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Gamma Dose Rate And Effective Dose Equivalent Due To Gamma Radiation From Granite Samples Collected From Prominent Quarry Sites In Oyo State, Nigeria.

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Abstract-The global attention to the problem of exposure due to natural gamma radiation and associated health risk in dwelling using some materials for building and construction called for this study. Due to the widespread and the high percentage use of granite as building and decoration materials, radiometric analysis was done on granite samples collected from prominent quarry across Oyo state of Nigeria using Nal (TI) Gamma-ray spectrometer techniques. The activity concentration of primordial radionuclides ^{226}Ra, ^{232}Th and ^{40}K in the samples range from 51.45 to 25.30 $Bqkg^{-1}$, 38.26 to 17.44 $Bqkg^{-1}$ and 432.02 to104.20 $Bqkg^{-1}$ respectively. The radium equivalent activity (Ra_{eq}), the external hazard index (H_{ex}) and the internal hazard index (H_{in}) were also determined and found within accepted values by (UNSCEAR). The radium equivalent activities in all the granite samples were lower than the limit (370$Bqkg^{-1}$) set in the Organization for Economic Cooperation and Development (OECD) report and the dose equivalent was within the safe limit of 1 $mSvy^{-1}$.

I. INTRODUCTION

Several studies have reported over 60 radionuclides present in nature with variation in concentration in different components of the environments. High quantity of radionuclides have been reported in rocks types and colour (L. Xinwei *et al.,2005*).The possible exposure to $\gamma -$ radiation emitted from these radionuclides is not only limited to outdoor environment but can also occurs in offices and residential. Investigations have shown that natural radioactivity and the associated exposure due to gamma radiation depends primarily on geological conditions and colours (Mantilla *et al.*, 2004). This study takes a look into some granites samples such as: Pegmatite (dark brown), Gneiss (white pink), Hornblende, Biotite and Porphyrite using for construction and building. Analysis showed that the natural radionuclide contents of granite are related to their mineral compositions and general petrologic feature. The knowledge of natural radioactivity of building materials is important for the determination of population exposure to radiations, as most of the residents spend about 75% of their time indoors. The rapid increase in the use of granite material in construction and building in various sectors prompted this study. The exposure to ionizing radiations from natural sources occurs because of naturally occurring radioactive elements in soil and rocks, cosmic rays entering the earth's atmosphere from outer space and the internal exposure from radioactive elements through food, water and inhalation. According to the assessments made by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), attention to the problem of radon exposure and the associated health risks has thus been growing around the world with about 53% of the human exposure to natural radiation. Such investigations can be useful for both the assessment of public dose rates and the performance of epidemiological studies, as well as to keep reference-data records, to ascertain possible changes in the environmental radioactivity due to nuclear, industrial, and other human activities. Hence the aim of this study is to determine the activity concentration due to some selected radionuclides in granite samples collected from prominent quarry sites across Oyo state of Nigeria.

II. MATERIALS AND METHODS

One hundred and twenty granite samples were collected from six prominent quarry sites across the study area for analysis. The sites were chosen because of their mass production and patronage. In order to reduce the laboratory workload and the corresponding monitoring cost, a composite sampling was employed (Katz 1992). This method is a combination of the sub-sample; therefore the data contained in a composite sub-sample is an average of all the sub-samples making up the composite sub-sample. Thus, this

method provides an excellent estimate of the mean concentration for the sampling area without providing any information about the variation within that area (EPA, 1992). The collected samples were dried at room temperature to constant weight. This is in a bid to avoid any external factors that might alter the natural content; they were then crushed and pass through 2mm sieve to homogenize them. Representative samples were packed into polyethylene cylindrical containers of 95mm diameter and 38mm height. The packed samples were tightly sealed and kept for 28 days to attain a state of secular equilibrium between radon and its decay products. The samples were thereafter counted for a period of 36000s, using a gamma spectrometry system with NaI (TI) as the detector. The scintillation detector, a 3x3 inch NaI (TI), a product of Princeton Gamma Tech. USA was placed in a lead shield to reduce the effect of background radiation. Energy and efficiency calibrations of the detector were carried out using a standard source traceable to Analytical Quality Control Services (AQCS), USA; which contains ten radionuclides of γ-emitters with energies ranging from 59.54 to 1836keV. The activity concentration of ^{238}U was determined from the 63.3 KeV peak of ^{234}Th, ^{226}Ra was determined from the average activity concentration of 295.3KeV of ^{214}Pb and 1764.5 KeV of ^{214}Bi. The activity concentration of ^{234}Th was determined from the average concentration of ^{212}Pb (238.6 keV), ^{228}Ac (911.1 keV) and ^{208}Tl (2614.7 keV), and that of ^{40}K 1460.0 keV. The activity concentration of ^{235}U was determined from the 185.7 keV gamma line, which were corrected by removing the contribution from the 186.2 keV of ^{226}Ra using the following equation:

$$A\,(^{238}U) = \frac{N_{186} - A(^{226}Ra)\cdot f_E\,(^{226}Ra)\cdot \eta_{186}\cdot M\cdot Tc}{\eta_{186}\cdot f_E(^{235}U)\cdot M\cdot Tc} \qquad (1)$$

Where, N_{186} is the total counts for the 186 keV doublet. A (^{235}U) and A(^{226}Ra) are the activity concentrations of ^{235}U and ^{226}Ra respectively, η_{186} is the detection efficiency of the 186keV line, f_E(^{235}U) and f_E(^{236}Ra) are the emission probabilities of the 185.7 and 186.2keV gamma lines of ^{235}U and ^{226}Ra respectively. T_c is the counting time and M is the mass of sample. The Minimum Detectable Activity (MDA) for each radionuclide ^{226}Ra, ^{232}Th and ^{40}K was calculated using the following equation:

$$MDA = \frac{1.645\sqrt{N_B}}{f_E\cdot \eta(E).t_C\cdot M} \qquad (2)$$

Where, 1.645 is the statistical coverage factor at 95% confidence level, N_B is the background counts at the region of interest, t_C is the counting time, f_E is the gamma emission probability, η(E) is the photopeak efficiency and M is the mass of sample. The MDA for each of the radionuclide were calculated as 0.30Bq/kg for ^{238}U, 0.12Bq/kg for ^{226}Ra, 0.11Bq/kg for ^{232}Th and 0.9Bq/kg for ^{40}K respectively.

A. Radium Equivalent Activity

The exposure due to the γ radiation, defined in terms of the radium equivalent activity Ra_{eq} is given by equation (3) (Faheem *et al*, 2008):

$$Ra_{eq} = A_{Ra} + 1.43\,A_{Th} + 0.07\,A_K \qquad (3)$$

Where A_{Ra}, A_{Th} and A_K are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in Bqkg^{-1}, respectively. While defining Ra_{eq} activity, it has been assumed that 370Bqkg^{-1} ^{226}Ra or 259Bqkg^{-1} ^{232}Th or 4810Bqkg^{-1} ^{40}K produce the same gamma dose rate.

B. Calculation of the Absorbed Dose Rate

The external terrestrial γ-radiation absorbed dose rate in air at a height of about 1m above the ground was calculated by using the conversion rate of 0.0414 nGyh^{-1}/Bqkg^{-1} for ^{40}K, 0.461 nGyh^{-1}/Bqkg^{-1} for ^{226}Ra and 0.623 nGyh^{-1}/Bqkg^{-1} for ^{232}Th (UNSCEAR,1993) assuming that ^{137}Cs, ^{90}Sr and the ^{235}U decay series can be neglected as they contribute very little to the total dose from environmental background (Kocher and Sjoreen, 1985; Jacob et al., 1986; Leung et al, 1990).

$$D\ (nGyh^{-1}) = 0.461A_{Ra} + 0.623A_{Th} + 0.0414A_k \qquad (4)$$

Where A_{Ra}, A_{Th} and A_K are the activity concentrations (Bqkg^{-1}) of Radium, Thorium and Potassium in the samples.

C. Calculation of Annual Effective Dose

Annual estimated average effective dose equivalent received by a member was calculated using a conversion factor 0.7 SvGy^{-1},

which was used to convert the absorbed rate to human effective dose equivalent with an outdoor occupancy of 20% and 80% for indoors (UNSCEAR, 1993).

The annual effective doses were determined as follows:

$$\text{Indoor (nSv)} = \text{(Absorbed dose) nGyh}^{-1} \times 8760\ \text{h} \times 0.8 \times 0.7\ \text{SvGy}^{-1}. \quad (5)$$

$$\text{Outdoor (nSv)} = \text{(Absorbed dose) nGyh}^{-1} \times 8760\ \text{h} \times 0.2 \times 0.7\ \text{SvGy}^{-1}. \quad (6)$$

D. External Hazard Index (H_{ex})

The external hazard index H_{ex} was be calculated by the following equation (Beretka and Mathew, 1985):

$$H_{ex} = A_{Ra} / 370 + A_{Th}/259 + A_k/4810 \quad (7)$$

Where A_{Ra}, A_{Th} and A_K are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in Bqkg^{-1}, respectively. The value of this index must be less than unity in order to keep the radiation hazard to be insignificant. The maximum value of H_{ex} equal to unity corresponds to the upper limit of Ra_{eq} (370Bqkg^{-1}).

In addition to the external hazard, radon and its short-lived products are also hazardous to the respiratory organs. The internal exposure to radon and its daughter products was calculated by the equation: (Beretka and Mathew)

$$H_{in} = (C_{Ra}/185) + (C_{Th} / 259) + (C_k/4810) \quad (8)$$

For the safe use of a material in the construction of dwellings, internal hazard index (H_{in}) should be less unity.

III. RESULT AND DISCUSSION

Activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K of prominent granite samples across Oyo state of Nigeria had been undertaken. Table 1 presents the activity concentrations ranging from 51.45 ± 2.1 to 25.30±2.4 Bqkg^{-1}, 38.26 ±2.4 to17.44 ± 1.3 Bqkg^{-1} and 580.26±2.4 to 104.20±3.5BqKg^{-1} respectively. The natural radionuclide concentration of the samples assayed varied with the colours and the production sites. The mean value of the activity concentration of ^{226}Ra, ^{232}Th and ^{40}K in granite samples from Morlab and Alaguntan quarry sites located in Igbeti is higher than that of Kopek, Igbote and Alaguntan located at Ibadan and Ogbomoso respectively. The mean activity concentrations of primordial radionuclides in all granite samples under test are lower than the most published data. It is important to point out that these value were not the representative values for the country but for the study areas were the samples were collected. Radium equivalent activity, absorbed dose rates and the corresponding external and internal hazard indices due to study area are presented in table 2 and all found within the acceptable limit values by UNSCEAR.

Table 1: Activity concentration of ^{226}Ra, ^{232}Th and ^{40}K in Bq/Kg.

Production site	Number of sample	^{226}Ra	^{232}Th	^{40}K
WESPRO	20	42.33 ± 1.5	17.44±1.3	282.32 ±4.4
KOPEK, IBADAN	20	45.54 ±2.0	38.36 ± 2.4	193.14 ± 2.2
MORLAB, IGBETI	20	51.45 ± 2.1	18.12 ± 1.6	380.96 ±3.4
ALAGUNTAN, IGBETI	20	25.30 ± 2.4	28.01 ± 1.2	432.02 ± 3.6
IRESA, OGBOMOSO	20	29.50 ± 1.1	30.55 ± 1.1	104.20 ± 2.4
IGBO-ILE, OGBOMOSO	20	38.82± 1.82	26.49 ± 1.52	278.52 ± 3.2
MEAN		38.82±1.82	26.50±1.52	278.53± 3.2

TABLE 2: Radium equivalent activity (Ra_{eq}) Absorbed dose rates and the corresponding external and internal hazard indices due to Oyo state granite

QUARRY	Ra_{eq} (Bq/kg)	Absorbed dose rate. nGh^{-1}	Indoor (msv)	Outdoor (msv)	H_{ex}	H_{in}
WESPRO	87.03± 0.1	42.06±2.6	0.21	0.52	0.24	0.35
KOPEK, IBADAN	113.07± 1.6	52.20±1.9	0.26	0.65	0.31	0.43
MORLAB, IGBETI	104.07± 0.2	50.14±3.1	0.25	0.63	0.29	0.43
ALAGUNTAN	95.06±1.3	46.05 ±1.8	0.23	0.58	0.27	0.33
IRESA, IGBETI	80.02± 0.7	36.38±1.6	0.18	0.45	0.22	0.33
IGBO-ILE	96.15± 0.9	45.99 ±2.4	0.23	0.56	0.27	0.37

IV. CONCLUSION

This study has presented the results of measured activity concentration of granite samples from prominent quarry sites across Oyo state of Nigeria. The measurement was carried out using NaI(TI) detector . The measured value of the activities concentration of ^{226}Ra, ^{232}Th and ^{40}K in the samples were found in the range of 25.30 ± 2.4 to 51.45 ± 2.1Bqkg^{-1}, 17.44±1.3 to 38.36±2.4Bqkg^{-1} and 104.20±204 to 432.02±3.6Bqkg^{-1} respectively. The natural radionuclide concentration varied with colour and production site. The mean values of the activity concentration of ^{226}Ra, ^{232}Th and ^{40}K in samples of granite collected from Igbeti were higher than those in Ibadan and Ogbomoso. The values of absorbed dose rates, Radium equivalent, indoor, and there equivalent external and internal hazard index were all found below world accepted values by the regulatory body as presented in table 2 Hence none of the studied samples is considered a radiological hazard and granites can be safely used in construction without posing any significant radiological threat to dwelling population.

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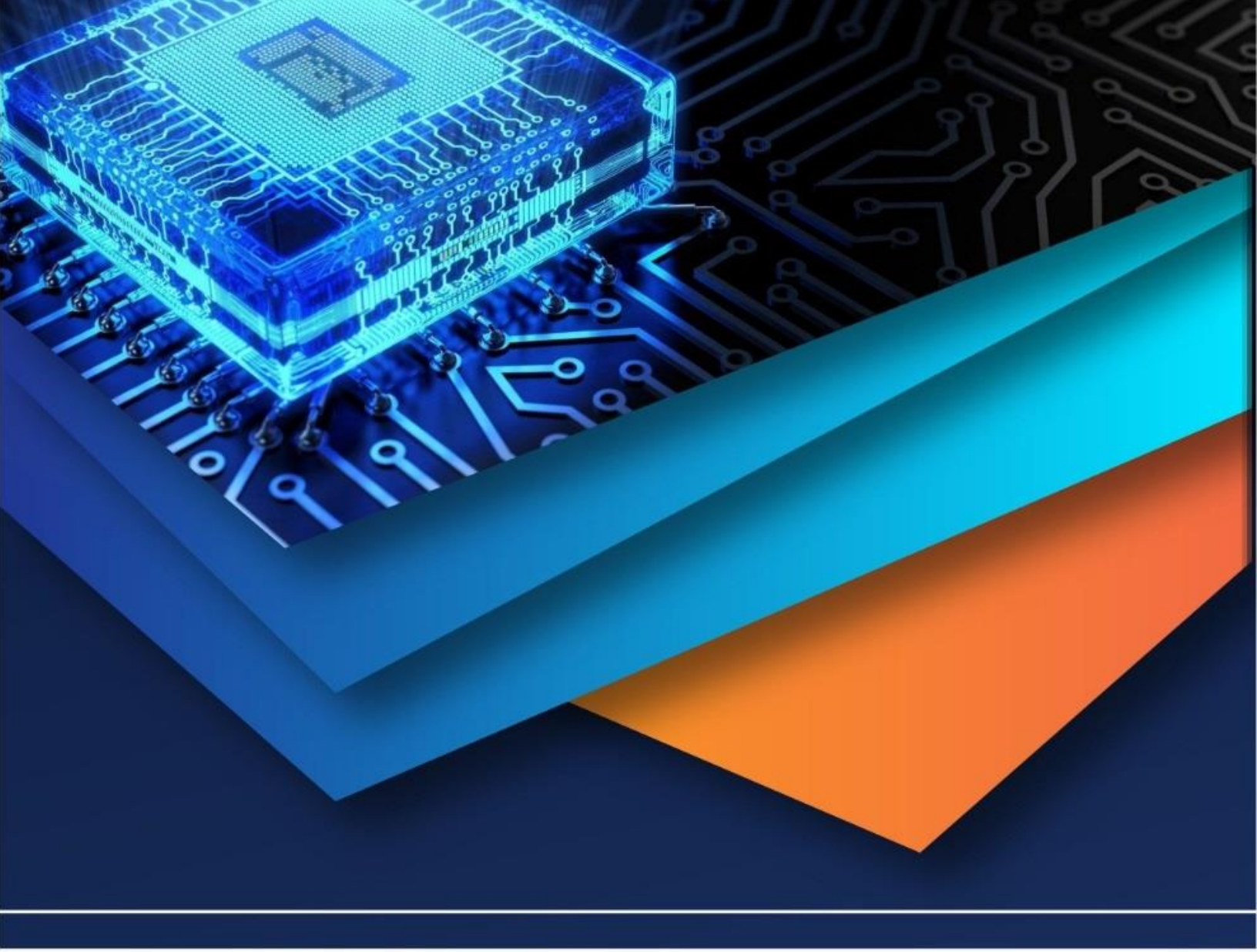

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