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Natural Radioactivity Levels in Rocks from Ogun State, Nigeria

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Abstract: Natural radioactivity levels of 232Th, 238U and 40K in rock samples collected from selected locations in Ogun State was determined using NaI (Tl) detector. The mean radioactivity levels of 232Th, 238U and 40K were found to be 16.26, 11.34 and 60.81 Bqkg-$_1$, respectively. The mean values of the absorbed dose rate, annual effective dose, outdoor radiation index , indoor radiation index. Radium equivalent for the area under study were determined as 26.96 nGyh-1, 0.16 mSvy-1 and 67.11 Bqkg-$_1$, respectively. The health hazards index obtained are well below unity. The hazard parameters estimated in all the locations are within the safe limit for general public background radiation. Thus, the samples are fit for building and construction purposes without exposing the dwellers to any radiation burden.

Key words: Natural radioactivity, hazard index, rocks, radiological parameters, Ogun State

INTRODUCTION

Rock is a solid; it has more than one component of a mineraloid or mineral. There are three fundamental classes of rocks which are; igneous rocks, sedimentary rocks and metamorphic rocks. They are classified accordance to their origin. Igneous rocks are formed from the cooling bodies of magma. These latter goes through weathering processes which erode these rocks and the resulting particles or chemicals settle into beds, compressed and cemented into what is called sedimentary rocks. Also, if these rocks are heated, buried and strongly compressed metamorphic rocks will be formed. Upon continuous heating of these rocks and compression to the point of melting, then igneous rock might be formed from the molten rock. This is called the rock cycle. Complete circle is obtained as one rock can be transformed into another.

Radionuclides with long half-lives or their corresponding decay products existing in terrestrial material such as ^{232}Th, ^{238}U and ^{40}K are of upmost important. These radionuclides are not equally spread, the knowledge and understanding of their spread in soil and rock play a vital role in radiation protection and measurement (Tso and Leung, 2000). Radiation levels from these materials form the chief source of external irradiation to the human body (Usikalu *et al*., 2015; Tzortzis *et al*., 2004; Najam *et al*., 2015; Al Mugren, 2015). Therefore, radionuclides concentration in rock form a vital part of the natural background radiation exposure to human population (Usikalu *et al*., 2014; Gbadebo, 2011). Hence, this work aim is to measure the natural radioactivity and estimate the annual effective, absorbed doses and health hazards index due to the radionuclides in rocks obtained from Ogun State, Nigeria.

MATERIALS AND METHODS

Ogun state is situated in Southwest Nigeria, it has a tropical climate with two distinct seasons; wet season and dry season of about 130 day. It has a population of about 3,751,140 people as at 2006 census and has twenty local government headquarters. Ogun State has two fundamental rock sorts. These are the storm cellar complex rocks of the Precambrian age which are comprised of the more seasoned and more youthful stones in the northern parts of the state.

The geography of Ogun State embodies sedimentary rocks which underlie roughly three-quarter of the entire surface zone of the state extending from the northwest to the southeast and Basement complex rocks which underlie the staying one-quarter of the surface of the state (Okedeyi *et al*., 2012).

At each location groups of five different rock samples were taken for better sampling. They were kept in ziplock bags and labeled accordingly making a total of one hundred (90) samples from all the locations. The samples were pulverized, oven-dried at 110°C to ensure complete removal of moisture and passed through a 2 mm sieve. Total 100 g of each sample were placed in radon tight plastic of 9 cm diameter vessels with a total capacity of 300 cm^3. The containers were weighted and sealed with sealant for about 30 days so as to allow the daughter of ^{238}U and ^{232}. Th attain secular equilibrium (Myrick *et al*., 1983).

The radiometric system consists of a 7.6×7.6 cm Nal (Tl) scintillation detector which encapsulated in a 5 cm

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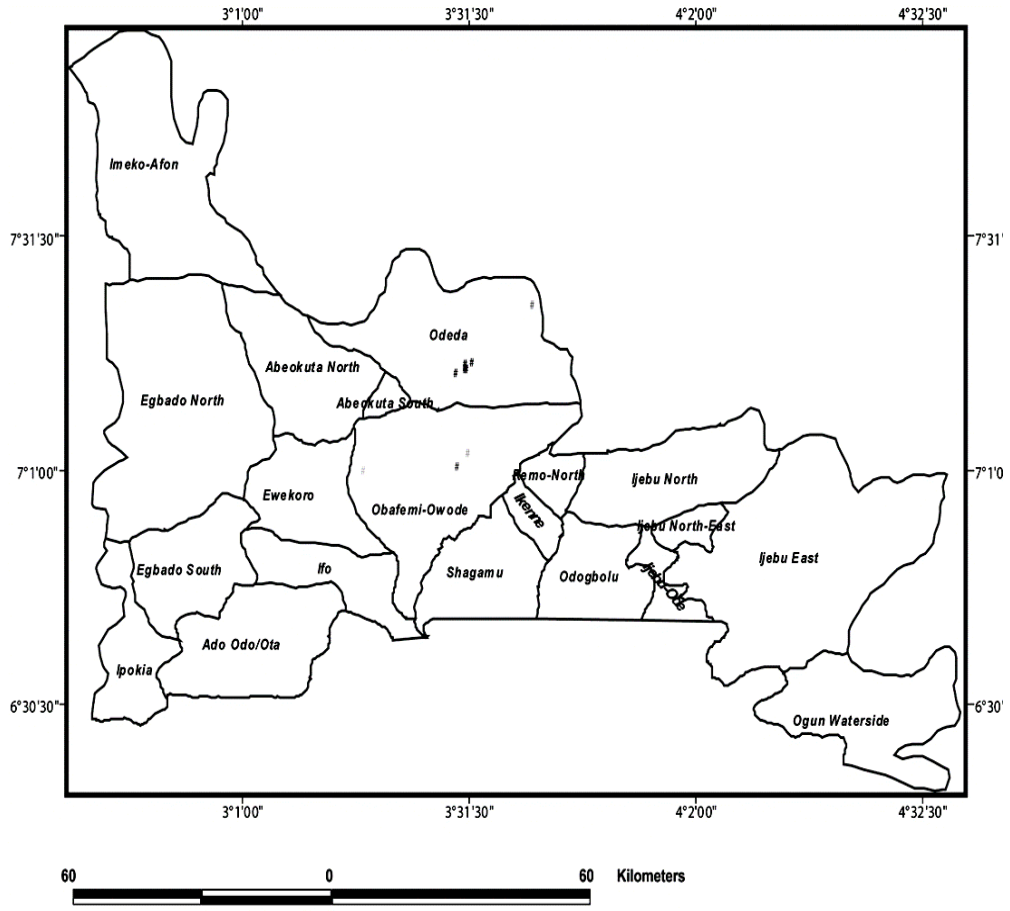

Fig. 1: Map of study area

thick lead shielded material. This is couple to a set of preamplifier and Analog-to-Digital Converter (ADC) bring out an output through a Canberra S100 Multi-Channel Analyzer (MCA) using a spectrum analysis program called SAMPO 90. The detector efficiency was about 20% and the calibration was obtained using an IAEA-375 (IAEA, 1989) reference sample supplied by the national institute of radiation protection and research. The reference sample container has same geometry with that used for each for background and standard measurement.

The counting time for each sample is about 36,000 sec for quality and good statistics. The gamma ray spectroscopy analysis adopted in that work was used by several researchers (Olomo *et al*., 1994; Ajayi and Ajayi, 1999; Jibiri *et al*., 1999; Iqbal *et al*., 2000). The photo peak used to identify ^{40}K was at 1,461 KeV, while those for ^{238}U were ^{214}Bi at 1,764 and 609.3 KeV and for ^{232}Th, ^{288}Ac and ^{208}Ti at 911.0 and 583.5 keV, respectively (Fig. 1).

RESULTS AND DISCUSSION

The average radioactivity levels measured in the rocks collected from the study area are 16.26, 11.34 and 60.81 Bqkg^{-1} for^{232}Th, ^{238}U and ^{40}K, respectively. The radionuclides are not evenly spread due to the difference in geological formation of the rocks and the geology of these areas. The highest level of thorium was obtained from the rocks collected from Ijebu East while the highest level of uranium was obtained from samples from Odogbolu. The highest level of potassium was gotten from samples from Odeda this is in consonance with the results obtained from the soil collected from these areas (Usikalu *et al*., 2014). This could be one of the reasons why Odeda has good farm yield because of the high level of potassium found in the area. The results presented here are within the limit of the average concentration of these radionuclides (UNSCEAR, 2000).

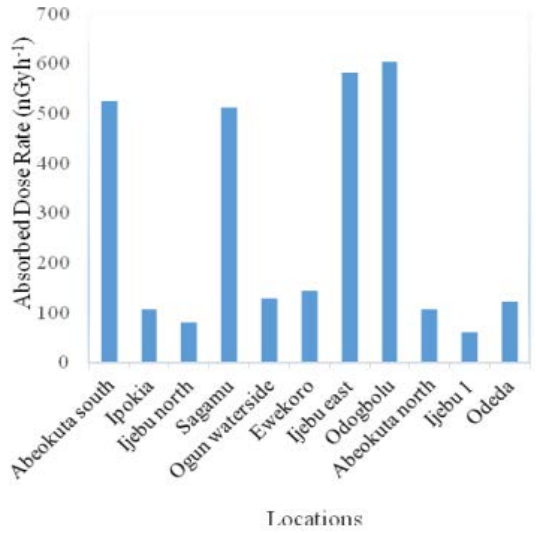

Fig. 2: Variation of absorbed dose rate

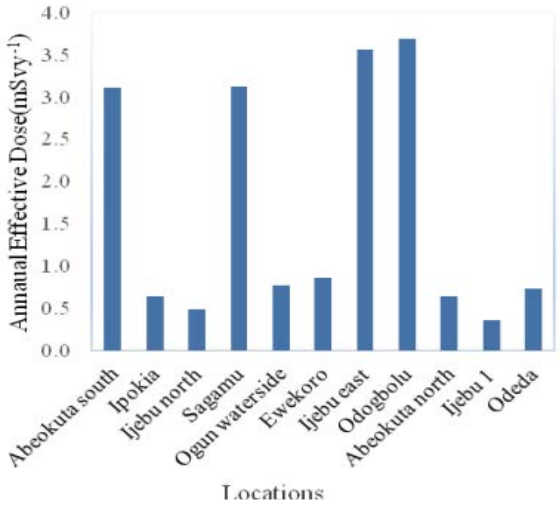

Fig. 3: Variation of the Annual effective dose

The absorbed Dose rate (D) was estimated using the conversion factor of published by the UNSCEAR (1988) and Eq. 1 (ICRP-60, 1991):

$$D = (6.62A_{Th} + 4.27A_{U} + 0.43A_{K}) \times 10^{-10} Gyh^{-1}$$

where the coefficient A_{Th}, A_{U} and A_{K} are the average activity concentration of thorium, uranium and potassium respectively. The absorbed dose calculated for study areas is shown column 1 of Table 1. It is displayed pictorially in Fig. 2 with Odogbolu having the highest absorbed dose rate. The estimated value for the dose rate is comparable with the recommended safe limit.

The effective dose equivalent was obtained so as to determine what would be received by the public residing in the area due to activity in the rocks, the annual effective dose was calculated using Eq. 2:

$$E_{air} = TQD \times 10^{-6}$$

The D is the absorbed dose rate in air, Q is the conversion factor which is 0.7 Sv Gy^{-1} and this is the factor that translates the absorbed dose to human effective dose in adults, T the duration in hours for 1 year, i.e., 8,760 h. The annual effective dose calculated for all samples are shown in Table 1 and displayed in Fig.3 with Odogbolu having the highest annual effective dose. The annual effective doses obtained vary between 0.036 and 0.37 $mSvy^{-1}$ with a mean value of 0.16 mSv. This value is lower than the recommended limit for normal background radiation (ICRP-60, 1991).

The radium equivalent activity was estimated in order to compare the specific activities of materials containing different amount of uranium, thorium and potassium. The index is calculated using Eq. 3:

$$Ra_{eq} = A_{Ra} + 1.43A_{Th} + 0.07A_{k}$$

where, A_{ra}, A_{th} and A_{k} are the activities of ^{238}U, ^{232}Th and ^{40}K, respectively in $Bqkg^{-1}$. The Ra_{eq} estimated range between 14.08 and 141.08 $Bqkg^{-1}$ with an average value of 67.11 $Bqkg^{-1}$. This is also lower that the 300 $Bqkg^{-1}$ recommended limit given for background radiation (UNSCEAR, 1988).

The radiation hazards due to naturally occurring radionuclides may be indoor or outdoor depending on the location of the receptor. H_i and H_o stand for the radiation hazard index which is obtained in relation whether the radiation is indoor or outdoor. They were computed using Eq. 4 (Xinwei *et al*., 2006):

$$H_i = \frac{C_{Th}}{259} + \frac{C_{Ra}}{185} + \frac{C_K}{4810}$$

$$H_o = \frac{C_{Th}}{259} + \frac{C_{Ra}}{370} + \frac{C_K}{4810}$$

The C_{ra}, C_{Th} and C_K is the concentrations of ^{238}U, ^{232}Th and ^{40}K, respectively. The indoor hazard index was estimated in order to find the radiation hazard that could be done to respiratory systems due to ^{222}Rn (daughter of ^{226}Ra) and its other short-lived decay products. The values obtained for H_i and H_o in this study was found to be less than unity as shown in Table 1. This suggests that there is no potential indoor or outdoor radiation hazard that could arise due to usage of these samples.

Table 1: Estimated radiological parameters in the rocks samples

Locations	Absorbed dose rate ($nGyh^{-1}$)	Annual effective dose ($mSvy^{-1}$)	Outdoor radiation index	Indoor radiation index	Radium equivalent ($Bqkg^{-1}$)
Abeokuta South	52.49	0.310	0.360	0.36	114.77
Ipokia	10.58	0.640	0.060	0.06	22.85
Ijebu North	8.04	0.490	0.050	0.05	20.31
Sagamu	51.07	0.310	0.320	0.32	119.09
Ogun Waterside	12.77	0.780	0.080	0.08	30.19
Ewekoro	14.29	0.870	0.190	0.19	37.72
Ijebu East	58.22	0.360	0.360	0.36	134.80
Odogbolu	60.24	0.370	0.380	0.76	141.08
Abeokuta North	10.72	0.070	0.110	0.13	40.37
Ijebu 1	6.01	0.040	0.030	0.07	14.08
Odeda	12.17	0.080	0.180	0.18	63.02
Minimum	6.01	0.037	0.003	0.05	14.08
Maximum	60.24	0.370	0.380	0.76	141.08
Average	26.96	0.160	0.160	0.23	67.11

CONCLUSION

The natural activity concentrations of rock samples collected from selected locations in Ogun state, Nigeria has been determined using NaI (Tl) detector. The mean activity measured, the estimated absorbed dose, the annual dose equivalent and the health hazard index were within the recommended limit for normal background radiation. On the basis of our results, we conclude that the rock samples are good for building and construction purposes. Therefore, the samples do not pose any radiological health hazard to the public living and working with the samples.

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