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Indoor and outdoor gamma radiation exposure levels in selected residential buildings across Ondo state, Nigeria

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► ***Original article***

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ABSTRACT

Background*:** Indoor and outdoor gamma radiation exposure levels were measured in a total of 360 randomly selected dwellings categorized as local, semi-modern and modern buildings across Ondo State, Nigeria to determine the annual effective doses. ***Materials and Methods*:** All radiation measurements were taken using a calibrated Kindenoo PG-15 Geiger Muller detector and a GPS for geographical coordinates of sample points. Equal number (360) sample point measurements were carried out for indoor and outdoor measurements. Measurements at each location point were performed holding the survey meter at 1 m above ground surface or floor to avoid unwanted effects of radiation from soil or building floor. The detector was also held at least six to seven meters away from buildings nearby in order to avoid unwanted effects of the building materials on outdoor measurements. Each measurement was repeated six times and the average was taken to represent the value for a sample point. ***Results: The average outdoor and indoor dose rates were determined as 263 ± 32 μSvh-1 and 213 ± 64 μSvh-1 respectively. The highest contribution to the total indoor dose was from the local buildings followed by semi modern buildings and the modern buildings contributed the least dose. The average annual effective dose was calculated as 1.56 ± 0.33 mSv, which is higher than the world average value (0.48 mSv). ***Conclusion:*** In view of the potential radiation resulting from building materials, comprehensive assessment of natural radiations in such materials is required.

Keywords: *Natural radiation, indoor radiation exposure, outdoor radiation exposure, annual effective dose, building materials.*

INTRODUCTION

Assessments of natural background radiations for radiation protection are of great significance to health physicists not only because human beings are constantly exposed to varying level of ionizing radiations from natural origin but also more than 90% of human radiation exposure arises from natural sources. The sources are; cosmic rays from the Sun and interstellar space, terrestrial radionuclides that are found in the Earth's crust, building materials, air, water, food and the human body itself being a product of the environment (1). Exposures to radiation due to terrestrial radionuclides are mainly from ^{40}K, the decay series of ^{232}Th and ^{238}U which are found in different amount from one region to the other on the Earth's surface depending on the geological and geographical features and as well as the materials used for buildings in such region. The concentrations of the terrestrial radionuclides are found to vary with geological and geographical features of any region (2-14). Studies (indoor and outdoor) on natural radioactivity have been conducted in many countries of the world. This is because the knowledge of natural radioactivity is very important to accurately assess any possible radiological risk to human health and to establish local controls where needed [15-30]. As part of the contribution to the global data on natural radioactivity from Nigeria, this study was carried out to assess the indoor/outdoor gamma background radiation across residential buildings in Ondo state, South-Western Nigeria. Although, previous reports from studies on background radiation in some states of Nigeria have been carried out but data from Ondo state on environmental radioactivity is quite scanty [16,19]. Moreover, the state is one of the oil producing states with heavy oil exploitation and other activities such as mining that can result to Technologically Enhanced Naturally Occurring Radionuclides Materials (TENORM) which may further contribute to human exposure to natural sources of radiation. Noticeably in some parts of the state there are many quarry industries as the state is endowed with igneous rocks (such as granites) and sedimentary rocks (such as shale) [29]. These types of rocks have been identified to contain high levels of natural radionuclides [1]. There is therefore a need to carry out a compressive study of the natural radioactivity in the state. The results from this study will be geared towards estimating annual effective dose of the residents in the study area and form part of the baseline data for future use.

Ondo state in Nigeria lies between latitudes 5^{o} 45' and 7^{0} 52'N and longitudes 4^{0}20' and 6^{0} 05'E. Its land area is about 15,500 square kilometers. Figure 1 shows the geological map of the state with the names of the head quarters of the 18 Local Government Areas (L.G.As) indicated, namely; Names (headquarters); Akure South (Akure), Akure North (Iju/Itaogbolu), Ifedore (Igbara Oke), Idanre (Owena), Ondo West (Ondo), Ondo East (Bolorundoro), Ileoluji/OkeIgbo (Ileoluji), Odigbo (Ore), Irele (Irele), Ese-Odo (Igbekebo), Okitipupa (Okitipupa), Owo (Owo), Ose (Ifon), Akoko South West (Oka), Akoko North East (Ikare), Akoko South East (Isua Akoko), Akoko North West (Oke-Agbe), and Ilaje (Igbokoda) [29].

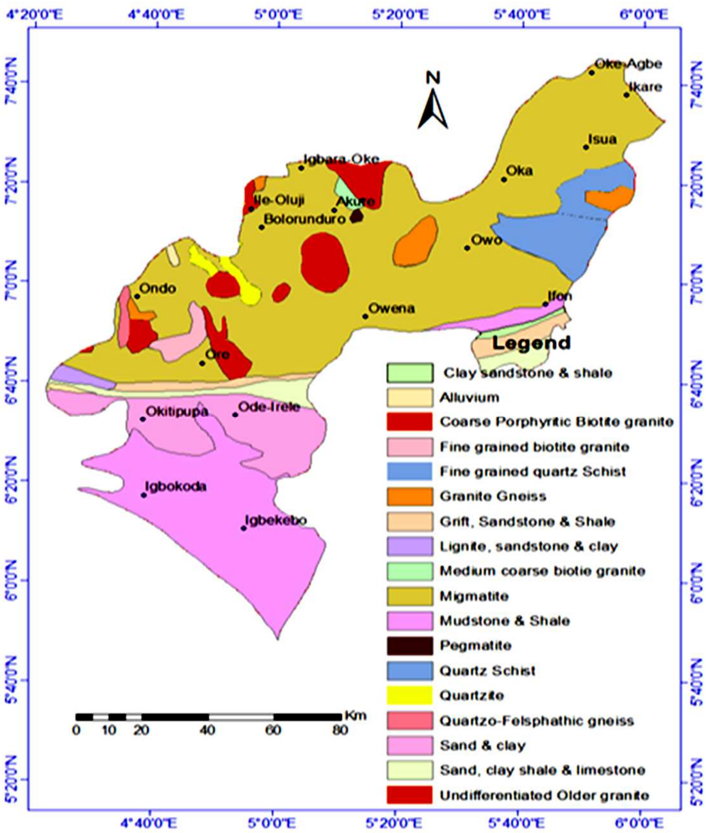

Figure 1. Map showing the geological map of Ondo state.

MATERIALS AND METHODS

The indoor/outdoor radiation survey was performed using a Kindenoo PG-15 Geiger Counter version 38.0 with serial number 0018B2012589. Its measurement range is between 0.05 μSv/h and 300 μSv/h with maximum radiation measurement of 250 mSv and maximum time measurement of 10 years. The detector was calibrated at National Institute of Radiation Protection and Research, a secondary standard laboratory certified by International Atomic Energy Agency (IAEA) and a division of the Nigerian Nuclear Regulatory Authority (NNRA). The characteristic features of this instrument are the small size, the flexibility of operation and its superior measurement performance which is provided by the use of low power technology.

A GPS system was used to obtain information about the geographical coordinates that enhance easy reference to each selected point for other research. Residential buildings from each of the eighteen (18) local Governments in the study area were randomly selected. The choices cities/ towns took into consideration population, geological and the geographical location. The residential buildings used for this research were categorized into three groups which are local building (buildings with bare floor, wood/no ceiling, just roof, no fan, made with mud/clay bricks), semi-modern building (buildings with cemented floor, asbestos ceiling, galvanized roofing sheet, plastered/concrete wall and fan), and modern building (buildings with tiled floors, marble wall, plaster of Paris, PVC ceiling or aluminum roofing sheet, air conditioner).

A total of 360 dwellings (one floor and iron roofed) were randomly selected for indoor measurement across the study area. Measurements at each location point were performed holding the survey meter at 1 m above the ground surface and from the wall to avoid unwanted effects of radiation from soil or building materials. In the same vein, 360 location points were also used for the outdoor measurements. Each of the outdoor measurement was taken at least six meter from the walls of nearby building (30). Each measurement was repeated six times and the average was taken to represent the value for the location point. At each point the corresponding geographical position was taken and recorded. The data obtained from the measurements were used to calculate the indoor (IAED) and the outdoor (OAED) annual effective doses in using equations:

$$IAED(mSvy^{-1}) = Xmean \times 8760hr/yr \times 0.8 \times CF \quad \text{-------------- 1}$$

$$OAED(mSvy^{-1}) = Ymean \times 8760hr/yr \times 0.2 \times CF \quad \text{---------------2}$$

Where X and Y are the indoor and outdoor dose rates in μSv/h obtained from the Geiger Muller Counter, CF is the conversion factor (0.7 for adult), 0.8 and 0.2 are the indoor and outdoor occupancy factors respectively as recommended by (1). The results were analyzed using Microsoft excel.

RESULTS

Table 1 shows the results of the measurements of indoor and outdoor absorbed dose rates (mean) in air due to gamma background radiation in the 18 local governments of Ondo state Nigeria based on the building categories. Measurements showed that the indoor and the outdoor doses are in the range of 0.17 ± 0.02 to 0.38 ± 0.02 μSv h^{-1} with a mean value of 0.24 ± 0.05 μSv h^{-1} and 0.16 ± 0.01 to 0.32 ± 0.01 μSv h^{-1} with a mean value of 0.21 ± 0.04 μSv h^{-1} respectively for the modern buildings. The indoor and the outdoor absorbed dose rates for the semi-modern buildings were found in the range of 0.18 ± 0.01 to 0.39 ± 0.01 μSv h^{-1} with a mean value of 0.25 ± 0.05 μSv h^{-1} and 0.14 ± 0.01 to 0.29 ± 0.01 μSv h^{-1} with a mean value of 0.21 ± 0.04 μSv h^{-1} respectively. In the same vein, the indoor and the outdoor values for the local buildings were found in the range of 0.18 ± 0.02 to 0.52 ± 0.02 μSv h^{-1} with a mean value of 0.30 ± 0.09 μSv h^{-1} and 0.16 ± 0.01 to 0.34 ± 0.02 μSv h^{-1} with a mean value of 0.22 ± 0.05 μSv h^{-1} respectively. The minimum and maximum outdoor dose rates were 0.14 ± 0.01 μSv h^{-1} (Okitipupa) and 0.34 ± 0.02 μSv h^{-1} (Ile-Oluji/Okeigbo) respectively. While the minimum and the maximum indoor dose rates were recorded as 0.17 ± 0.02 μSv h^{-1} (Ese-Odo, Modern buildings) and 0.52 ± 0.02 μSv h^{-1} (Ilaje, local buildings) respectively. The annual effective dose rates were also calculated for each of the local government using equations 1 and 2 with the result as shown in figure 2. It can be seen that the maximum and the minimum annual effective dose rates are 2.22 mSv (Akoko south East Local government) and 1.1 mSv (Ese-Odo Local government) respectively. The average annual effective dose in the study area is 1.56 ± 0.33 mSv which is more than the global value (0.48 mSv) with the range of 0.3-0.6 mSv.

Table 1. Indoor and Outdoor Values of Dose Rate Due Ambient Gamma Radiation in Ondo State (μSv/h).

Local Government Names	Modern Building		Sem-Modern Buildings		Local Buildings	
	Indoor Dose	Outdoor Dose	Indoor Dose	Outdoor Dose	Indoor Dose	Outdoor Dose
AKOKO NORTH EAST	0.02 ± 0.27	0.02 ± 0.21	0.01 ± 0.24	0.01 ± 0.19	0.02 ± 0.29	0.01 ± 0.22
AKOKO NORTH WEST	0.02 ± 0.29	0.01 ± 0.23	0.01 ± 0.28	0.02 ± 0.18	0.01 ± 0.26	0.01 ± 0.2
AKOKO SOUTH EAST	0.02 ± 0.38	0.01 ± 0.32	0.01 ± 0.39	0.01 ± 0.27	0.02 ± 0.37	0.02 ± 0.27
AKOKO SOUTH WEST	0.02 ± 0.25	0.01 ± 0.22	0.01 ± 0.29	0.02 ± 0.23	0.01 ± 0.29	0.02 ± 0.26
AKURE NORTH	0.01 ± 0.22	0.01 ± 0.23	0.01 ± 0.26	0.01 ± 0.24	0.01 ± 0.24	0.01 ± 0.21
AKURE SOUTH	0.03 ± 0.24	0.02 ± 0.23	0.02 ± 0.26	0.02 ± 0.22	0.03 ± 0.38	0.03 ± 0.29
ESE ODO	0.01 ± 0.17	0.01 ± 0.18	0.01 ± 0.18	0.01 ± 0.15	0.01 ± 0.2	0.02 ± 0.17
IDANRE	0.01 ± 0.32	0.01 ± 0.23	0.01 ± 0.28	0.02 ± 0.23	0.01 ± 0.38	0.01 ± 0.27
IFEDORE	0.02 ± 0.26	0.01 ± 0.21	0.01 ± 0.27	0.01 ± 0.18	0.02 ± 0.28	0.01 ± 0.18
ILAJE	0.02 ± 0.23	0.01 ± 0.19	0.01 ± 0.29	0.02 ± 0.21	0.02 ± 0.52	0.01 ± 0.23
ILE-OLUJI/OKEIGBO	0.02 ± 0.31	0.01 ± 0.28	0.01 ± 0.32	0.01 ± 0.29	0.01 ± 0.41	0.02 ± 0.34
IRELE	0.01 ± 0.19	0.01 ± 0.18	0.02 ± 0.19	0.01 ± 0.18	0.02 ± 0.18	0.01 ± 0.16
ODIGBO	0.02 ± 0.18	0.02 ± 0.18	0.02 ± 0.21	0.03 ± 0.19	0.01 ± 0.19	0.01 ± 0.18
OKITIPUPA	0.01 ± 0.19	0.01 ± 0.16	0.02 ± 0.18	0.01 ± 0.14	0.01 ± 0.22	0.01 ± 0.17
ONDO EAST	0.02 ± 0.22	0.02 ± 0.19	0.01 ± 0.24	0.01 ± 0.18	0.01 ± 0.33	0.01 ± 0.23
ONDO WEST	0.01 ± 0.22	0.01 ± 0.18	0.04 ± 0.22	0.01 ± 0.21	0.02 ± 0.24	0.01 ± 0.19
OSE	0.01 ± 0.21	0.01 ± 0.20	0.01 ± 0.24	0.01 ± 0.23	0.03 ± 0.38	0.02 ± 0.26
OWO	0.03 ± 0.21	0.01 ± 0.16	0.02 ± 0.23	0.01 ± 0.18	0.02 ± 0.23	0.01 ± 0.19

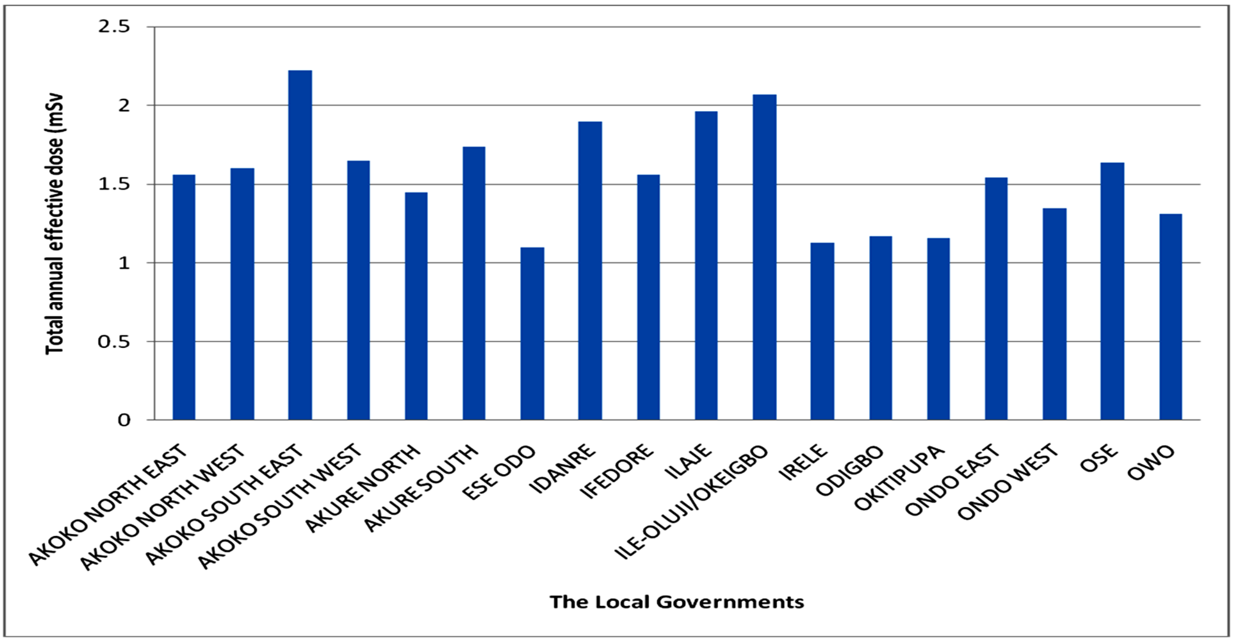

Figure 2. showing the annual effective dose of the building types.

DISCUSSION

In this study, background gamma dose rates (outdoor and indoor) and the corresponding annual effective dose were determined for three categories of buildings in Ondo state Nigeria using direct method (a Geiger-Muller counter). The results of this measurement showed that the average indoor dose rate was 263 ± 32 nSv h^{-1}. This value in comparison with the mean value, 84 nSv h^{-1} reported by UNSCEAR 2000 in the range of 20-200 nSv h^{-1} from different countries was significantly higher [1]. Based on the categories of buildings according to this study, the mean values obtained were 240 ± 40, 250 ± 50, 300 ± 90 nSv h^{-1} for the modern buildings, semi-modern building and the local building respectively. However, an ANOVA test was performed on the raw data to ascertain the significant differences between the groups of doses based on the building types. The test showed that there was significant variation within the three group of the indoor absorbed dose rate for the three categories of the buildings ($F(2,357)=12.68$, $P<0.001$) and consequently a post hoc analysis was run using the Least Significant Difference Test (LSD) with “equal variance” assumed. The test showed that there is significant difference between the indoor absorbed dose obtained between the modern buildings and the local buildings and between the semi modern buildings and the local buildings all at $p <0.001$. No significant difference was observed between the values for modern buildings and the semi-modern buildings. The differences in the distribution of the indoor dose rates might have resulted from the contribution of the building materials of which the building were made and the geology of the study area. In addition, the local buildings were observed to have the highest contribution to the total indoor doses rates, this might have resulted from the fact that the local buildings are characterized with bare floors and walls of the buildings were built with mud or clay bricks. The clay and the mud as the major building material for local buildings may contain higher concentrations of natural radionuclides than the material such as tiles, asbestos, concrete floor used for modern and semi modern buildings. Therefore, it is very important that the radiological contents of the building materials from the study areas especially the local building materials (mainly mud/clay) be extensively assessed. An ANOVA test was carried on the values of the outdoor absorbed dose rates, the test showed that no significance difference exists between the group of the dose rates based on the building types ($F (2,357)=3.575$, $P>0.001$). This was expected because radiations from building materials and cosmic radiation due altitudes (525 m highest recorded) have no contribution to the outdoor measurements in this study. The variations in the measurement of the outdoor dose rates are due to chance.

According to the results shown in figure 2 the highest average annual effective dose was recorded at Akoko South East L.G.A. and the lowest value recorded at Ese-Odo. The variation might have been due to geological feature of the study area. Akoko South East L.G.A. is one the L.G.A. that is endowed with igneous rocks such as granite that may contain higher concentration of natural radiaonuclides than other parts of the states like Ese-Odo with sand. The average annual effective doses, 0.25 mSv (outdoor) and 1.31 mSv (indoor) with a total average value of 1.56 mSv obtained in this study are observed to be greater than the world average annual effective dose for normal background radiation, 0.072 mSv (outdoor) and 0.41 mSv (indoor) with a total average value of 0.48 mSv respectively [1]. The average value (1.56 mSv) is also observed to be far greater than any of the reported values of some other countries in the world Iran (0.65 mSv), Malaysia (0.58 mSv), USA (0.25 mSv), Chile (0.36 mSv), Norway (0.48 mSv), Finland (0.45 mSv), UK (0.33 mSv), Hungary (0.55 mSv), Portugal (0.60 mSv), Iceland (0.14 mSv), France (0.45 mSv), Romania (0.48 mSv), Italy (0.61 mSv), Spain (0.63 mSv) [1, 31-51]. In addition, the average value (1.56 mSv) of this study is greater than some recently reported values of other studies for example, Muzaffarabad in Pakistan (0.72 mSv), Bushehr city in Iran (0.36 mSv), Yazd Province in Iran (0.72 mSv), Vietnam in eastern Idochina Peninsula (0.54 mSv), Lorestan Province in Iran

(0.72 mSv), Zanjan in Iran (0.82 mSv) [3,7,30,51,52]. But annual outdoor effective dose (0.25 mSv) of this study is far less than the value (74.2 mSv) obtained by Ajayi *et al.* [25] in a study carried out in the whole South West Nigeria using soil samples of which a few soil sample was collected from this study area. Consequently, the results of this study call for urgent attention to further extensively probe the building materials and soil used in the study area for radionuclide concentration especially with other methods. Since this is a direct measurement of background radiation there is a possibility that radon and its gamma-emitting decay products indoors would have contributed greater part of the indoor dose as the values estimated from direct method of measurement can sometimes differ by up to 50 % from the values obtained with the use of activity concentration in soil samples [1].

Cosmic radiation from extraterrestrial sources is a contributor to natural background radiation. But the absorbed dose rate from it is a function of both altitude and latitude, i.e its intensity increases with altitude because of the decreased shielding effects of the atmosphere and increases with increasing latitude north and south of the equator because the Earth's magnetic field deflects the high-velocity charged component particles of the radiation that are cutting across the magnetic force field [53]. In view of this, the contribution of the cosmic radiation to the total absorbed dose rate measured in this study may have little or no effect because of the geographical position of the study area. All the components of the cosmic radiations would have been totally attenuated before reaching the maximum altitude (525 m) recorded in this study as the intensity of the components of cosmic radiation level decrease rapidly from the altitude of 10-20 km to small or nothing at the sea level [1].

CONCLUSION

In this study, ambient ionizing radiation levels (indoor and outdoor levels) in some selected residential buildings in Ondo State, Nigeria have be determined. The buildings were categorized into local, modern and semi-modern buildings based on the types of materials used for their construction. The highest contribution to the total indoor absorbed dose is from the local building followed by the semi modern building and the modern buildings contribute least. The radiological content of the building materials in the study area should be thoroughly assessed. The average annual effective dose obtained in this study is (1.56 mSv), this value was compared with results from related work around the world. The value was found to be higher than any of the results including the value for the world average (0.48 mSv).

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Conflicts of interest: *Declared none.*

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