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ASSESSMENT OF INDOOR AND OUTDOOR RADIATION DOSE LEVELS IN DELTA STATE POLYTECHNIC, OGWASHI-UKU, DELTA STATE, NIGERIA.

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ABSTRACT

This study assessed the indoor and outdoor radiation dose levels of twelve (12) laboratories of Delta State Polytechnic, Ogwashi-Uku using a handheld inspector survey meter and estimation revealed that the average BIR, average annual equivalent dose rate (EDR), average annual absorbed dose rate (ADR), average annual effective dose equivalent (AEDE), average excess lifetime cancer risk (ELCR) is 0.0116 mR/hr, 0.9733 mSv/yr, 100.69 nGy/hr, 0.4940 mSv/yr and 1.755. Dose to organs showed that the testes received the highest dose, while the liver received the lowest dose for indoor and outdoor, respectively. In general, indoor and outdoor BIR, ED, AD, and AEDE values are less than the recommended limit of unity (1 mSv/yr) for public exposure (ICRP). ELCR indoors and outdoors is above the world permissible limit of 0.29×10^{-3}. The calculated ELCR in the study area is 1:29719 (about 33 in 1 million) indoors and 1:115735 (9 in 1 million) outdoors. Although the average value for ELCR in this study is high further analysis and studies need to be carried out to ascertain the risk of staff and students to cancer.

Keywords: *Effective Dose, Equivalent Dose, Excess Lifetime Cancer Risk, Ionizing Radiation.*

INTRODUCTION

Humans are continuously exposed to background radiation that is ubiquitous in our environment. This radiation can come from natural sources called Naturally Occurring Radioactive Materials (NORMs) or Technologically Enhanced Naturally Occurring Radioactive Materials (TENORMs). Natural background radiation is radiation that occurs in the environment close to humans, from solar radiation and anthropogenic radiation (WHO, 2016, UNSCEAR, 2000, Nwankwo and Akoshile, 2005). Natural radionuclides from natural sources and cosmic rays account for more than 80% of the annual radiation dose received per person (UNSCEAR, 2000; Belivermis *et al*., 2010; Oladele *et al*. 2018; James *et al*. 2020). A report by the International Commission on Radiological Protection (ICRP), and World Health Organization, (WHO) shows that people living in climate zones spend 80% of their time indoors and 20% outside (Chad-Umoren *et al*., 2007). The annual effective dose from natural sources is estimated by UNSCEAR (UNSCEAR, 2000) as 2.4 mSv. Radioactive isotopes such as Uranium, Thorium, and Radium are abundant in the earth's crust. This radioactive isotope has different decay products and different half-lives. The persistent accumulation of decomposed Radon-222, ^{222}Rn with a half-life of 3.82 days and the effects of its products in the human lung are carcinogenic as revealed in the literature that there is a strong relationship between lung cancer and radon exposure even at low doses (Chad-Umoren *et al*, 2007; Usikalu *et al*., 2017). Background radiation also comes from man's activities such as oil exploration, mining, nuclear weapons testing, disposal of radioactive waste, and use of radioisotopes in radiation therapy, among others (Al-Azmi, 2014; James *et al*., 2020). These activities may cause TENORM and contribute to human exposure to background radiation.

Measurements of background radiation levels were carried out in two tertiary institutions in Minna, Niger State (Olarinoye*et al*., 2010). The results of the study show that the average annual effective dose received is 0.189 mSv/hr, which is within the permissible limit of 1mSv/hr. A study was conducted to assess the indoor and outdoor background ionizing radiation of the Sheda Science and Technology Complex, Abuja. The results showed that the total dose (indoor and outdoor), the total dose equivalent (indoor and outdoor), the annual effective dose equivalent (indoor and outdoor), and the age-related excess cancer risk (indoor and outdoor) were 0.113 ± 0.113. 0.022 µSv/h, 0.071 ± 0.016 µSv/h, 0.794 ± 0.155 mSv/h, 0.0.124 ± 0.074 mSv/h, 0.556 ± 0.109 mSv/h, 0.556 ± 0.109 mSv/h, (James *et al*., 2020). Indoor and outdoor background radiation measurements were carried out in various tertiary institutions in Nigeria. Sadiq and Agba investigated indoor and outdoor background radiation in Akwanga, Nasarawa State. The study showed that the annual average dose in an indoor and outdoor environment is 1.29 ± 0.13 and 0.31 ± 0.14 mSv/day respectively (Sadiq and Agba, 2011). An assessment of indoor and outdoor environmental radiation levels from several areas of Mkar University was conducted (Tyovenda *et al*., 2011). The results revealed safety levels in most indoor and outdoor facilities, except for the granite asphalt road outside the school gate, above the ICRP recommended limit of 1 mSv/h. Background ionizing radiation in several laboratories at Bokkos Plateau State University. The study found that the average equivalent dose for indoor and outdoor background radiation was 0.256 mSv/h and 0.249 µSv/h, respectively (Felix *et al*. 2015).

Background radiation dose level was measured within 29 rooms of Queen Amina hall of the Ahmadu Bello University, Zaria and their measurements revealed that the radiation dose ranged between 0.13 nGy/h to 0.43 nGy/h for indoor and 0.54 nGy/h to 1.72 nGy/h for outdoor while the annual effective doses in the study area are 0.01 mSv/y. In Ogwashi-Uku, there is no documented literature on the monitoring or measurements of background radiation dose levels which necessitated the need for this study as continuous exposure to background radiation dose levels even at low doses could increase the chances of cancer (Chad-Umoren *et al*, 2007; Usikalu *et al*., 2017). Hence the purpose of this study is to measure the background radiation dose level of the indoor and outdoor environment of laboratories in the Delta State Polytechnic, Ogwashi-Uku which will serve as baseline data for future studies and references and compare obtained values with internationally permissible limits.

MATERIALS AND METHODS

Background radiation measurements were carried out within the indoor and outdoor environment of 12 laboratories at Delta State Polytechnic, Ogwashi-Uku. Aniocha South Local Government Area located at $6^0$10'59.06 N and $6^0$31'27.72 E using a handheld inspector survey meter, a 1 m retorts stand, a GPS, and a notepad for recording data.

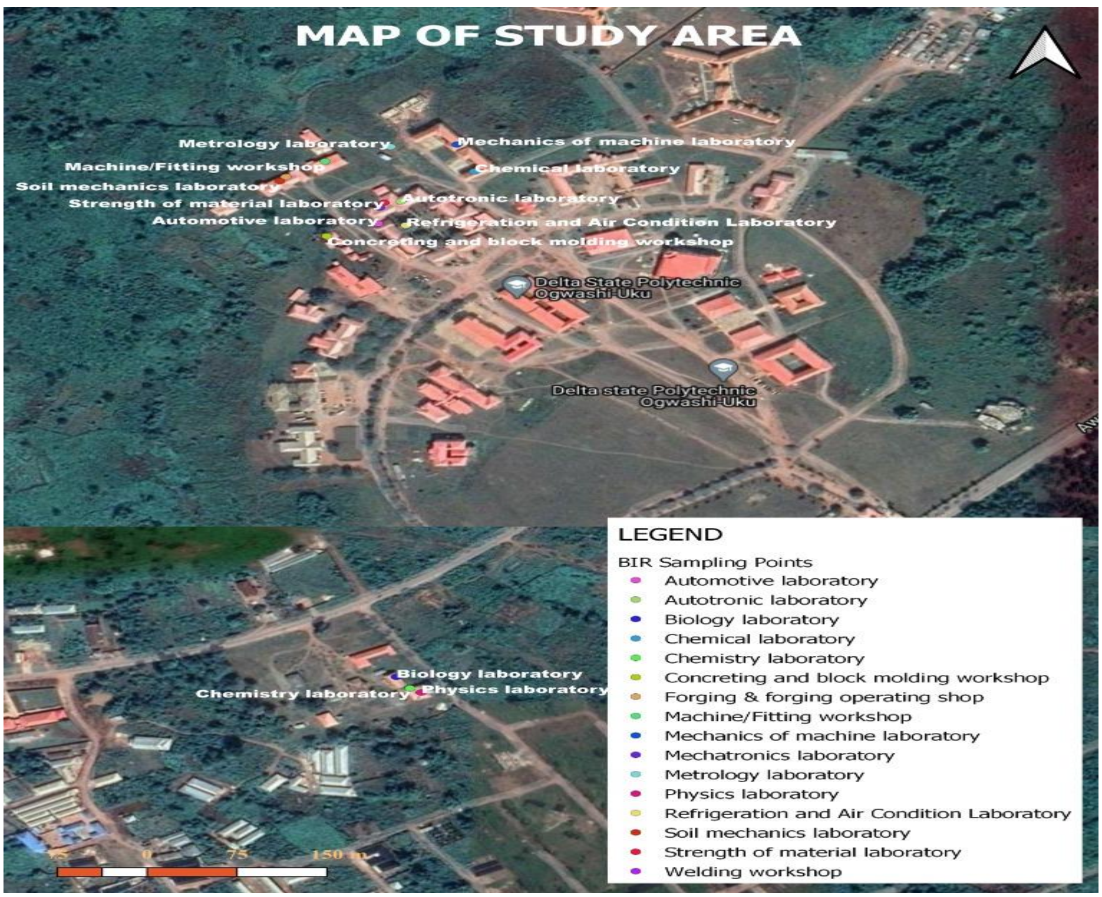

Figure 1: Map of Study Area Showing Laboratories

Table 1: Locations, Points, and Coordinates of the study area

Locations	Points	Coordinates
MET	Indoor	N06^0 13.4470′ E06^0 33.8200′
	Outdoor	N06^0 13.4500′ E06^0 33.8300′
CET	Indoor	N06^0 13.4890′ E06^0 33.8610′
	Outdoor	N060 13.4900′ E06^0 33.8570′
FET	Indoor	N06^0 13.4860′ E06^0 33.7780′
	Outdoor	N06^0 13.4870′ E06^0 33.7800′
CiET	Indoor	N06^0 13.4810′ E06^0 33.7720′
	Outdoor	N06^0 13.4830′ E06^0 33.7740′
WET	Indoor	N06^0 13.4570′ E06^0 33.8540′
	Outdoor	N06^0 13.4450′ E06^0 33.8440′
SLT	Indoor	N06^0 12.2350′ E06^0 33.3630′
	Outdoor	N06^0 12.2360′ E06^0 33.3630′

MET: Mechanical Engineering Technology, CET: Chemical Engineering Technology, FET: Foundry Engineering Technology, CiET: Civil Engineering Technology, WFT: Welding and Fabrication Technology, SLT: Science Laboratory Technology

The choice of location was based on the population size of the study area as there are very large numbers of students and staff who spend a minimum of 8 hours from Monday through Friday in the study area. An In-situ approach was adopted for this study to enable the laboratories to retain their original characteristics. A calibrated Inspector USB radiation survey meter (Radiation Alert) manufactured by S.E International shown in figure 2 was used for this study.

Figure 2: A Radiation alert USB Inspector meter (S.E International)

The meter is calibrated to detect and measure low doses of Alpha (α), Beta (β) particles, Gamma rays (γ), and X-rays. The meter is suspended 1 m above ground level using a stand placed 30 cm from the individual's work area. Measurements are taken twice from four points in the indoor and outdoor environment, and the average value is determined and recorded, which is then used to determine the exposure level.

Health Hazard Assessment

A risk assessment must determine the nature and extent of any radiation hazard that may arise from either the intended use of the source or any anticipated accident, incident, or event.

Annual Equivalent Dose, AEDR: The average equivalent dose rate in μSv/hr is obtained from processing measurements and then used to calculate the annual effective dose in mSv/yr using a mathematical relationship (equation 1) (James *et al*., 2020).

$$\text{AEDE (mSv/yr)} = \delta \times \mu \times 8760\text{(hr/yr)} \times 10^{-3} \quad (1)$$

Where: δ = Equivalent dose rate in mSv/hr.

μ= Occupancy factor (0.8 for indoor and 0.2 for outdoor)

Therefore, the following equation is used to calculate the annual equivalent dose indoors and outdoors.

$$\text{Annual Indoor Equivalent Dose Rate (mSv/yr)} = \delta \times \mu \times 8760\text{ (hr/yr)} \times 0.8 \times 0.001 \quad (2)$$

Annual Outdoor Equivalent Dose Rate (mSv/**y) =**

$$\delta \times \mu \times 8760 \text{ (hr/yr)} \times 0.2 \times 0.001 \qquad (3)$$

Excess Lifetime Cancer Risk (ELCR): This tells the contingency of someone having cancer over his lifetime when exposed to certain radiological materials. The ELCR in the study has been calculated using equation 4 (Darwish *et al*., 2015).

$$ELCR = AEDE \times DL \times RF \qquad (4)$$

Where 70 years average is a person's life duration denoted as DL and RF measured in Sievert is the cancer risk factor. Hence to calculate ELCR for Indoor and Outdoor environments, equations 5 and 6 are employed:

$$ELCR \text{ (indoor)} = AEDE \text{ (indoor)} \times DL \times RF \qquad (5)$$

$$ELCR \text{ (outdoor)} = AEDE \text{ (outdoor)} \times DL \times RF \qquad (6)$$

Figure 4 shows that the ELCR indoor value range from 1.2250 to 2.4938 with an average value of 1.729 while the ELCR outdoor value range from 0.3136 to 0.6920 with an average value of 0.4493.

Effective dose rate for various organs and tissues of the body (Torgan): Effective dose for organs (Torgan) calculates the amount of radiation dose to various organs and tissues of the body. The effective dose delivered to a specific organ can be calculated using this relationship (Darwich *et al*., 2015):

$$Dorgan \text{ (mSv/yr)} = AEDE \times F \qquad (7)$$

For outdoor and indoor Dorgan we used,

$$Dorgan \text{ (mSv) /yr)} = O \times AEDE \times F \qquad (8)$$

0.8 (indoor) and 0.2 (outdoor) are values for the occupancy factor and F is the conversion factor from air dose to organ dose.

RESULTS AND DISCUSSION

The results for the measured indoor and outdoor BIR, and calculated annual absorbed dose rate, annual equivalent dose rate, annual effective dose equivalent, and excess lifetime cancer risk for the studied area are presented in table 2.

Table 2: Measured average Indoor and Outdoor Dose Rate and Calculated Hazard Indices

S/N	Lab Code	BIR (mR/hr)	EDR (mSv/yr) (x10-3)	ADR (ηGy/yr)	AEDE (mSv/yr)	ELCR
1	MET (Indoor)	0.0122	1.0281	106.36	0.5218	1.9512
	MET (Outdoor)	0.0124	1.0407	107.66	0.1465	0.5128
2	CET (Indoor)	0.0140	1.1773	121.8	0.5975	2.0912
	CET (Outdoor)	0.0128	1.0764	111.36	0.1366	0.4781
3	FET (Indoor)	0.0103	0.8662	89.61	0.4396	1.5386
	FET (Outdoor)	0.0118	0.9923	102.66	0.1259	0.4407
4	CiET (Indoor)	0.0101	0.8494	87.87	0.4311	1.5386
	CiET (Outdoor)	0.0104	0.8704	90.05	0.1104	0.3864
5	WFT (Indoor)	0.0119	0.9965	103.1	0.5058	1.7702
	WFT (Outdoor)	0.0117	0.9839	101.79	0.1249	0.4370
6	SLT (Indoor)	0.0110	0.9223	95.41	0.468	1.6382
	SLT (Outdoor)	0.0118	0.9924	102.66	0.1259	0.4408
Average (Indoor)		0.0116	0.9733	100.69	0.4940	1.755
Average (Outdoor)		0.0118	0.9927	102.70	0.1284	0.4493
World Average		0.0130	1.000	59.00	0.0700	0.2900

Table 3: Estimation of Dose OF Different Organ and Whole Body

Organ	Lungs	Ovaries	Bone marrow	Testes	Kidney	Liver	Whole body
This study (Indoor)	0.253	0.229	0.273	0.324	0.245	0.166	0.269
This study (Outdoor)	0.016	0.015	0.018	0.021	0.016	0.011	0.017
UNSCEAR 2000, ICRP 2007	0.64	0.58	0.69	0.82	0.62	0.42	0.68

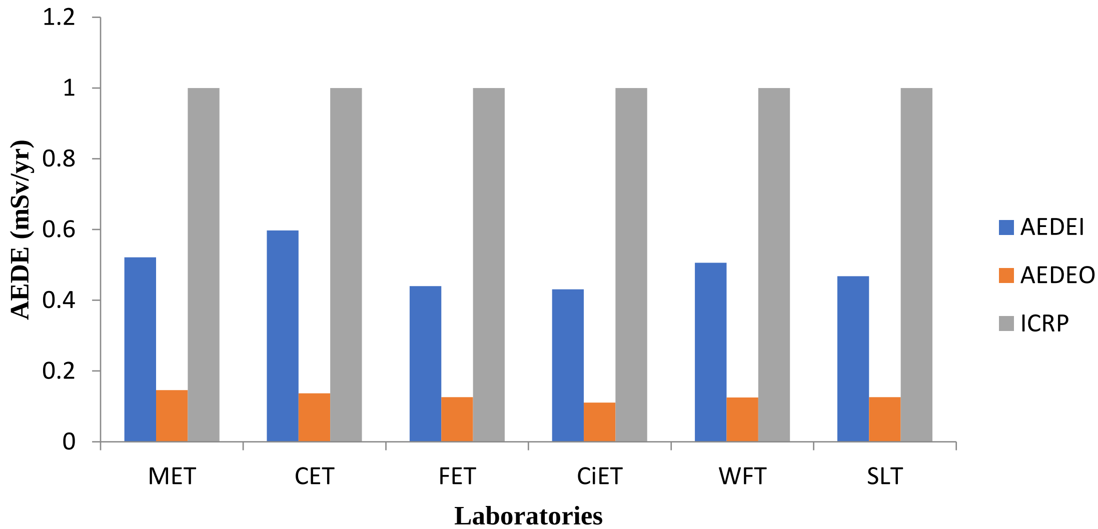

Figure 3: Annual Effective Dose Equivalent for Indoor and Outdoor for the Laboratories.

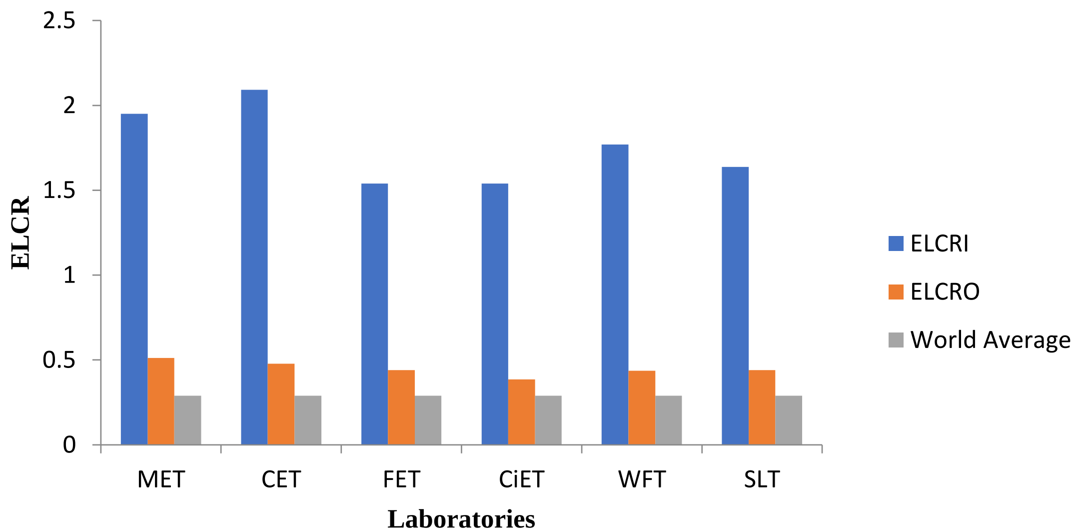

Figure 4: Excess Lifetime Cancer Risk for Indoor and Outdoor Laboratories

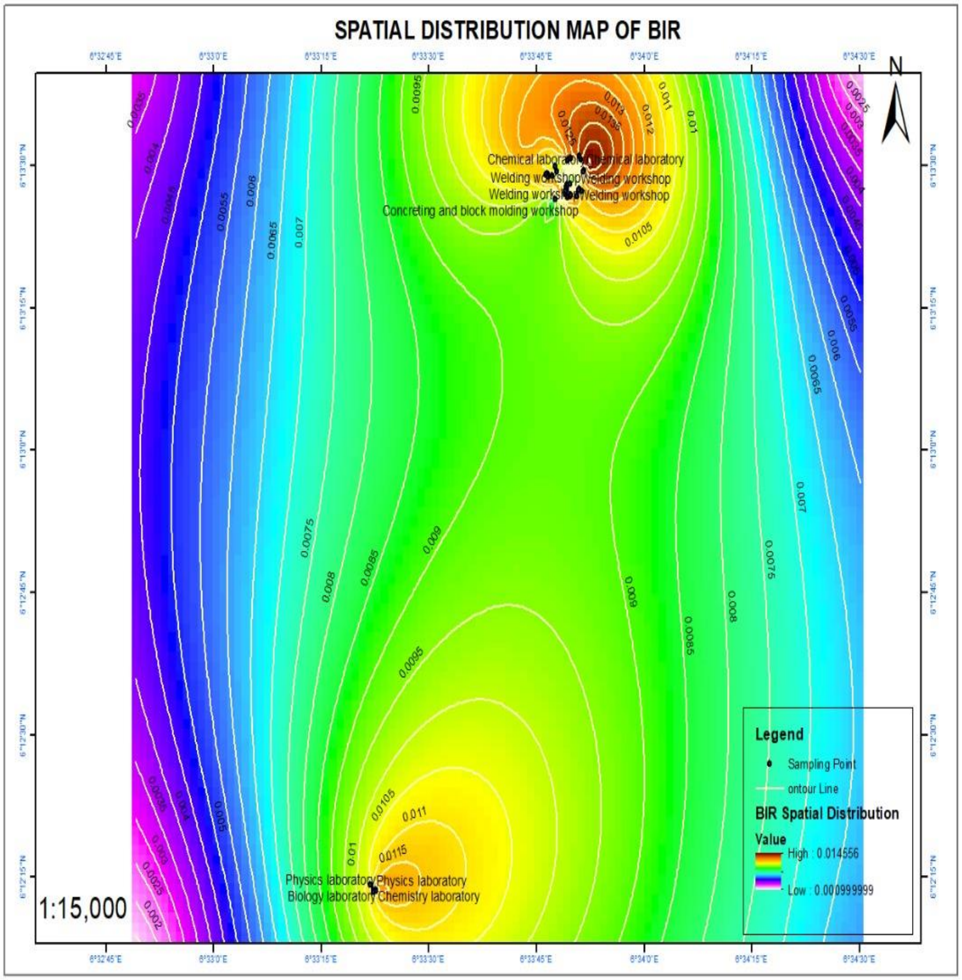

Figure 5: GIS Contour Map of the Study Area showing sampled points with BIR Measurements

As shown in Table 2, the results for indoor annual dose rate range from 87 ηGy/yr to 121.8 ηGy/yr with an average of 100.69 ηGy/yr. The estimated annual equivalent dose rate for indoors ranges from 0.8494 mSv/yr to 1.1773 mSv/yr with an average value of 0.9733 mSv/yr. For estimated indoor annual effective dose equivalent, values range between 0.4311 mSv/yr to 0.5975 mSv/yr with an average value of 0.4940 mSv/yr. The values measured for outdoor laboratory range between 90 ηGy/yr to 111.36 ηGy/yr with an average of 102.70 ηGy/yr for annual dose rate and 0.8704 mSv/yr to 1.0764 mSv/yr with an average of 0.9927 mSv/yr for annual equivalent dose rate while the annual effective dose equivalent range between 0.1104 mSv/yr to 0.1465 mSv/yr with an average of 0.1284 mSv/yr. As depicted in figure 3, the estimated values of AEDE indoors are higher than the values of AEDE outside the laboratories but are lower than the recommended limit of 1 mSv/yr and 20 mSv/yr set by ICRP for the individual and general public (ICRP, 2007). This high difference in the value of the indoor and outdoor area may be due to accumulated radionuclides in the laboratories, poor ventilation, and lock up of the laboratory when not in use. This is an indication that the polytechnic is not entirely in agreement with the set limit but further studies will ascertain if the staffs, students, and visitors are under any immediate radiological threat that may arise from exposure to BIR.

The calculated value for ELCR (as presented in table 2) ranges from 1.5386 to 2.00912 with an average value of 1.755 for indoor and 0.3864 to 0.5128 with an average value of 0.4493 for outdoor respectively. As revealed in figure 4, the values are higher that the recommended limit of 0.29×10^{-3}. The results of the effective dose delivered to different organs and the whole body are presented in table 3. The values of the lung, ovary, bone marrow, testicle, kidney, liver, and whole body due to radiation exposure and inhalation in the study area are below the ICRP and UNSCEAR recommended limits for lung, ovary, bone marrow, testes, kidney, liver, and whole body, respectively (UNSCEAR, 2000, ICRP, 2007).

These results however appear to be less than the international recommended limits as presented in table 3. The high dose received by the testes and the low dose received by the liver may be due to the rate of absorption of dietary nutrients (Zaid *et al*, 2010). Figure 5 shows the level and distribution of BIR according to the laboratories considered in this study.

CONCLUSION

This study has assessed the indoor and outdoor radiation dose levels of twelve (12) laboratories of the Delta State Polytechnic, Ogwashi-Uku and results revealed that the average BIR, average EDR, and average ADR for the indoor and outdoor environments are slightly less than world permissible limits. The average AEDE and ELCR for indoor and outdoor which are slightly higher than the world average recommended limit of 0.29×10^{-3} is in agreement with similar research done by (Anyalebechi *et al*, 2021) which may be due to the accumulation and concentration of indoor radiation, especially in the indoor laboratories. AEDE and ELCR exceeding recommended limit imply that it increases the probability of a person developing cancer over a lifetime. It is recommended that periodic assessment of BIR concentration is carried out by management and relevant radiation monitoring authority to keep radiation levels as low as reasonably achievable (ALARA).

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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