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In-Situ Determination of Terrestrial Gamma Dose Rate within Ladoke Akintola University of Technology, Ogbomoso Oyo State, Nigeria

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ABSTRACT

The understanding of terrestrial gamma radiation and its effect on human beings is intertwined with advancements in radiation science, health physics, and environmental monitoring. It is because of this that the study investigated the terrestrial radiation level within Ladoke Akintola University Technology-Main Campus (MC), College of Health Sciences (CHS) and Teaching Hospital (TH) of the institution. A total of 137 sampling points were assessed for terrestrial gamma dose rate using a portable radiation dosimeter. The measured dose rate was subjected to statistical analysis using analysis of variance with a Tukey post-hoc test. The results of absorbed dose rates for MC, CHS and TH ranged from 0.10 - 0.22 µSvhr^{-1}, 0.11 - 0.24 µSvhr^{-1} and 0.10 - 0.22 µSvhr^{-1} respectively and their corresponding mean values were found to be 0.150 µSvhr^{-1}, 0.152 µSvhr^{-1} and 0.170 µSvhr^{-1} respectively. The statistical analysis and the post-hoc test revealed that the medical activities involving the use of radiation at the TH contributed significantly to the dose level of the environment at $p = 0.05$. The estimated annual effective dose equivalent ranged from 0.18 to 0.42 mSvyr^{-1} which is within the recommended limit of 1 mSvyr^{-1} for the public set by the International Commission on Radiological Protection. Also, Excess Lifetime Cancer Risk was calculated from the Annual Effective Dose Equivalent obtained. The findings of this study provide valuable information on the radiation level of three studied environments and hereby recommended that the general public be radiation cautious by minimizing the amount of time spent within the environment of teaching hospitals to mitigate the radiological hazard.

INTRODUCTION

The discovery of natural radioactivity in the late 19th and early 20th centuries laid the foundation for understanding terrestrial gamma radiation (TGR). Pioneering work by (Maia *et al.*, 2024) provided insights into the presence of radioactive elements in the Earth's crust. Throughout the early to mid-20th century, the field of radiation dosimetry developed, enabling scientists to measure and quantify radiation exposure more accurately. Hence, the measurement of

TGR dose rates has received global interest and led to extensive surveys in many countries (Wu *et al*., 2025).

Terrestrial gamma radiation primarily originates from the decay of natural radionuclides such as uranium, thorium, and potassium-40 present in the earth's crust. These radionuclides emit gamma rays during their decay processes, contributing to the ambient radiation levels in the environment (Shahbazi-Gahrouei *et al*., 2013). Thus, human beings, irrespective of race, complexion and location, is unavoidably and constantly exposed to varying doses of background radiation (Ugbede and Echeweozo, 2017; Isola *et al*., 2019). There can be large variances in natural background radiation levels from place to place, as well as changes in the same location over time (Kendall *et al*., 2016). The radioactivity level of naturally occurring radionuclide materials is found in greater quantity in some areas of the country than others (Akinloye *et al.*, 2012). On average, two-thirds of the effective dose that people receive from natural sources comes from radioactive substances in the air inhaled, food intake and water consumed (Akinloye and Abodunrin, 2008).

Studying the levels of radionuclide distribution in the environment provides essential radiological information. In addition, natural background sources and anthropogenic activities such as exploration and exploitation of natural resources have continued to make significant additions to the background radiation levels of varying environments, thus resulting in increased exposure for the general public (Ugbede *et al*., 2020). In many parts of the world, radiation exposure levels are being monitored regularly, to address increased public concern over radiation safety. In the time past, terrestrial gamma radiation levels, for the majority part of the Nigerian environment, were believed not to have been established (Abba *et al*., 2017), but in recent times, terrestrial gamma radiation levels have been measured and mapped in various parts of Nigeria, providing valuable data for radiation protection and environmental monitoring (Ononugbo and Anekwe, 2020). Despite all the measurement and mapping in various parts of the Nigerian environment, many people are still unaware that radioactivity is present in the environment naturally (Omeje *et al.*, 2023).

Hence, studies like the measurement of radiation dose rates in air derived from terrestrial gamma rays play an important role in radiation protection and monitoring. Hence, the determination of terrestrial gamma dose rate is crucial for assessing radiation exposure levels in a given area, especially within educational institutions. Understanding the gamma radiation levels within the environment is essential for ensuring the safety and well-being of students, faculty, and staff. This study thereby assesses the terrestrial gamma dose rates of three different environments of Ladoke Akintola University of Technology, Ogbomoso. The data expected from this study will be an addition to the already existing radiation dose databank of the country which will be of importance to the regulatory activities of the Nigeria Nuclear Regulatory Authority (NNRA).

MATERIALS AND METHODS

An in-situ method was used for this research to measure the terrestrial gamma dose rate within the Ladoke Akintola University of Technology, Oyo State, Nigeria.

Study Area

The study was carried out at Ladoke Akintola University of Technology's main campus, college of health sciences and teaching hospital which are all located at Ogbomoso North Local Government, Ogbomoso Oyo State, Nigeria with geographical coordinate of latitude 8° 8' 0" North and longitude 4° 16' 0" East. The dominant rock type in the area is granite, which is a coarse-grained, light-colored, and acidic igneous rock. Sandy loam soils are also present in some areas of the study areas which are well-drained and suitable for agriculture.

Sampling Locations

Since each of the study areas has different dimensions, sampling locations were chosen from each of them depending on their sizes. A total of 137 in-situ measurements were taken within the study areas which were randomly selected to cover the studied locations. 102 sampling locations were chosen at the Main Campus to cover all the faculties in the main campus (MC), 15 sampling locations were chosen at the College of Health Sciences (CH), and 20 sampling locations were chosen at the Teaching Hospital (TH).

Measurement of Background radiation

A portable environmental radiation dosimeter called RADEX RD1503 manufactured by QUARTA-RAD Ltd, Moscow was used and the equipment uses a Geiger counter to detect the amount of gamma radiation within 40 seconds and indicates the values in $\mu Svhr^{-1}$ and µRem/hr on an LCD screen. The range of gamma radiation energy of the device is between (0.1-1.25) MeV. The instrument has a detection range of 0.05 - 9.90 $\mu Svhr^{-1}$ with no additional calibration because the device is pre-calibrated with a tolerance of +/- 15% and is capable of measuring Gamma, Beta and X-ray radiation. The instrument is very sensitive, relatively inexpensive, rugged and suitable for environmental gamma radiation. An in-situ approach of Terrestrial Gamma Radiation Dose (TGRD) rate measurement was carried out at 1 meter standard height above the ground level in the outdoor environment of the chosen locations. This is to avoid the effects of ground and buildings on outdoor measurements and to retain at least six meters away from the walls of any building nearby (Gholami *et al.*, 2011). Three sets of readings were taken at each sampling location from which the average was recorded at intervals of two minutes, this was done to minimize error and to account for the fluctuating nature of background radiation (Ononugbo *et al.*, 2017; Ugbede and Benson, 2018). The areas chosen for background radiation measurements covered the entire university community. The absorbed dose rate was measured in $\mu Svhr\text{-}^{1}$. The data measured were read directly from the display screen of the dosimeter. This method of TGRD measurement enables the study locations to maintain their original environmental characteristics (Ugbede and Benson, 2018).

Estimation of Annual Absorbed Dose

The annual absorbed dose rate D, was calculated from the measured absorbed dose rate in $\mu Svyr\text{-}^{1}$ using equation 1:

$$D = G \times 24\ hrs\ \times 365\ days \qquad (1)$$

where G represents the mean outdoor dose rate recorded at each sampling location in $\mu Svhr^{-1}$,

Estimation of Annual Effective Dose Equivalent

The Annual Effective Dose Equivalent (AEDE) is a measure of the total radiation dose received by an individual in a given year, taking into account the effective dose from various sources of ionizing radiation. It is typically expressed in millisieverts (mSv). UNSCEAR (1988) 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. Equation 2 was used to convert the dose rate in $\mu Svhr^{-1}$ into the annual effective dose equivalent (AEDE) in $mSvyr^{-1}$.

$$AEDE = \frac{D(\mu Svy^{-1}) \times 0.2}{1000} \quad (2)$$

where D is the estimated annual absorbed dose rate ($\mu Svyr^{-1}$), AEDE is the estimated annual effective dose equivalent ($mSvyr^{-1}$), 0.2 is the outdoor occupancy factor and 1000 is the conversion factor used to convert from microsieverts per hour to millisieverts per year.

Excess Lifetime Cancer Risk (ELCR)

Excess Lifetime Cancer Risk (ELCR) for each study area was also estimated, the Annual Effective Dose Equivalent (AEDE) values and a risk coefficient were substituted into equation (3) below:

ELCR (%) = AEDE ($mSvyr^{-1}$) x Risk Coefficient (%/Sv) (3)

Risk Coefficient

Based on the ICRP publication 103 (2007), 5% /Sv was recommended as the risk coefficient for cancer incidence (5% increase in cancer risk per sievert of radiation exposure). This value was used for Excess Lifetime Cancer Risk (ELCR) calculations.

Calculation of Excess Lifetime Cancer Risk

Study Area A (LAUTECH Main Campus)

AEDE = 0.260 $mSvyr^{-1}$

ELCR (%) = 0.26 mSv/yr x 5%/Sv = 0.013% or approximately 1 in 7692

Study Area B (College of Health Science)

AEDE = 0.270 $mSvyr^{-1}$

ELCR (%) = 0.27 $mSvyr^{-1}$ x 5%/Sv = 0.0135% or approximately 1 in 7407

Study Area C (LAUTECH Teaching Hospital)

AEDE = 0.300 $mSvyr^{-1}$

ELCR (%) = 0.3 $mSvyr^{-1}$ x 5%/Sv = 0.015% or approximately 1 in 6667

RESULTS AND DISCUSSION

Table 1 gives a summary of the descriptive results obtained from the in-situ measurements of background ionizing radiation at the Main Campus, College of Health Sciences and Teaching Hospital of the university. The highest dose rate was recorded at the Dental Centre at the College of Health Sciences which could be a result of radiographic equipment such as a Dental X-ray machine, while the lowest was recorded at the Architecture 250 Lecture Theatre in the Main Campus which may be as a result of absence of radiographic equipment as lecture theatres do not always house radiographic equipment. These differences in the mean of absorbed dose rate values can be linked to the varying geological factors and soil properties across the sampling locations, which affect the distribution and accumulation of naturally occurring radioactive materials (Ilori *et al*., 2024).

Mathematical Expressions for Mean and Standard Deviation

(i) Mean: The mean was estimated using equation (4)

This can be expressed mathematically as;

$$\mu = \Sigma x_i / n \quad (4)$$

Where:

μ = mean, Σx_i = the sum of the values of all individual sampling points, n = number of sampling points

Table 1: Descriptive Statistics

Location Code	Min ($\mu Svhr^{-1}$,)	Max ($\mu Svhr^{1}$)	Mean ($\mu Svhr^{-1}$)	SD ($\mu Svhr^{-1}$)
MC	0.10	*0.22*	0.150	0.0263
CH	*0.11*	*0.24*	0.152	0.0308
TH	*0.10*	*0.23*	0.170	0.0333

MC – Main Campus, CH – College of Health Sciences, TH – Teaching Hospital

(ii) Standard Deviation: The standard deviation SD was estimated using equation (5) below

$$\sigma = \sqrt{[(\Sigma(xi - \mu)^2) / n]} \qquad (5)$$

Where:

σ = standard deviation, x_i = individual sampling point

μ = mean, n = number of sampling points

Σ = summation symbol, indicating the sum of the values.

The standard deviation of all the sampling locations was obtained using equation four (4). In Table 2, the total mean absorbed dose value was also compared with results from earlier research. Though not all of these studies were conducted in the same study area as the present study a major comparison of the present study was done with other works both outside and within educational institutions. Overall, these studies confirm that the background gamma radiation levels found in the current research area fall within acceptable bounds. The study results are consistent with the variety of background radiations reported in the literature. The variation recorded can be attributed to human activity and geological features that existed at the sites of earlier research. Generally, these studies confirm that the background gamma radiation levels found in the current research area fall within acceptable bounds.

Table 2: Comparison of present work result obtained for Mean Absorbed Dose Rate with those from other works

Author	Mean Absorbed Dose Rate (μSvh^{-1})
Akinloye *et al,* 2007	0.04
Ajayi and Ibikunle, 2013	0.13
Oladapo and Oni, 2014	0.04
Osimobi *et al*., 2015	0.16
Isola *et al*., 2018	0.02
Ajetunmobi *et al*., 2023	0.10
Present Study	0.16

The Tukey posthoc test revealed no significant difference at p = 0.05 level of significance between locations CH-MC and TH-CH respectively. However, a comparison of TH-MC revealed a significant difference at $p = 0.05$. This test of significance further confirmed that the activity at the Teaching Hospital contributes significantly to the radiation level of the environment.

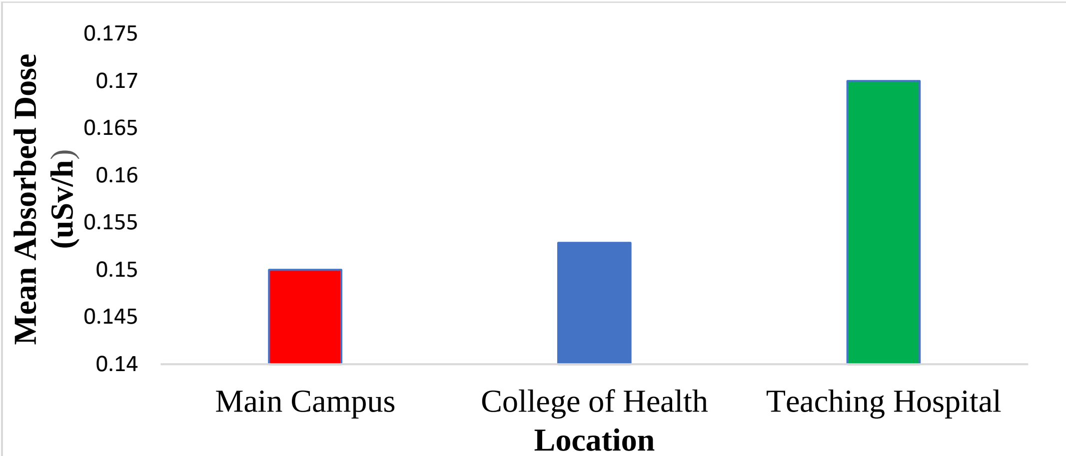

Figure 1**:** Bar Chart of the Studied Locations with their Corresponding Mean Outdoor Absorbed Dose Rate

Table 3: Descriptive summary of the Annual Effective Dose Equivalent (AEDE) at each studied location

Locations	**Min (**$mSvyr^{-1}$**)**	**Max (**$mSvyr^{-1}$**)**	**Mean (**$mSvyr^{-1}$**)**
MC	0.18	0.39	0.260
CH	0.19	0.42	0.270
TH	0.18	0.39	0.300

From Figure 1, it can be deduced that natural background radiation is the primary source of radiation at both the main campus and college of Health Science and that human activities are negligible whereas radiation-emitting equipment like X-ray machines as well as radioactive materials used for medical procedures within Teaching Hospital contribute to highest mean values of absorbed dose.

Table 3 shows the summary of the estimated annual effective dose equivalent (AEDE) values that were converted from the background radiation results. The results showed that, accordingly, the Teaching Hospital had the greatest AEDE value and the Main Campus had the lowest. The computed AEDE has an overall mean of 0.28 $mSvy^{-1}$, with a range of 0.26 to 0.30 $mSvy^{-1}$. This value demonstrates compliance with internationally accepted radiation safety standards since it is 28.0% below the ICRP's set limit (ICRP, 2007) recommended maximum limit of 1 $mSvy^{-1}$ for the general public. The results obtained are in agreement with AEDE values from previous research. Even if all projected values are within acceptable ranges for public exposure, it is imperative to continue monitoring, all the study locations to forestall any unnecessary hazards from radiation exposure. Table 4 shows a descriptive summary of the annual effective dose equivalent (AEDE), Risk Coefficient and Excess Lifetime Cancer Risk (ELCR) for each of the study locations, variation in the results was due to the absorbed dose from each of the locations; LAUTECH Teaching Hospital has the highest ELCR, followed by LAUTECH College of Health Sciences, and then LAUTECH Main Campus.

Table 4: Descriptive Summary of the AEDE, Risk Coefficient and ELCR results of each Study Location

LOCATION	AEDE($mSvyr^{-1}$)	RISK COEFFECIENT (%/Sv)	ELCR (%)
LAUTECH Main Campus	0.260	5	0.013
LAUTECH College of Health Sciences	0.270	5	0.0135
LAUTECH Teaching Hospital	0.300	5	0.015

CONCLUSION

The findings from this study provide valuable information on the gamma radiation level within the main campus, College of Health and teaching hospital of Ladoke Akintola University of Technology, Ogbomoso Oyo State, Nigeria. Moreover, the absorbed dose rate, annual dose rate and annual effective dose equivalent values obtained are within the safety limit recommended by the International Commission on Radiological Protection (ICRP). It is hereby recommended that the general public should be radiation cautious by minimizing the amount of time that will be spent within the environment of LAUTECH Teaching Hospital where the mean of the absorbed dose rate is higher to mitigate the radiological hazard.

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