1}, respectively.

Radon exposure (inhalation) has also been linked to an increased risk of lung cancer [20, 21].
Figures in the ICRP [22] statement imply that the risk of death from radon exposure at work and at home may be greater than that observed from driving, and the estimated risk of lung cancer from radon exposure may be greater than the observed risk of lung cancer from all other causes. Cancer (stomach, breast, lung, liver, leukemia, and thyroid) is a major health concern in Malaysia, and it has been medically confirmed as the fourth largest cause of death [23]. Quantities such as the absorbed dosage, effective dose, and equivalent dose have been used to specify the dose received as well as its biological effectiveness [24]. The absorbed dose (D) indicates the quantity of radiation absorbed per unit mass of material. The S.I. unit is gray. ($1 \text{ Gy} = 1 \text{ J kg}^{-1}$). The absorbed dose rate (DR) is the rate at which an absorbed dose is received, measured in Gys^{-1} and mGyhr^{-1}. It is important to note, however, that the biological effect is determined not only by the overall amount to which the tissue is exposed but also by the pace at which the dose is delivered. The equivalent dose rate (EDR) is a superior dose quality measure since the absorbed dose does not provide a good indicator of the harm that radiation might cause because similar absorbed doses do not always have the same biological effects. The equivalent dose is used to reflect the harm caused by various forms of radiation on biological systems. It is described in terms of the absorbed dosage multiplied by a factor specific to the type of radiation. The unit of measurement is Sievert (Sv). Ionizing radiation exposure is associated with a high risk of cancer induction, radiation cataractogenesis, and indirect chromosomal change. The ALARA concept [25] refers to the technique of limiting one's exposure to ionizing radiation to the lowest level achievable. However, radon (222Rn) enters the building via construction materials, diffusion, convection, and the soil beneath it. Some construction materials are known to be radioactive [26].

Also, according to [6], the worldwide annual effective dosage from natural sources is estimated to be 2.4 mSv, with natural radionuclides of both terrestrial and cosmogenic origin accounting for approximately 85% of a person's annual total radiation dose [27, 6]. Also, for those for ICRP [28], the recommended annual effective dose equivalent (AEDE) levels for occupationally exposed workers from natural sources are estimated to be 1.0 mSv/y for the general public. Furthermore, the global average for indoor ELCR is estimated at 1.16×10^{-3} [29]. Many building materials are derived from the earth's crust and, when in touch with them, cause malignant radiation exposure levels. According to studies, indoor gamma radiation exposure is higher than outdoor gamma radiation exposure because most people spend less than 20% of their time outside and 80% of their time indoors [30, 31]. The more the radiation dose a person takes, the greater the risk of acquiring cancer. Cancer may not develop for many years after receiving the radiation dosage (usually 10-40 years), and there is no level below which we can conclude that an exposure does not constitute a risk to life [32].

This paper presents an outdoor background radiation level assessment: the absorbed dose rate (ADR), the annual effective dose (AED), the annual effective dose equivalent (AEDE), the excess lifetime cancer risk (ELCR), and the dosage to organs (Dorgan) values for the occupationally exposed workers and students within Lead City University, Ibadan premises, and their comparisons with the world standard recommended limits;

2.0 Materials and Methods/Methodology
Study Area
Lead City University (LCU) is located in the Toll Gate Area, off Oba Otudeko Avenue, Ibadan, Oyo State, Nigeria, at 7.32756° N and 3.87642° E. The institution is located in an urban location, surrounded by academic buildings, residential areas, and open spaces that are frequently used by students and staff. The region's tropical warmth, combined with its mix of natural and man-made surroundings, creates an ideal scenario for assessing outdoor radiation exposure in the academic setting. Using a GAMMA-SCOUT survey meter, which can detect alpha, beta, and gamma radiation, outdoor radiation measurements were conducted at selected sampling locations within Lead City University.

Sampling Locations

The radiation measurements were taken at various locations across the Lead City University campus, including the Car-park, Tree1 (Ground), Tree2 (Shield), lecture hall 14, School field: bleachers (Bleacher1 and Bleacher2), and the track. These locations were selected to represent a range of outdoor environments, including areas with natural vegetation, and recreational spaces, providing a comprehensive assessment of outdoor radiation exposure in the academic setting.

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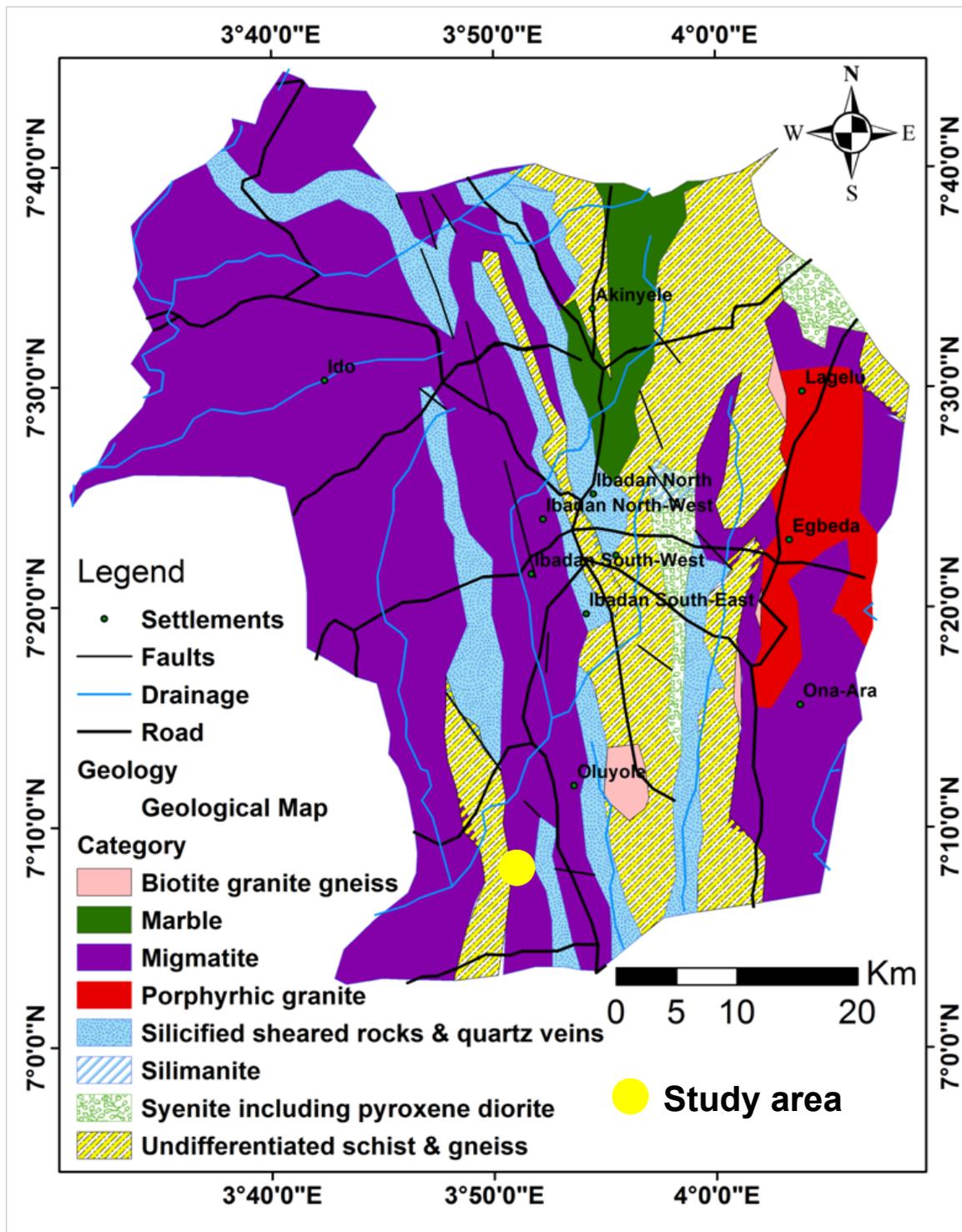

Figure 1: Map of Ibadan showing the study area

Radiation Measurements

The study was conducted using a portable Gamma-Scout survey meter calibrated with a Cs-137 standard source and adjusted to the middle measuring selection (gamma-γ) for environmental radiation measurement [33]. The university parking lot and the school field were the two primary outdoor locations where measurements were made. In order to record spatial variance, readings were recorded from several locations within each area. To represent the average height of human exposure, a small number of measurements were made at each location, around one meter above the ground. The weather was stable for all of the measurements.

To conduct standard exposure and radiological impact assessments, the measurements were converted appropriately to standard radiation impact parameters. Estimated standard values from measurements were compared with international recommended safety limits. These parameters have been itemized below:

Equivalent dose rate (EDR): This is the direct values obtain from measuring with the Gamma Scout Geiger counter. It is the measure of the biological impact of radiation on humans per time, and it is expressed in units of micro-sieverts per hour ($\mu Sv/hr$). It is normally obtained by multiplying the absorbed dose rate (ADR) with the radiation weighting factor, w_R (in the case of gamma measurement ($w_R = 1$).

Equivalent dose rate in mSv/y can be obtained with the expression for Outdoor measurements

$$EDR_{Outdoor}\left(m\frac{Sv}{y}\right) = EDR_{Outdoor}\left(\mu\frac{Sv}{hr}\right) \times 8.76 \tag{1}$$

The conversion factor of 8.76 is based on continuous exposure throughout the year [6].
Background ionizing radiations (BIR) above 0.133 µSv/hr,as recommended by the ICRP is considered to be of elevated levels for any area [34].

Absorbed Dose Rate (ADR): the Outdoor absorbed dose rate *(ADR Outdoor)* for Outdoor exposure is measured in $\frac{nGy}{y}$ and it can be derived from the relation

$$ADR_{Outdoor}\left(\frac{nGy}{h}\right) = \frac{EDR_{Outdoor}\left(\mu\frac{Sv}{h}\right) x\, 10^{-3}}{Q} \tag{2}$$

where Q is the quality factor (Q=1 for gamma radiation)
The world standard limits as recommended by UNSCEAR [6] is 55 nGy/h.

Annual Effective Dose Equivalent (AEDE): the Outdoor annual effective dose equivalent (*AEDE Outdoor*) in units of $\frac{mSv}{y}$ is related to the Absorbed dose (*ADR Outdoor*) in units of $\frac{nGy}{h}$ with the equation [6, 35]

$$AEDE_{Outdoor}\left(\frac{mSv}{y}\right) = ADR_{Outdoor}\left(\frac{nGy}{h}\right) x\, 8760\left(\frac{h}{y}\right) x\, 0.7\left(\frac{Sv}{Gy}\right) x\, O.F \tag{3}$$

where OF is the occupancy factor (0.2 for Outdoor exposure)
The global recommended limits of 1.0 mSv/y for the public and 20 mSv/y for occupationally exposed workers have been set by ICRP.

Excess Lifetime Cancer Risks (ELCR): This gives the probability of developing cancer over a lifetime at a given exposure level. The Outdoor excess lifetime cancer risks (*ELCR Outdoor*) value in unitless dimension is expressed as [36]

$$ELCR_{Outdoor} = AEDE_{Outdoor}\left(\frac{mSv}{y}\right) x\, DL\,(y) x\, RF\left(\frac{1}{Sv}\right) \tag{4}$$

where DL is the duration of life (70 years average is often used) and RF is the risk factor (in per Sv) i.e. fatal cancer risk per Sievert. For stochastic effects, the ICRP 106 used a value of RF = 0.05 for the public. The standard value of 0.29×10^{-3} [37] is the world's benchmark.

Effective dose rate (D-organ) to different body organs and tissues: The effective dose to organs (D-organ) estimates the amount of radiation dose intake to various body organs and tissues. The effective dose rate delivered to a particular organ can be calculated using the following relation [38]. It is generally expressed by

$$D_{orgaan}\left(\frac{mSv}{y}\right) = AEDE_{Outdoor}\left(\frac{mSv}{y}\right) x\, F \tag{5}$$

where F is the conversion factor of organ dose from air dose. The F value for the whole-body, lungs, ovaries, bone marrow, testes, kidney, and liver as given by ICRP [39]. are 0.68, 0.64, 0.58, 0.69, 0.82, 0.62, and 0.46 respectively. The international recommended limit for the Dorgan for body organs is 1.0 mSv/y [40. 41, 42]. All data was manually logged and analyzed using Microsoft Excel.

3.0 Results and Discussion

The results from the measurements showed that radiation levels varied amongst the outdoor locations sampled on the Lead City University campus. In general, open
The detailed results of the measurements across the different locations are presented in the table and graph below:

Table 1 shows the gps mapping of the nine outdoor locations considered for the study.   Each location represented with their respective tags

Table 1: Outdoor GPS and UTM Coordinates for sampled locations

Area Code	Location Description	GPS Coordinates (Zone/Easting/Northing)	UTM Coordinates
CPT1	Tree 1	31N0596848	UTM0810049
CPG	Ground	31N0596828	UTM0810080
CPT2	Tree 2	31N0596838	UTM0810082
CPS	Shield	31N0596857	UTM0810134
CPH	Hall 14	31N0596848	UTM0810134
SFB1			
SFB2	Bleacher 1	31N0597029	UTM0809979
SFG	Bleacher 2	31N0597030	UTM0809980
SFT	Ground	31N0597029	UTM0809979
CPT1	Track	31N0597062	UTM0809909

3.1 Equivalents Dose Rate (EDR)

In terms of the dose equivalents (EDR), all measured locations obtained average EDR values higher (0.21 μSv/h) than the ICRP world standard limit of 0.133 μSv/h while the ground measurement of CPG location had the minimum value (0.17 μSv/h) and the SFB1 location had the maximum values (0.25 μSv/h). An overall summary of the dose equivalent values for each location is itemized in table 2 and their comparison with world standard limits have been plotted in figure 2.

Table 2: Radiation levels recorded with Gamma Scout Survey Meter at selected outdoor locations within Lead City University campus

Locations	*Tags*	*Dose Equivalent (μSv/h)*
Car-park	Tree1	0.1700
	Ground	0.1700
	Tree2	0.2000
	Shield	0.2000
	Hall 14	0.2300
School Field	Bleacher1	0.2000
	Bleacher2	0.2500
	Ground	0.2400
	Track	0.1900
	MIN	0.1700
	MAX	0.2500
	AVG	0.2056

Recommended limit: Background ionizing radiations (BIR) below 0.133 μSv/hr, by ICRP [43].
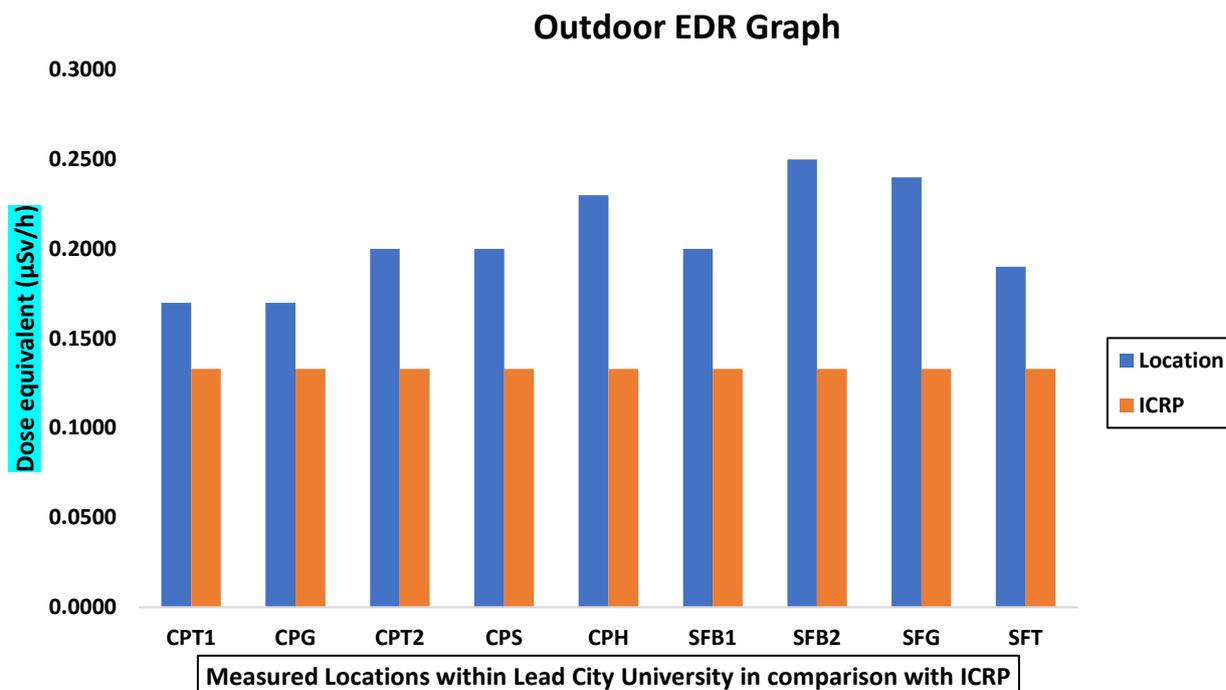
Outdoor EDR Graph

Figure 2: Measured EDR for Outdoor Locations and Comparison with World Standard Limits

3.2 Absorbed Dose Rate (ADR)

In terms of the ADR values, all measured locations obtained average absorbed dose rate higher (205 nGy/h) than the UNSCEAR world standard limit of 55 nGy/h while the ground measurement of CPT1 and CPG locations had minimum value (170 nGy/h) and SFB2 location had maximum values (250 nGy/h). An overall summary of the ADR values for each location is itemized in table 3 and their comparison with world standard limits have been plotted in figure 3.

Table 3: Outdoor absorbed dose rate (ADR) measurement for different locations within Lead City University

Location Tags	ADR (nGy/h)
CPT1	169.9977
CPG	169.9977
CPT2	200.0000
CPS	200.0000
CPH	230.0023
SFB1	200.0000
SFB2	250.0000
SFG	239.9954
SFT	189.9954
MIN	169.9977
MAX	250.0000
AVG	205.5543

UNSCEAR recommended ADR limit: 55.0 nGy/h

Outdoor ADR Graph

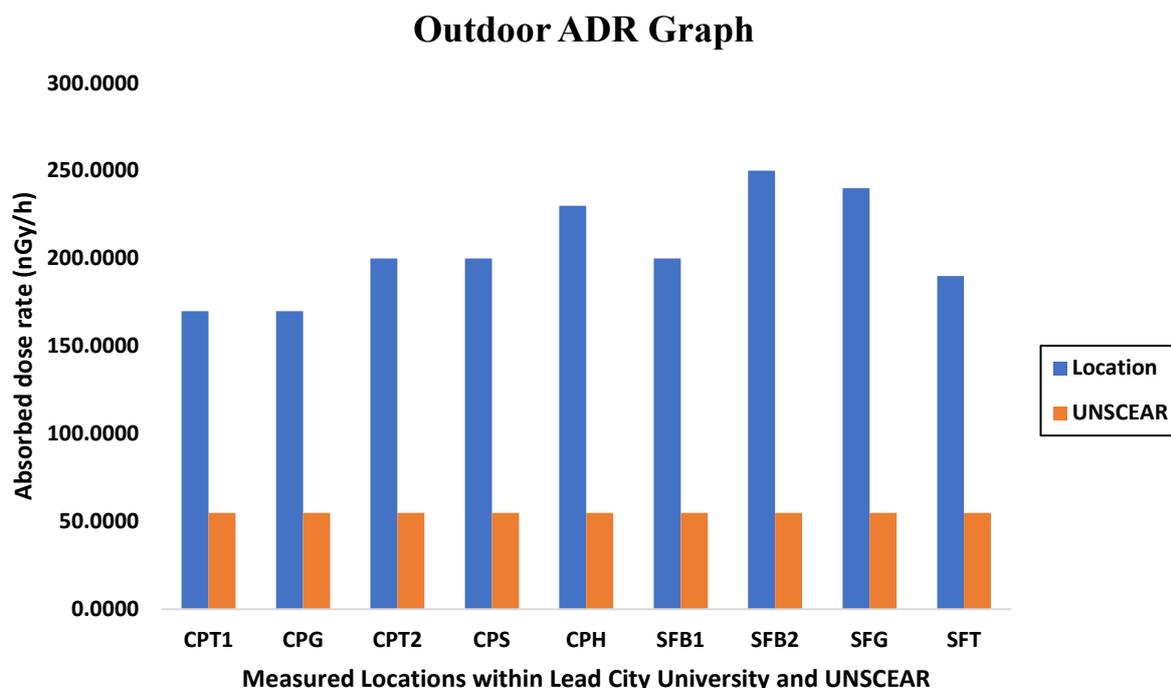

Figure 3: Measured ADR for Outdoor Locations and Comparison with World Standard Limits

3.3 Annual Effective Dose Equivalent (AEDE)

In terms of the annual effective dose equivalent (AEDE) values, all measured locations obtained average AEDE values much lower (0.25 mSv/y) than the ICRP world standard limit of 1 mSv/h while the ground measurement of CPT1 and CPG locations had the lowest average value (0.21 mSv/y) and the SFB2 location had the highest mean values (0.31 mSv/y). An overall summary of the AEDE values for each location is itemized in table 4 and their comparison with world standard limits have been plotted in figure 4.

Table 4: Outdoor annual effective dose equivalent measurement for different locations within Lead City University

Location Tags	AEDE (mSv/y)
CPT1	0.2085
CPG	0.2085
CPT2	0.2453
CPS	0.2453
CPH	0.2821
SFB1	0.2453
SFB2	0.3066
SFG	0.2943
SFT	0.2330
MIN	0.2085
MAX	0.3066
AVG	0.2521

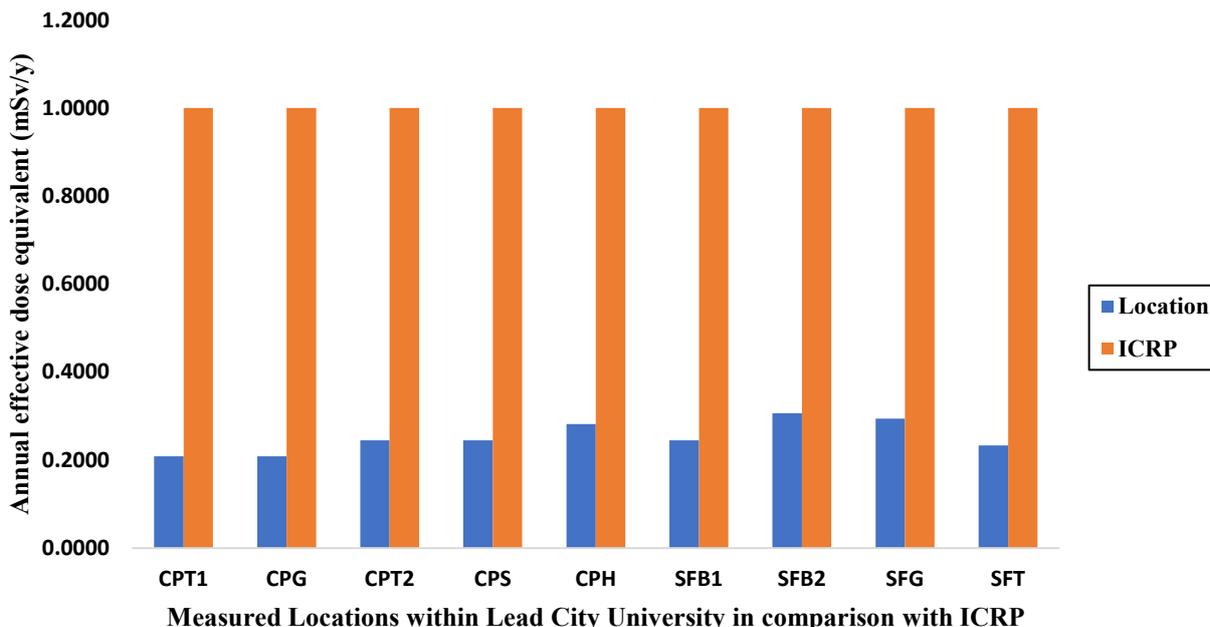**ICRP recommended AEDE limit: 1.0 mSv/y**

Outdoor AEDE Graph

Figure 4: Measured AEDE for Outdoor Locations and Comparison with World Standard Limits

3.4 Excess Lifetime Cancer Risks (ELCR)

In terms of the Excess Lifetime Cancer Risks (ELCR) values, all measured locations obtained average ELCR values much higher (0.92×10^{-3}) than the ICRP world standard limit of 0.293×10^{-3} for outdoor measurement while the ground measurement of CPT1 and CPG locations had the lowest average ELCR value (0.73×10^{-3}) and the SFB2 location had the highest mean values (1.07×10^{-3}). An overall summary of the ELCR values for each location is itemized in table 6 and their comparison with world standard limits have been plotted in figure 5.

Table 5: Outdoor excess lifetime cancer risks (ELCR) measurement for different locations within Lead City University

Location Tags	ECLR ($\times 10^{-3}$)
CPT1	0.7297
CPG	0.7297
CPT2	0.8585
CPS	0.8585
CPH	0.9873
SFB1	0.8585
SFB2	1.0731
SFG	1.0302
SFT	0.8155
MIN	0.7297
MAX	1.0731
AVG	0.9259

ICRP recommended ELCR limit: (0.29×10^{-3})
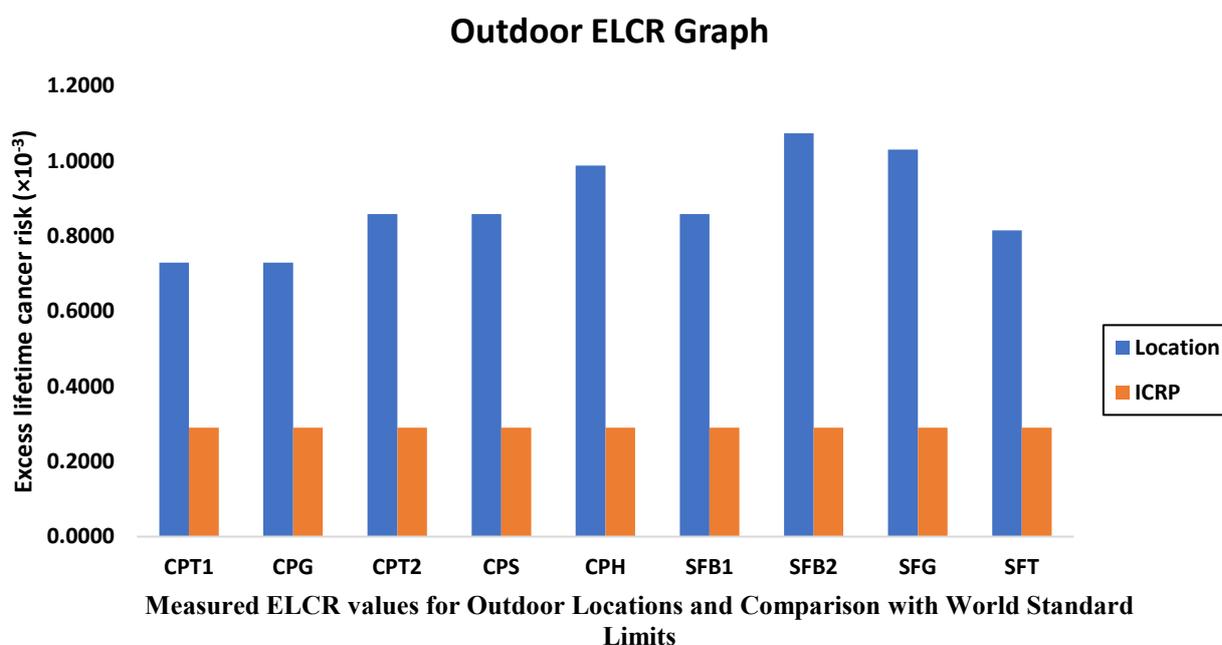
Outdoor ELCR Graph

Figure 5: Measured ELCR values for Outdoor Locations and Comparison with World Standard Limits

3.5 Dose to Organ (Dorgan)

In terms of the Effective Dose Rate to the organ (Dorgan) values, all measured locations obtained relatively lower Dorgan values than the world average (1 mSv/y). For the whole body, an average value of 0.173 mSv/y was estimated, the values ranging between 0.142 mSv/y (in locations CPT1 and CPG) and 0.209 mSv/y (in location SFB2). In the case of the lungs, an average value of 0.16 mSv/y was estimated, with all locations having values ranging between 0.133 mSv and 0.196 mSv/y in the same locations highlighted before. In the case of the ovaries, an average value of 0.3 mSv/y was estimated, with all locations having values ranging between 0.20 mSv/y and 0.40 mSv/y in the same locations highlighted before. In the case of the bone marrow, an average value of 0.4 mSv/y was estimated, with all locations having values ranging between 0.03 mSv/y and 0.04 mSv/y in the same locations highlighted before. In the case of the testes, an average value of 0.04 mSv/y was estimated, with all locations having values ranging between 0.03 mSv/y and 0.05 mSv/y. In the case of the kidney, an average value of 0.03 mSv/y was estimated, with all locations having values ranging between 0.03 mSv/y and 0.4 mSv/y in the same locations highlighted before. Lastly, in the case of the liver, an average value of 0.02 mSv/y was estimated, with all locations having values ranging between 0.02 mSv/y and 0.03 mSv/y in the same locations highlighted before. An overall summary of the Dorgan values for each organ is itemized in table 6 and their comparison with world standard limits have been plotted in figure 6.

Effective Dose Rate to the Organs (D-Organ value [mSv/y])							
Organ	**Wholebody**	**Lungs**	**Ovaries**	**Bone marr.**	**Testes**	**Kidney**	**Liver**
Location							
CPT1	0.1418	0.1334	0.0242	0.0288	0.0342	0.0259	0.0192
CPG	0.1418	0.1334	0.0242	0.0288	0.0342	0.0259	0.0192
CPT2	0.1668	0.1570	0.0285	0.0338	0.0402	0.0304	0.0226
CPS	0.1668	0.1570	0.0285	0.0338	0.0402	0.0304	0.0226
CPH	0.1918	0.1805	0.0327	0.0389	0.0463	0.0350	0.0260
SFB1	0.1668	0.1570	0.0285	0.0338	0.0402	0.0304	0.0226
SFB2	0.2085	0.1962	0.0356	0.0423	0.0503	0.0380	0.0282
SFG	0.2001	0.1884	0.0341	0.0406	0.0483	0.0365	0.0271
SFT	0.1584	0.1491	0.0270	0.0322	0.0382	0.0289	0.0214
MIN	0.1418	0.1334	0.0242	0.0288	0.0342	0.0259	0.0192
MAX	0.2085	0.1962	0.0356	0.0423	0.0503	0.0380	0.0282
AVG	0.1730	0.1629	0.0295	0.0351	0.0417	0.0316	0.0234

Table 6: Outdoor D-organ values measurement for different locations within Lead City University
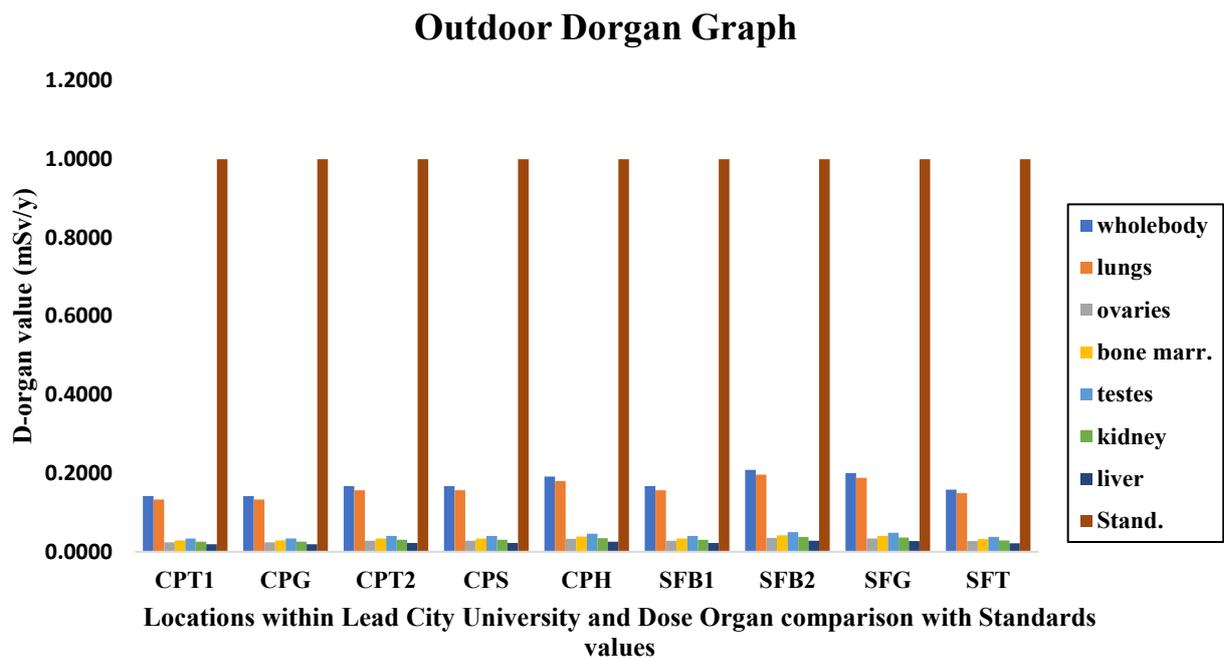

Figure 6.   Measured Dorgan for Outdoor Locations and Comparison with World Standard Limits [40,41,42]

4.0 Conclusion

This study evaluated outdoor radiation exposure within the academic environment of Lead City University by measuring ionizing radiation levels at selected locations across the campus. The findings revealed that for the EDR measurements, all measured values were higher than ICRP standard value. Similarly, for ADR measurements, the values obtained were higher than UNSCEAR standard value. Evaluated ELCR values were also higher than the ICRP recommended value showing that the probability of developing cancer over a lifetime at a given exposure level is very high, For AEDE (mSv/y), the values measured were below the ICRP standard limits showing a low effect on yearly dose based on background gamma radiation. For D-organ, none of the organs were as high as the recommended limit so it does not pose any risk on the organs on a short-term basis but may on a long-term basis. Overall, this study suggests a potential for increased cancer risk over a lifetime, but not immediate health risks from radiation sickness or acute effects. The elevated ADR, EDR, and ELCR indicate a higher-than-average

radiation level in the area, potentially increasing the long-term cancer risk for individuals exposed. However, the lower AEDE and Dorgan values suggest that the overall radiation dose received by individuals is not high enough to cause immediate health issues like acute radiation sickness or significant organ damage.

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