



Investigation of Indoor Radiation Levels within Lead City University's Academic Buildings

Ruth R. ADELAJA^{1*}, Rhoda I. ADELAJA², Henry OTOBRISE³, Adefope OWOJORI⁴, Babatunde ADEBO⁵

^{1*,2,3,4,5}Department of Physics, Lead City University, Ibadan, Oyo State, Nigeria

^{1*}ruthadelaja2003@gmail.com, ²adelajarhoda@gmail.com, ³otobrise.henry@lcu.edu.ng, ⁴owojori.adefope@lcu.edu.ng, ⁵adebo.babatunde@lcu.edu.ng

Abstract

A study was conducted at Lead City University to evaluate indoor gamma radiation exposure and its potential health implications. Measurements were taken using a Gamma Scout Geiger counter at walls, floors, and room centers across 10 aerated and non-aerated locations. In aerated areas, the average equivalent dose rate (EDR) ranged from 0.614 $\mu\text{Sv}/\text{h}$ (SB) to 2.104 $\mu\text{Sv}/\text{h}$ (LO1), with a mean of 1.438 $\mu\text{Sv}/\text{h}$. Non-aerated locations showed a slightly higher average value, with each location values ranging from 1.227 $\mu\text{Sv}/\text{h}$ (AH, PL, CL, SC) to 2.016 $\mu\text{Sv}/\text{h}$ (LO1, SC) and an average EDR value of 1.490 $\mu\text{Sv}/\text{h}$, with both averages exceeding the global average of 0.133 $\mu\text{Sv}/\text{h}$. Absorbed Dose Rates (ADR) were within safe limits. Aerated rooms recorded values between 0.61 and 2.10 nGy/h (mean: 1.44 nGy/h), while non-aerated rooms ranged from 1.22 to 2.01 nGy/h (mean: 1.49 nGy/h), all below the global average of 55 nGy/h. Annual Effective Dose Equivalent (AEDE) values were also below the recommended threshold of 1 mSv/y. Aerated areas ranged from 0.0030 to 0.0103 mSv/y (mean: 0.0070 mSv/y), and non-aerated areas from 0.0060 to 0.0099 mSv/y (mean: 0.0073). Excess Lifetime Cancer Risk (ELCR) values remained below the global average of 1.16×10^{-3} , with aerated spaces ranging from 0.15 to 0.51×10^{-3} and non-aerated areas from 0.3008 to 0.4942×10^{-3} . However, whole-body organ dose (D-organ) values exceeded the global average of 1 mSv/y. Aerated locations recorded 1.63 to 5.61 mSv/y (mean: 2.33 mSv/y), and non-aerated areas showed consistent values around 3.27 to 5.37 mSv/y. Conclusion: Despite the equivalent dose rate being above recommended limits, the AEDE, ELCR, and organ dose values remain within safe thresholds. This indicates that the elevated dose rate may result from temporary factors. Since overall exposure is low, the likelihood of long-term health risks, such as cancer, remains minimal in the school environment.

Keywords: Indoor exposure, background radiation, equivalent dose rate, gamma-scout survey meter.

1.0 Introduction

Our surroundings are filled with radiation, which is a type of energy that travels through space as waves or particles [1]. Background radiation comes from both natural and man-made sources. According to Karmaker and others [2], Alpha, beta, and gamma rays are examples of ionizing radiation that has sufficient energy to ionize atoms and perhaps harm living things. It is crucial to keep an eye on these exposures, especially in populous settings like campuses. Electromagnetic radiation is radiation that takes the form of electromagnetic waves, including radio waves, ultraviolet light, and gamma rays. Radiation that manifests as particles, such as beta and alpha particles, is referred to as particle radiation. Depending on how it interacts with matter, radiation can also be categorized as either ionizing or nonionizing. [2]. The natural and manmade environments are constantly surrounded by radiation, which comes from a variety of sources, including terrestrial radionuclides, cosmic rays, and man-made sources like building materials, electronics, and lab equipment [3]. Radiation is essential in various areas of modern life, from powering houses and diagnosing ailments to advancing scientific research and maintaining industrial safety [4]. Conversely, the excessive exposure to ionizing radiation can lead to negative effects such as radiation sickness, an increased risk of cancer, and genetic abnormalities. [5]. Proximity to radiation sources can influence significant risk effects through absorbed doses from overexposure. According to UNSCEAR [6], the worldwide recommended limit for the annual effective dose (AED) is 2.4 mSv. Also, for those for ICRP [7], the annual effective dose equivalent (AEDE) recommended limits for occupationally exposed workers from natural sources is estimated to be 1.0 mSv/y for the public and 20 mSv/y. In addition, the global average for indoor ELCR is estimated at 1.16×10^{-3} [8]. Many of the building materials come from the crust of the earth, they lead to malignant radiation exposure levels when come in contact with. Studies have shown that indoor gamma radiation exposure would be higher than outdoor gamma radiation exposure as most people only spend 20% of their time outdoor than 80% of their time indoors [9, 10].

As a result, understanding the radiation levels inside buildings where people spend long hours is very important. Some everyday materials used in construction naturally contain radioactive elements that can increase indoor exposure. These include floor tiles, wall paint, concrete, and some stones. Without proper checks, these

materials may cause radiation levels to rise beyond recommended limits, especially in enclosed spaces with poor airflow [2,5]

In addition, electrical appliances and laboratory instruments may add to background radiation. While these levels are often small, their long-term effect should not be ignored [11]. Studies have also shown that exposure to indoor gamma radiation tends to be higher than outdoor exposure, mainly because people spend more time indoors [9, 10].

Although previous studies, such as that by Adebo and others [13], have examined other environmental risks on the Lead City University campus, there is still limited information on radiation levels within the school environment. This makes it necessary to carry out a proper assessment of indoor gamma radiation and evaluate the possible health risks to staff and students.

This paper presents indoor background gamma radiation level assessment: the Equivalent dose rate (EDR), absorbed dose rate (ADR), Annual Effective Dose Equivalent (AEDE), the excess life time cancer risk (ELCR) and the dosage to organs (D_{organ}) 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 Methodology

2.1 Study Area

The study was carried out at Lead City University, located within Ibadan South-East Local Government Area, Ibadan, Oyo State, Nigeria. Its geographical coordinates are approximately 7.32756° N latitude and 3.87642° E longitude. The study focused on indoor environments across various academic buildings within the university, including lecture halls, laboratories, offices, and libraries where students and staff spend extended periods of time. These areas were selected based on their high occupancy rates and potential exposure to background radiation from building materials, electrical appliances, and surrounding environmental factors.

Lead City University is a private institution with a growing academic population and the institution has provided a suitable setting for assessing indoor radiation levels within a typical academic environment.

2.2 Sampling Locations

Radiation measurements were collected at eight different locations across Lead City University. These included two offices (Office A and Office B), two laboratories (Physics and Chemistry), the school hall (Adeline Hall), the Sports Center; three lecture rooms, the school library, and the New Horizon office. These areas were chosen because they are often visited by students and faculty. Measurements were taken at each location on the wall, the floor, and in the center of the room, both in well-ventilated (Aerated) and non-ventilated (non-Aerated) areas. Aeration is defined under classes of closed areas with open windows to allow free passage of air in and out of the area while non-aerated is defined on bases of closed areas without open windows.

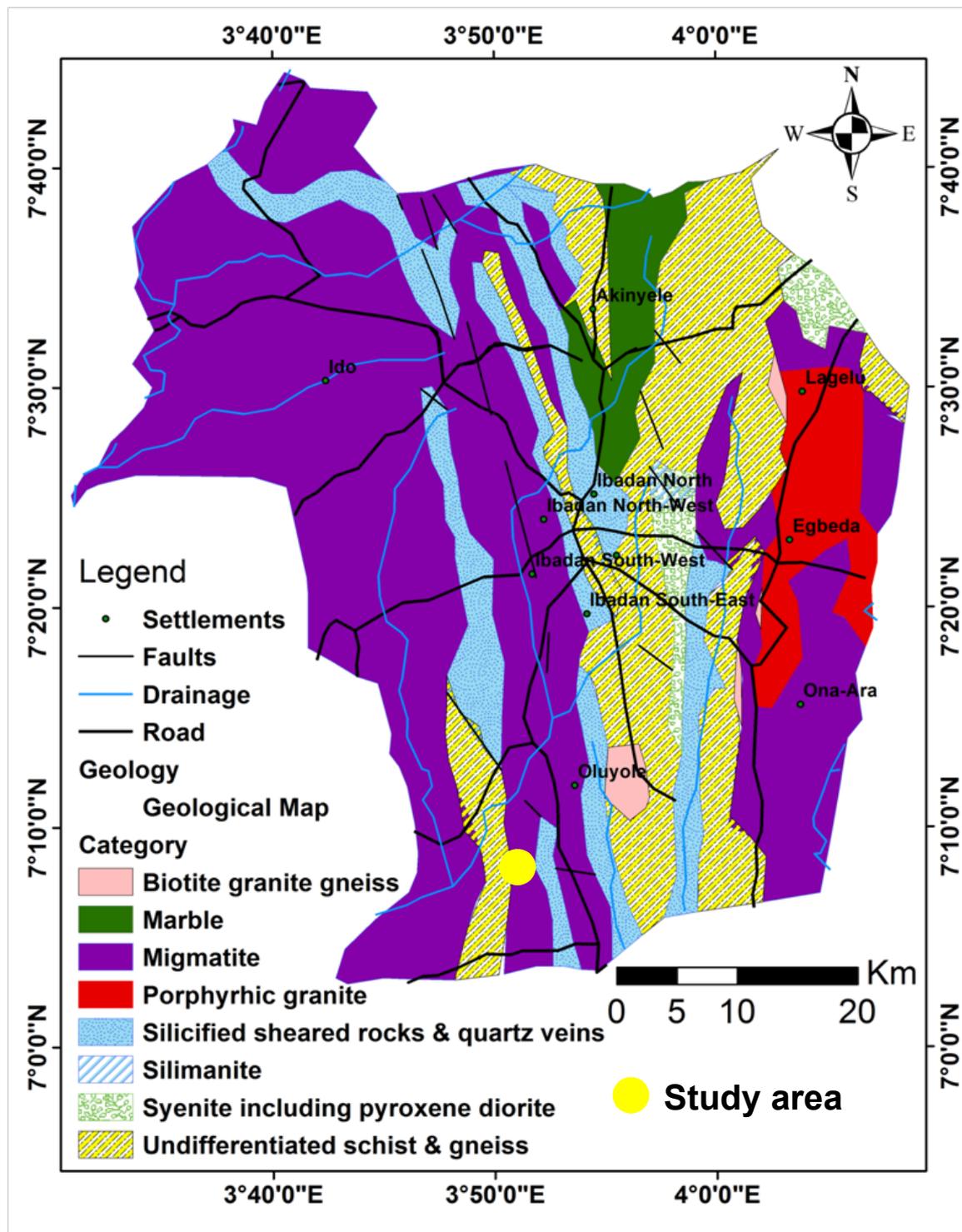


Figure 1: Map of Lead City University showing selected indoor locations where radiation exposure measurements were taken
 Source: [14]

2.3 Radiation Measurements

The study was conducted using a Cs-137 calibrated portable Gamma-Scout survey meter adjusted to measure environmental gamma- γ radiation [15]. Ten (10) locations measured at different heights (0m-1m) under aerated and non-aerated conditions, covering the wall, center, and floor were investigated. These areas included offices, laboratories, lecture rooms, the sports center, the library, and the New Horizon office. All radiation measurements were made under ambient temperature and under humid weather condition. The survey meter measured in units of $\mu\text{Sv/hr}$. Each location was measured 5 times with each measurement taking a duration of four (4) minutes. 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 ($\mu\text{Sv/hr}$). 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 indoor measurements

$$EDR_{Indoor} \left(m \frac{\text{Sv}}{\text{y}} \right) = EDR_{Indoor} \left(\mu \frac{\text{Sv}}{\text{hr}} \right) \times 8.76 \quad (1)$$

The conversion factor of 8.76 is based on continuous exposure throughout the year [6]. Average background ionizing radiations (BIR) above $0.133 \mu\text{Sv/h}$ is considered to be of elevated levels for any area [16]

Absorbed Dose Rate (ADR): the indoor absorbed dose rate (ADR_{Indoor}) for indoor exposure is measured in $\frac{\text{nGy}}{\text{h}}$ and it can be derived from the relation

$$ADR_{Indoor} \left(\frac{\text{nGy}}{\text{h}} \right) = \frac{EDR_{Indoor} \left(\mu \frac{\text{Sv}}{\text{y}} \right) \times 10^{-3}}{Q} \quad (2)$$

where Q is the quality factor (Q=1 for gamma radiation)

The world standard recommended limits of 55nGy/h have been set by UNSCEAR [6].

Annual Effective Dose Equivalent (AEDE): the indoor annual effective dose equivalent ($AEDE_{Indoor}$) in units of $\frac{\text{mSv}}{\text{y}}$ is related to the Absorbed dose (ADR_{Indoor}) with the equation [6, 17]

$$AEDE_{Indoor} \left(\frac{\text{mSv}}{\text{y}} \right) = ADR_{Indoor} \left(\frac{\text{nGy}}{\text{h}} \right) \times 8760 \left(\frac{\text{h}}{\text{y}} \right) \times 0.7 \left(\frac{\text{Sv}}{\text{Gy}} \right) \times OF \times 10^{-3} \quad (3)$$

where OF is the occupancy factor (0.8 for indoor exposure).

The world standard recommended limits of 1.0 mSv/y for the public and 20 mSv/y for occupationally exposed workers have been given by ICRP [18].

Excess Lifetime Cancer Risks (ELCR): This gives the probability of developing cancer over a lifetime at a given exposure level. The indoor excess lifetime cancer risks ($ELCR_{Indoor}$) value in unitless dimension is expressed as (Darwish et al., 2015)

$$ELCR_{Indoor} = AEDE_{Indoor} \left(\frac{\text{mSv}}{\text{y}} \right) \times DL \times RF \quad (4)$$

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 average value of 0.29×10^{-3} [19] is the world's recommended limit.

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 (Darwich et al., 2015). It is generally expressed by

$$D_{organ} \left(\frac{\text{mSv}}{\text{y}} \right) = AEDE_{indoor} \left(\frac{\text{mSv}}{\text{y}} \right) \times F \quad (5)$$

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 [18]. are 0.68, 0.64, 0.58, 0.69, 0.82, 0.62, and 0.46 respectively. The international tolerable limit for the Dorgan for body organs is 1.0 mSv/y [20, 21]. All data were manually inputted and analyzed using Microsoft Excel.

3.0 Results and Discussion

Levels of radiation differed by surface and location. Indoor exposure values were generally greater on the floor and higher (1 m height) in locations with inadequate ventilation. The table 1 gives a summary of the locations and their gps mappings.

Table 1: Measured indoor GPS and UTM coordinates with elevation data for sampled locations

Area Code	Location Description	GPS Coordinates (Zone/Easting/Northing)	UTM Coordinates
LO1	Office 1	31N0596883	UTM0810118
LO2	Office 2	31N0596890	UTM0810087
AH-D	Adeline hall (downstairs)	31N0596890	UTM0810087
NH	New Horizon	31N0596869	UTM0810118
PL	Physics laboratory	31N0596865	UTM0810117
CL	Chemistry laboratory	31N0596894	UTM0810042
SC	Sports Centre	31N0597259	UTM0810116
SB	Senate building	31N0597175	UTM0810174
LR11	Lecture room 11	31N0596799	UTM0810118
LR17	Lecture room 17	31N0596863	UTM0810152

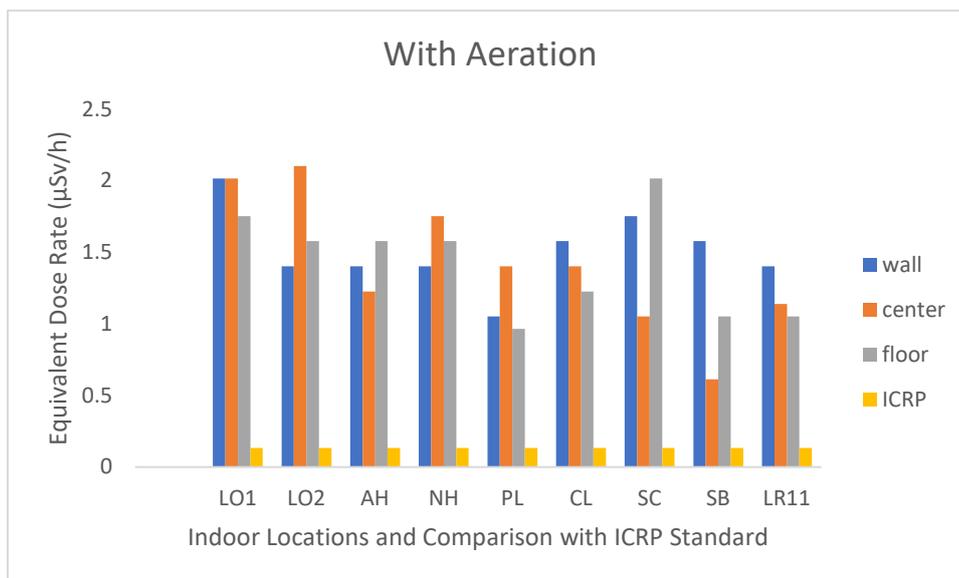
3.2 Equivalent dose rate (EDR)

The indoor equivalent dose rate (EDR) measurements carried out directly with the Gamma scout survey meter obtained a minimum value of 0.614 $\mu\text{Sv/h}$ (SB), maximum value of 2.104 $\mu\text{Sv/h}$ (LO1) and an average EDR value of 1.438 $\mu\text{Sv/h}$ for aerated locations and while for non-aerated locations, the minimum value of 1.227 $\mu\text{Sv/h}$ (AH, PL, CL, SC), maximum value of 2.016 $\mu\text{Sv/h}$ (LO1, SC) and an average EDR value of 1.490 $\mu\text{Sv/h}$, all measuring above the world recommended limit of 0.133 $\mu\text{Sv/h}$. The table 2 gives the summary of the EDR values for respective locations, and their comparison with the global average value in figure 3.

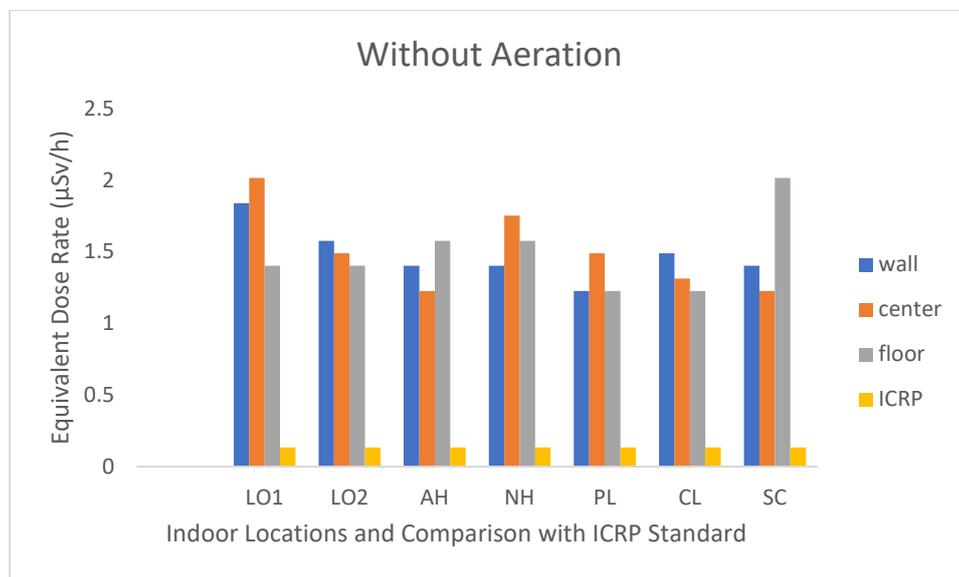
Table 2: Measured Indoor Equivalent Dose Rate (EDR)

Location Tag	Aeration						No Aeration					
	wall	$\pm\text{SD}$	Centre	$\pm\text{SD}$	floor	$\pm\text{SD}$	wall	$\pm\text{SD}$	Centre	$\pm\text{SD}$	floor	$\pm\text{SD}$
	$\mu\text{Sv/h}$		$\mu\text{Sv/h}$		$\mu\text{Sv/h}$		$\mu\text{Sv/h}$		$\mu\text{Sv/h}$		$\mu\text{Sv/h}$	
LO1	2.016	0.093	2.016	0.026	1.753	0.025	1.841	0.032	2.016	0.064	1.403	0.024
LO2	1.403	0.032	2.104	0.045	1.578	0.058	1.578	0.029	1.490	0.074	1.403	0.068
AH	1.403	0.091	1.227	0.039	1.578	0.047	1.403	0.042	1.227	0.085	1.578	0.029
NH	1.403	0.068	1.753	0.068	1.578	0.024	1.403	0.033	1.753	0.091	1.578	0.038
PL	1.052	0.098	1.403	0.073	0.964	0.020	1.227	0.092	1.490	0.067	1.227	0.047
CL	1.578	0.041	1.403	0.063	1.227	0.062	1.490	0.079	1.315	0.087	1.227	0.097
SC	1.753	0.060	1.052	0.079	2.016	0.025	1.403	0.087	1.227	0.045	2.016	0.065
SB	1.578	0.068	0.614	0.025	1.052	0.058						
LR11	1.403	0.070	1.140	0.068	1.052	0.067						
LR17	1.403	0.065	1.227	0.097	1.403	0.075						
MIN	1.052		0.614		0.964		1.227		1.227		1.227	
MAX	2.016		2.104		2.016		1.841		2.016		2.016	
AVG	1.499		1.394		1.420		1.478		1.503		1.490	

ICRP World Recommended Limit: 0.133 $\mu\text{Sv/h}$



(a.)



(b.)

Figure 2: Indoor EDR values for selected locations with Aeration (a.) and without Aeration (b.), and their comparison with global average value

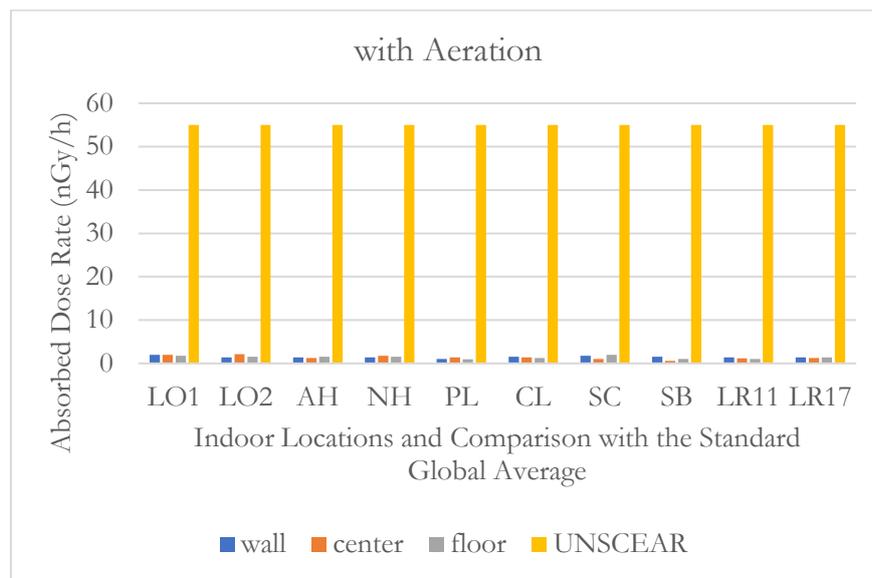
3.3 Absorbed Dose Rate (ADR)

In terms of the indoor absorbed dose rate (ADR), most indoor measurements obtained for aerated and non-aerated location were below world average of 55 nGy/h [6] with minimum, maximum and average values of 0.61 nGy/h (SB), 2.10 nGy/h (LO2) and 1.44 nGy/h respectively, while for non-aerated locations, the minimum, maximum and average were 1.22 nGy/h (AH,SC), 2.01 nGy/h (LO1) and 1.49 nGy/h respectively. The table 3 gives the summary of the ADR values for respective locations, and their comparison with the global average value in figure 3.

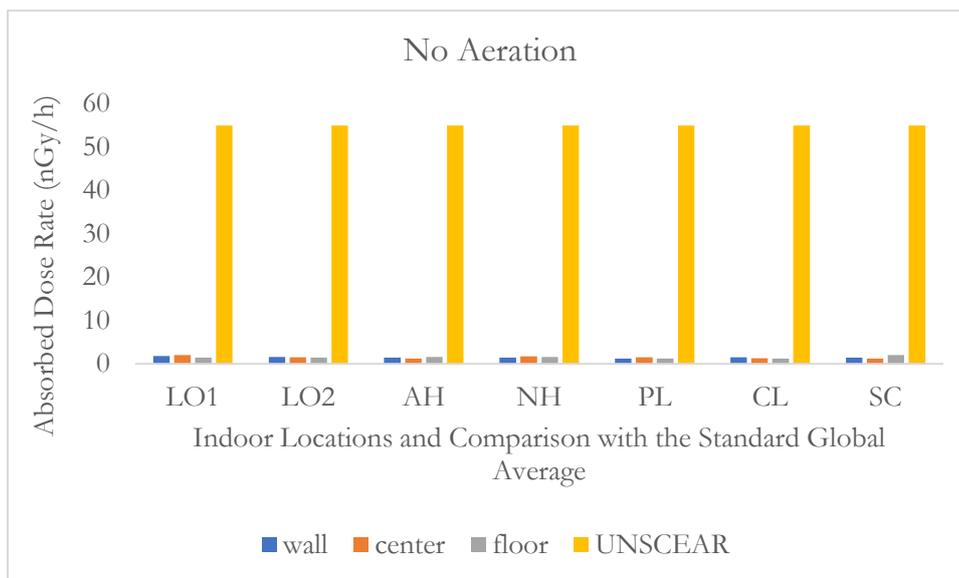
Table 3: Estimated Indoor Absorbed Dose Rate (ADR)

	ADR nGy/h	ADR nGy/h	ADR nGy/h	ADR nGy/h	ADR nGy/h	ADR nGy/h
Aeration				No Aeration		
Location	wall	center	floor	wall	center	floor
LO1	2.01482	2.01482	1.752	1.83964	2.01482	1.40164
LO2	1.40164	2.10236	1.57682	1.57682	1.48918	1.40164
AH	1.40164	1.22636	1.57682	1.40164	1.22636	1.57682
NH	1.40164	1.752	1.57682	1.40164	1.752	1.57682
PL	1.05118	1.40164	0.96364	1.22636	1.48918	1.22636
CL	1.57682	1.40164	1.22636	1.48918	1.314	1.22636
SC	1.752	1.05118	2.01482	1.40164	1.22636	2.01482
SB	1.57682	0.61318	1.05118			
LR11	1.40164	1.13882	1.05118			
LR17	1.40204	1.22616	1.40204			
MIN	1.05118	0.61318	0.96364	1.22636	1.22636	1.22636
MAX	2.01482	2.10236	2.01482	1.83964	2.01482	2.01482
AVG	1.498024	1.392816	1.419168	1.476703	1.5017	1.489209

UNSCEAR World Recommended Limit: 55 nGy/h



(a.)



(b.)

Figure 3: Indoor ADR values for selected locations with aeration (a.) and No Aeration (b.), and their comparison with global average value

3.3 Annual Effective Dose Equivalent (AEDE)

In terms of the indoor AEDE values, most measurements obtained for aerated and non-aerated location were below world average of 1 mSv/y minimum, maximum and average values of 0.0030 mSv/y (SB), 0.0103 mSv/y (LO2) and 0.0070 mSv/y respectively, while for non-aerated locations, the minimum, maximum and average were 0.0060 mSv/y (all), 0.0099 mSv/y (LO1, SC) and 0.0073 mSv/y respectively. The table 4 gives the summary of the AEDE values for respective locations, and their comparison with the global average value in figure 4.

Table 4: Estimated Indoor Annual Effective Dose Equivalent (AEDE)

	AEDE mSv/y	AEDE mSv/y	AEDE mSv/y	AEDE mSv/y	AEDE mSv/y	AEDE mSv/y
Aeration	Aeration			No Aeration		
Location	wall	center	floor	wall	center	floor
LO1	0.0099	0.0099	0.0086	0.0090	0.0099	0.0069
LO2	0.0069	0.0103	0.0077	0.0077	0.0073	0.0069
AH	0.0069	0.0060	0.0077	0.0069	0.0060	0.0077
NH	0.0069	0.0086	0.0077	0.0069	0.0086	0.0077
PL	0.0052	0.0069	0.0047	0.0060	0.0073	0.0060
CL	0.0077	0.0069	0.0060	0.0073	0.0064	0.0060
SC	0.0086	0.0052	0.0099	0.0069	0.0060	0.0099
SB	0.0077	0.0030	0.0052			
LR11	0.0069	0.0056	0.0052			
LR17	0.0069	0.0060	0.0069			
MIN	0.0052	0.0030	0.0047	0.0060	0.0060	0.0060
MAX	0.0099	0.0103	0.0099	0.0090	0.0099	0.0099
AVG	0.0073	0.0068	0.0070	0.0072	0.0074	0.0073
ICRP World Recommended Limit: 1 mSv/y						

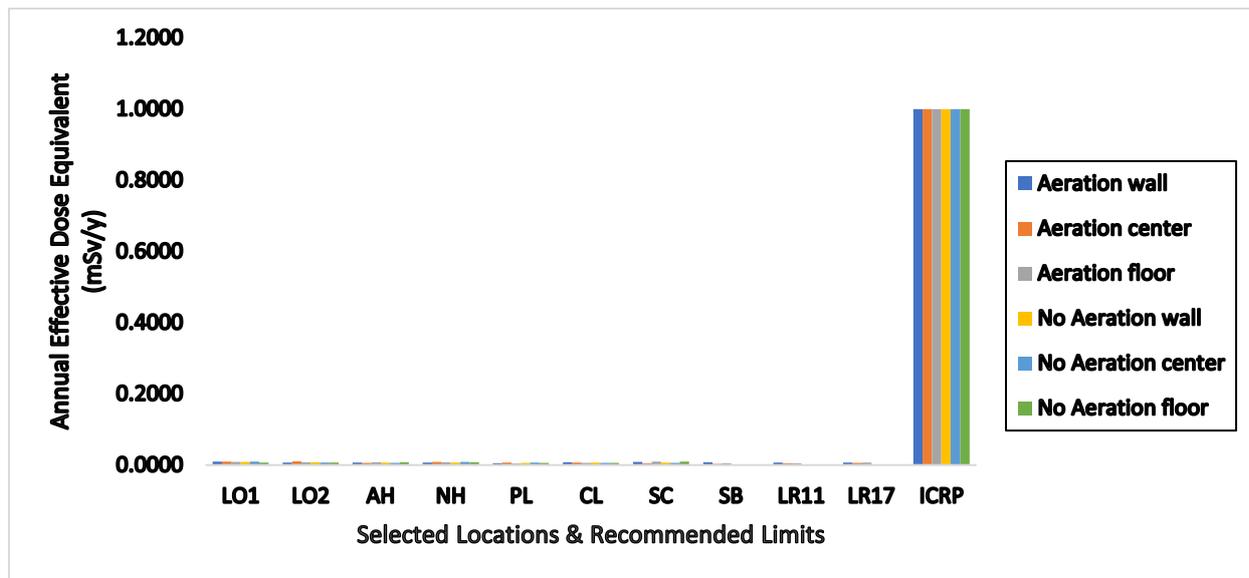


Figure 4: Indoor AEDE values for selected locations and their comparison with global average value

3.4 Excess Lifetime Cancer Risks (ELCR)

In terms of the indoor ELCR values, most indoor measurements obtained for aerated and non-aerated location were below world average of 1.16×10^{-3} minimum, maximum and average values of 0.15×10^{-3} (SB), 0.51×10^{-3} (LO2) and 0.35×10^{-3} respectively, while for non-aerated locations, the minimum, maximum and average were 0.3008×10^{-3} (all), 0.4942×10^{-3} (LO1, SC) and 0.365×10^{-3} respectively. The table 5 gives the summary of the ELCR values for respective locations, and their comparison with the global average value in figure 5.

Table 5: Estimated Indoor Excess Lifetime Cancer Risks (ELCR)

	ELCR $\times 10^{-3}$	ELCR $\times 10^{-3}$	ELCR $\times 10^{-3}$	ELCR $\times 10^{-3}$	ELCR $\times 10^{-3}$	ELCR $\times 10^{-3}$
	Aeration			No Aeration		
Location	wall	center	floor	wall	center	floor
LO1	0.4942	0.4942	0.4297	0.4512	0.4942	0.3438
LO2	0.3438	0.5157	0.3868	0.3868	0.3653	0.3438
AH	0.3438	0.3008	0.3868	0.3438	0.3008	0.3868
NH	0.3438	0.4297	0.3868	0.3438	0.4297	0.3868
PL	0.2578	0.3438	0.2364	0.3008	0.3653	0.3008
CL	0.3868	0.3438	0.3008	0.3653	0.3223	0.3008
SC	0.4297	0.2578	0.4942	0.3438	0.3008	0.4942
SB	0.3868	0.1504	0.2578			
LR11	0.3438	0.2793	0.2578			
LR17	0.3439	0.3008	0.3439			
MIN	0.2578	0.1504	0.2364	0.3008	0.3008	0.3008
MAX	0.4942	0.5157	0.4942	0.4512	0.4942	0.4942
AVG	0.3674	0.3416	0.3481	0.3622	0.3683	0.3653
World Recommend Limit:	1.16×10^{-3} [19]					

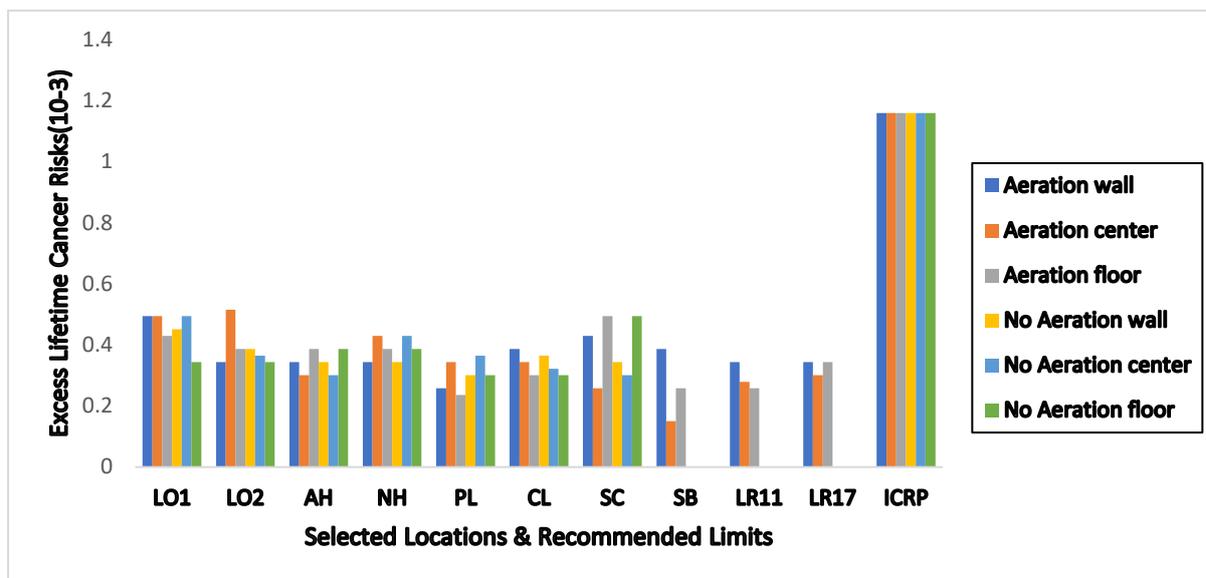


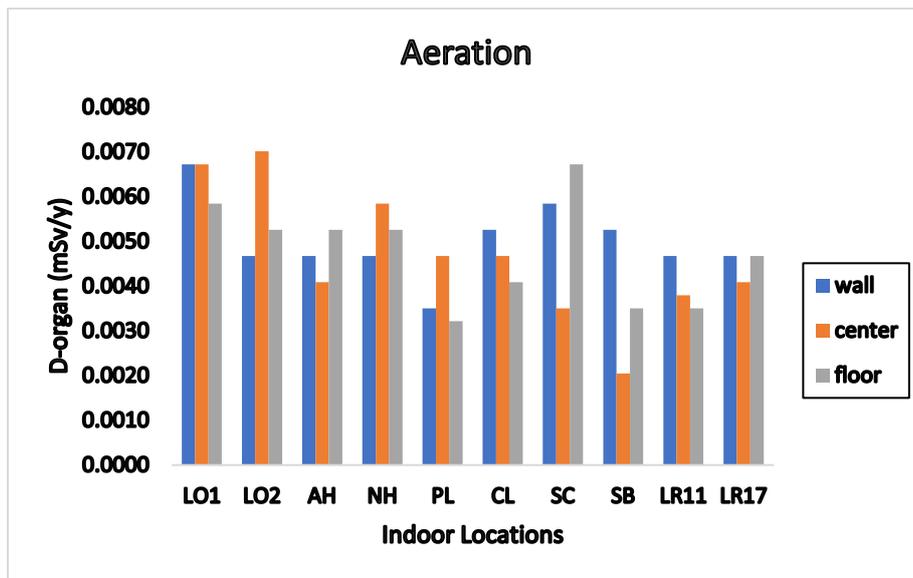
Figure 5. Indoor ELCR values for selected locations and their comparison with global average value

3.5 Indoor D-organ (Whole body)

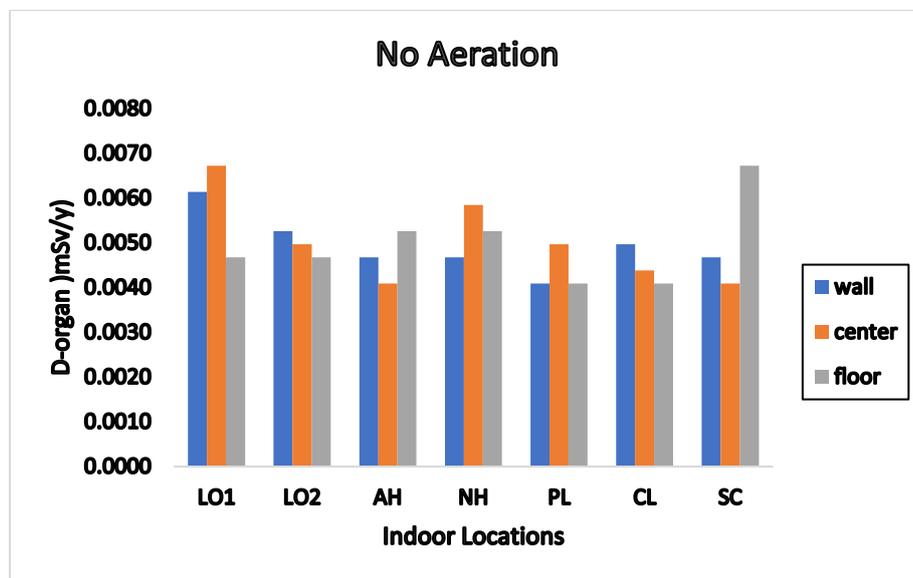
In terms of the indoor D-organ (whole body), all indoor measurements obtained for aerated location were below world average of 1 minimum, maximum and average values of 0/0020 mSv/y (SB), 0.0070 mSv/y (LO2) and 0.0048 mSv/y respectively, while for non-aerated locations, the minimum, maximum and average 0.0041 mSv/y (all), 0.0067mSv/y (LO1, SC) and 0.0050 mSv/y respectively. The table 6 gives the summary of the D-organ (Whole body) values for respective locations, and their comparison with the global average value in figure 6.

Table 6: Estimated Indoor D-organ (Whole body)

Aeration	Aeration			No Aeration			
	Location	wall	center	floor	wall	center	floor
		mSv/y	mSv/y	mSv/y	mSv/y	mSv/y	mSv/y
LO1		0.0067	0.0067	0.0058	0.0061	0.0067	0.0047
LO2		0.0047	0.0070	0.0053	0.0053	0.0050	0.0047
AH		0.0047	0.0041	0.0053	0.0047	0.0041	0.0053
NH		0.0047	0.0058	0.0053	0.0047	0.0058	0.0053
PL		0.0035	0.0047	0.0032	0.0041	0.0050	0.0041
CL		0.0053	0.0047	0.0041	0.0050	0.0044	0.0041
SC		0.0058	0.0035	0.0067	0.0047	0.0041	0.0067
SB		0.0053	0.0020	0.0035			
LR11		0.0047	0.0038	0.0035			
LR17		0.0047	0.0041	0.0047			
MIN		0.0035	0.0020	0.0032	0.0041	0.0041	0.0041
MAX		0.0067	0.0070	0.0067	0.0061	0.0067	0.0067
AVG		0.0050	0.0046	0.0047	0.0049	0.0050	0.0050
STAND. [20,21] World Recommended Limit: 1 mSv/y							



(a.)



(b.)

ICRP World Average limit: 1mSv/y

Figure 6. Indoor D-organ (Whole body) values for selected aerated (a.) and non-aerated (b.) locations

4.0 Conclusion

In total, ten indoor locations were assessed for exposure levels and health risks. The average indoor EDR measurements, for the aerated and non-aerated locations, obtained higher values than the world recommended limit of 0.133 $\mu\text{Sv/h}$.

The indoor ADR values obtained showed lower values than the world average value for aerated and non-aerated locations. The indoor AEDE values obtained for aerated and non-aerated location were similarly below the ICRP world average of 1 mSv/y minimum, with maximum values in locations LO1 and SC. The indoor ELCR values obtained for aerated and non-aerated location were below world average. In terms of the indoor D-organ (whole body), most indoor D-organ values obtained for aerated and non-aerated location were below the world average of 1mSv/y.

Overall, since the AEDE, ELCR and whole body organ dose values are within limits while the average equivalent dose rate values are higher than standards, it suggests that at the time of measurement, the high dose rate may indicate of elevated radiation levels which could be attributed to transient factors like localized radiation source or meteorological conditions and which may not lead to overall cancer risks in the short term. Also, since

AEDE and ELCR are below safe limits, then on average, the population in the school environment are not exposed to high levels consistently which may not lead to long term health risks.

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