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Determination of the radiological risk associated with naturally occurring radioactive materials (NORMS) in quarry products from quarries in Ekiti and Ogun states, Southwestern Nigeria

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Abstract
The radiological risk of quarry activities on workers and residency due to the presence of naturally occurring radionuclides in quarries products samples collected from quarries in Ekiti and Ogun States, Southwestern Nigeria using gamma ray spectroscopy, NaI (Tl) for its analysis had been carried out. The calculated activity concentrations ranged as presented for Ekiti State; ^{238}U [32.10 ± 2.18] to [5.48 ± 0.89] Bq/kg; ^{232}Th [(15.09 ± 1.32) to (3.92 ± 0.53) Bq/kg and ^{40}K [(512.38 ± 10.21) Bq/kg to (264.31 ± 3.38) Bq/kg, for Ogun State; ^{238}U [32.71 ± 2.03] to [6.02 ± 0.92] Bq/kg; ^{232}Th [(15.17 ± 2.01) to (4.21 ± 0.42) Bq/kg and ^{40}K [(518.23 ± 9.56) Bq/kg to (286.42 ± 4.48) Bq/kg respectively. The absorbed dose rate and annual effective dose equivalent and the radiological hazard index were estimated using the calculated activities concentration of the radionuclides. The mean absorbed dose rate and annual equivalent effective dose are 12.29 ± 2.31 nGy/h and 0.141 mSv/y respectively. The result shown that the activity concentration of ^{40}K is slightly greater than both ^{238}U and ^{232}Th which indicate the abundance of potassium in the study areas. It was also observed that the activity concentrations of all the radionuclides and the determined radiological hazard index of the product samples were found lower than the recommended permissible safety limits of 420 Bq/kg, 33 Bq/kg and 45 Bq/kg for ^{40}K, ^{238}U and ^{232}Th respectively.

Keywords: Radionuclides, quarry products, activity concentrations, Southwestern Nigeria, and radioactivity

Introduction

There is a great interest in the study of natural environmental radiation and radioactivity in soil due to population exposure to natural radioactivity at different levels depending on natural radioactive minerals present in a particular region (Akhtar *et al.*, 2005) [14]. The knowledge of natural radionuclides concentration levels and their distribution in the environment is of great interest in several fields of science, this distribution of external exposure due to terrestrial radiation in a giving place depends on the geographical characteristics of that place (Isola and Oni, 2015) [7]. High geochemical mobility of radionuclides in the environment allows them to move easily and contaminate much of the environment that humans come in contact with (El-Aydarous, 2007) [15]. Radiation exposure as a result of building materials has been divided into internal and external radiation exposure. This is because building materials have been found to contain various amounts of natural radioactive nuclides. Therefore, radiation is inescapable phenomenon on earth which had always been an integral part of human environment (Isola *et al.*, 2025).

Radionuclides such as ^{40}K, the decay series of ^{232}Th, and ^{238}U, constitute mainly the natural radionuclides which is found nearly everywhere in soil, water, and rock (Tzortzis and Tsertos, 2004) [12]. Hence, the knowledge of their distribution in soil plays an important role in radiation protection and the understanding of the decay chain where series of stepwise decay in terms of half-lives of nuclei of unstable in form of radionuclides lead to stable states in form of other nuclei which is so important. Alpha (α) and beta (β) particles are given off while gamma (γ) radiation is emitted. High levels of uranium and thorium and their decay series in rock and soil are the main sources of high background radiation. These rocks are generally widespread in various geological environments (Chang *et al.*, 2008) [4]. Therefore, there is a continuous bombardment of human and his environment by these radionuclides, which is the most significant part of the total exposure to radiation (Eke *et al.*, 2024).

The long-term exposure to uranium and radium through inhalation has several health effects such as acute leucopoenia, lung diseases and anaemia. Radium causes cranial, nasal tumours and bone marrow. Thorium exposure can cause leukaemia, kidney, bone and lung cancers. Therefore, gamma dose rates and radionuclides activity concentrations should be monitored due to their health implications. Besides, since radiation cannot be felt by the human sense organs, it is important that the total amount of radiation emitting-NORMs in a particular area is known and kept to a very minimal level in order to safeguard the live of the people and ensure radiation pollution free environment. The evaluation of the radiation hazards of these radionuclides to the human population and estimation of radiological hazard parameters is required for radiation protection and assessment because quarry products are widely used as building and construction materials all over the world.

These products may be a source of external and internal exposure of ionizing radiations to the quarry workers, products end-users or people dwelling in buildings built with the products. Though, the distribution of these radionuclides in quarry products is not uniform (Avwiri, 2005) [2]. Therefore, this study aimed to determine the radiological risk associated with naturally occurring radioactive materials resulting from prominent quarries in Ekiti and Ogun States, Southwestern Nigeria.

Materials and Methods

Study Areas

The study was carried out in Ekiti and Ogun States, southwestern geopolitical zone of Nigeria. Ekiti State lies between longitudes 4° 45' and 5° 50' E of the Greenwich Meridian and latitudes 7° 15' and 8° 10' N of the Equator (Bayowa *et al.*, 2014) [3] while Ogun State lies between longitudes 3° and 5° E of the Greenwich Meridian, latitudes 6.5° and 9° N of the Equator. The two States fall entirely in the tropics.

Samples Collection

A total number of 30 quarry product samples were collected from quarries in Ekiti and Ogun States, Southwestern Nigeria. The collected samples were labeled at the point of collection and were put in the polythene bags and then transported to the laboratory for further processing. The samples were coded in order to prevent identification error. Two alphabets and a number to connote the study areas where, the samples were collected. For instance, OG indicates samples from Ogun State, while EK stand for samples collected from Ekiti State.

Samples Preparation and Analysis

The collected samples were air dried at room temperature in the laboratory. The rock-lab ring mill at the Department of Earth Science, Ajayi Crowther University, Oyo, State, Nigeria was used to crush and pulverize the samples to powdery form and were filled into plastic containers then sealed hermetically with the aid of PVC tape to prevent the escape of progeny from the samples. The samples were weighed 200g and kept for 28 days prior to measurement in order to attain radioactive secular equilibrium between ^{226}Ra and ^{228}Ac and their short-lived progeny. After the secular equilibrium was attained, each sample was then analyzed for 18000 s using the gamma ray spectroscopy, NaI (Tl) facilities at the Radiation and Health Physics Laboratory, Department of Pure and Applied Physics, Ladoke Akintola University of Technology, Ogbomoso, Oyo State, Nigeria.

Radioactivity Concentration

The activities concentrations of the natural radionuclides (^{40}K, ^{238}U, and ^{232}Th) were determined using Equation (1) (Tzortzis *et al.*, 2003) [11]:

$$A\ (\text{Bq/kg}) = \frac{N_{sam}}{M \cdot \gamma_{E} \cdot \epsilon \cdot T_{c}} \qquad (1)$$

Where N_{sam} = net counts of the radionuclide present in the sample,

γ_{E} = gamma yield (gamma-ray emission probability), ε = total counting efficiency of the detector system, T_c = sample counting time and M = mass of sample (kg).

Radiological Parameters

The radiological parameters such as ADR, AEDE, Ra_{eq}, H_{int} and H_{ext} are determined as presented below

Absorbed Dose Rate in Air (ADR)

The gamma absorbed dose rate in the air at 1.0 m above the ground surface was calculated using Equation (2) (UNSCEAR, 2010) [13]

$$ADR\ (\text{nGy/h}) = 0.462\ C_U + 0.604\ C_{Th} + 0.0417\ C_K \qquad (2)$$

Where C_U, C_{Th}, and C_K are the radioactivity concentrations of ^{238}U, ^{232}Th, and ^{40}K, respectively.

Indoor Annual Effective Dose Equivalent ($AEDE_{indoor}$)

The absorbed dose rate in the air at about 1.0 m above the ground surface does not directly provide the radiological hazard to which an individual is exposed (Jibiri *et al.*, 2007). Using an indoor occupancy factor of 0.8 and conversion factor of 0.7 Sv/Gy, the AEDE due to terrestrial gamma radiation was calculated using Equation (3) (Ajayi ,2002) [1]:

$$AEDE_{indoor}\ (\text{mSv/y}) = DR\ (\text{nGy/h}) \times 8760\text{h} \times 0.8 \times 0.7(\text{Sv/Gy}) \times 10^{-6} \qquad (3)$$

Radium Equivalent Activity (Ra_{eq})

The distribution of ^{238}U, ^{232}Th, and ^{40}K in quarry products is not uniform (Avwiri, 2005) [2]. Uniformity with respect to the exposure to radiation has been defined in terms of Ra_{eq} which is a single quantity that compares the activity concentrations of the radionuclides in the quarry products samples in order to obtain a total or net activity concentration using Equation 4 (Shittu *et al.*, 2015) [10].

$$Ra_{eq}\ (\text{Bq/kg}) = C_U + 1.430\ C_{Th} + 0.077\ C_K \qquad (4)$$

Where C_U, C_{Th}, and C_K are the radioactivity concentrations of ^{238}U, ^{232}Th, and ^{40}K in the quarry products samples respectively.

Internal Hazard Index (H_{int})

Radon and its progenies pose radiological hazards to the respiratory organs. Therefore, the internal exposure to radon and its progenies are quantified by the H_{int} given by Equation (5) (Jegede *et al.*, 2019) [9]

$$H_{int}\ (\text{Bq/kg}) = \frac{C_K}{4810} + \frac{C_U}{185} + \frac{C_{Th}}{259} \qquad (5)$$

Where C_K, C_U, and C_{Th}, are the activity concentrations of ^{40}K, ^{238}U, and ^{232}Th, respectively.

External Hazard Index (H_{ext})

Radiation hazard incurred due to external exposure to gamma rays is quantified in terms of the external hazard index. The maximum permissible value for this index is unity (Essien *et al.*, 2017) [5]. This was estimated by Equation (6) (Jegede *et al.*, 2019) [9].

$$H_{ext}\ (\text{Bq/kg}) = \frac{A_U}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \qquad (6)$$

Where A_u, A_{Th}, and A_K are the radioactivity concentrations of ^{238}U, ^{232}Th and ^{40}K, respectively.

Results and Discussion

Radioactivity Concentrations of the Natural Radionuclides

Table 1 and Table 2 presents the radioactivity concentrations of the three natural radionuclides present in the samples in the two states of Ekiti and Ogun, activity concentration of the radionuclides ^{238}U, ^{232}Th and ^{40}K assayed ranged from [32.10 ± 2.18] to [5.48 ± 0.89] Bq/kg; [(15.09 ± 1.32) to (3.92 ± 0.53) Bq/kg and [(512.38 ± 10.21) Bq/kg to (264.31 ± 3.38) Bq/kg, for Ogun State; [32.71 ± 2.03] to [6.02 ± 0.92] Bq/kg; [(15.17 ± 2.01) to (4.21 ± 0.42) Bq/kg and [(518.23 ± 9.56) Bq/kg to (286.42 ± 4.48) Bq/kg respectively, with the mean values of 14.24 ± 1.62

Bq/kg, 8.80 ± 1.12 Bq/kg, and 394.94 ± 6.94 Bq/k for Ekiti State, and 14.77 ± 1.42 Bq/kg, 9.54 ± 1.14 Bq/kg, and 403.46 ± 6.87 Bq/k for Ogun State respectively. The results were found below permissible values of 33 Bq/kg for ^{238}U, 45 Bq/kg for ^{232}Th, and 420 Bq/kg for ^{40}K (UNSCEAR, 2010) [13].

Table 1: Activity Concentrations of Quarry Samples from Ekiti State

SAMPLE ID	U-238 (Bq/kg)	Th-232 (Bq/kg)	K-40 (Bq/kg)
EK 1	17.35 ± 1.35	10.24 ± 1.23	489.25 ± 8.36
EK 2	21.09 ± 1.17	8.23 ± 1.12	512.38 ± 10.21
EK 3	32.10 ± 2.18	10.46 ± 1.06	482.24 ± 9.32
EK 4	25.38 ± 2.15	14.58 ± 1.67	518.12 ± 13.12
EK 5	18.32 ± 1.85	8.15 ± 1.03	492.32 ± 10.92
EK 6	22.15 ± 2.10	15.09 ± 1.32	468.13 ± 10.12
EK 7	19.25 ± 1.03	10.31 ± 1.04	489.25 ± 11.38
EK 8	15.81 ± 2.38	12.12 ± 3.06	415.23 ± 3.28
EK 9	10.16 ± 1.82	5.28 ± 0.85	396.17 ± 2.13
EK 10	8.16 ± 1.03	6.31 ± 1.03	264.31 ± 3.38
EK 11	7.23 ± 1.53	5.27 ± 0.48	302.17 ± 5.18
EK 12	10.56 ± 2.82	12.02 ± 1.54	280.28 ± 4.94
EK 13	8.25 ± 1.35	6.92 ± 0.58	326.16 ± 3.68
EK 14	5.48 ± 0.89	7.28 ± 0.62	282.58 ± 5.92
EK 15	7.83 ± 2.03	3.92 ± 0.53	362.46 ± 5.60
EK 16	6.05 ± 1.03	8.03 ± 1.29	358.15 ± 6.32
EK 17	6.83 ± 3.05	5.46 ± 0.59	274.96 ± 4.15
Range	32.10 ± 2.18 5.48 ± 0.89	15.09 ± 1.32 3.92 ± 0.53	512.38 ± 10.21 264.31 ± 3.38
Mean	14.24 ± 1.62	8.80 ± 1.12	394.95 ± 6.94

Table 2: Activity Concentrations of Quarry Samples from Ogun State

SAMPLE ID	U-238 (Bq/kg)	Th-232 (Bq/kg)	K-40 (Bq/kg)
OG 1	26.23 ± 2.03	15.17 ± 2.01	581.23 ± 9.56
OG 2	17.35 ± 1.58	12.24 ± 1.22	525.45 ± 10.01
OG 3	26.24 ± 1.25	13.58 ± 1.23	542.56 ± 7.39
OG 4	15.18 ± 1.28	10.25 ± 1.27	489.67 ± 6.29
OG 5	32.71 ± 2.03	12.26 ± 1.23	420.41 ± 8.45
OG 6	18.34 ± 2.07	7.56 ± 0.79	502.34 ± 10.26
OG 7	10.12 ± 1.28	12.04 ± 1.38	356.12 ± 5.28
OG 8	8.26 ± 1.04	5.36 ± 0.70	289.30 ± 2.15
OG 9	10.84 ± 1.58	6.21 ± 1.06	301.28 ± 4.36
OG 10	6.02 ± 0.92	4.31 ± 0.36	296.97 ± 8.78
OG 11	7.06 ± 0.39	5.82 ± 0.53	302.14 ± 7.83
OG 12	7.35 ± 1.21	15.03 ± 2.56	351.13 ± 4.48
OG 13	6.35 ± 1.78	4.21 ± 0.42	286.42 ± 4.48
Range	32.71 ± 2.03 6.02 ± 0.92	15.17 ± 2.01 4.21 ± 0.42	581.23 ± 9.56 286.42 ± 4.48
Mean	14.77 ± 1.42	9.54 ± 1.14	403.46 ± 6.87

Absorbed Dose Rate in Air (DR)

The absorbed dose rate values varied from 42.137 ± 2.549 to 17.919 ± 1.939 nGy/h and 42.950 ± 1.63 to 17.420 ± 1.263 nGy/h for Ekiti and Ogun States respectively, with mean values of 28.363 ± 1.775 nGy/h and 29.413 ± 1.628 nGy/h as presented in Table 3 and Table 4. The calculated mean values of ADR are below the recommended limit of 84 nGy/h (UNSCEAR, 2008). Hence, the emitted radiations from natural radionuclides present in the products do not pose any significant radiological hazards.

Annual Effective Dose Equivalent ($AEDE_{indoor}$)

The estimated values of Indoor Annual Effective Dose Equivalent ranged from 0.207 ± 0.013 to 0.088 ± 0.010 mSv/y and 0.211 ± 0.008 to 0.085 ± 0.006 mSv/y for both states respectively with mean values of 0.139 ± 0.009 mSv/y and 0.144 ± 0.008 mSv/y. These mean values are below the world average value of 1 mSv/y (ICRP, 2010). This implies low level of hazard in terms of radiological assessment.

Radium Equivalent Activity Index (Ra_{eq})

The calculated values of Ra_{eq} ranged from 86.125 ± 5.548 to 35.810 ± 4.213 Bq/kg and 87.437 ± 3.578 to 34.425 ± 2.726 Bq/kg for Ekiti and Ogun States respectively with mean values of 57.234 ± 3.887 Bq/kg and 59.484 ± 3.571 Bq/kg which are lower than the safety limit of 370 Bq/kg (UNSCEAR, 2008). The implication of this result is that the products are safe for use from the radiological protection point of view.

Internal Hazard Index (H_{int})

Estimated values of H_{int} ranged from 0.314 ± 0.018 to 0.115 ± 0.020 Bq/kg and 0.307 ± 0.013 to 0.110 ± 0.012 Bq/kg respectively for the two states with average values of 0.193 ± 0.015 Bq/kg and 0.161 ± 0.10 Bq/kg which are lower than the safety limit of one (Essien *et al.*, 2017) [5], which implies that quarry workers, products end-users and the public dwelling in buildings built with the materials will not experience any significant radiological hazard.

External Hazard Index (H_{ext})

The estimated external hazard values are between 0.233 ± 0.015 to 0.097 ± 0.011 Bq/kg and 0.236 ± 0.010 to 0.093 ± 0.007 Bq/kg with average values of 0.155 ± 0.105 Bq/kg and 0.161 ± 0.10 Bq/kg which are lower than the recommended value reported by ICRP in 2010. Thus, the radiation hazard from external exposure of quarry workers, quarry products end-users and the dwellers in buildings constructed with these materials is low.

Table 3: Estimated Results of Radiological Parameters of Ekiti State

Sample Id	ADR (nGy/h)	AEDE (mSv/y)	Ra_{eq} (Bq/kg)	H_{in} (Bq/kg)	H_{ext} (Bq/kg)
EK 1	34.602 ± 1.715	0.170 ± 0.008	69.665 ± 3.753	0.235 ± 0.014	0.188 ± 0.010
EK 2	36.081 ± 1. 643	0.177 ± 0.008	72.312 ± 3.558	0.252 ± 0.013	0.195 ± 0.010
EK 3	41.257 ± 2.036	0.202 ± 0.010	84.190 ± 4.413	0.314 ± 0.018	0.227 ± 0.001
EK 4	42.137 ± 2.549	0.207 ± 0.013	86.125 ± 5.548	0.301 ± 0.021	0.233 ± 0.015
EK 5	33.916 ± 1.932	0.166 ± 0.009	67.883 ± 4.164	0.233 ± 0.016	0.183 ± 0.011
EK 6	38.869 ± 2.189	0.191 ± 0.011	79.775 ± 4.767	0.275 ± 0.019	0.215 ± 0.013
EK 7	35.522 ± 1.579	0.174 ± 0.008	71.666 ± 3.393	0.246 ± 0.012	0.194 ± 0.009
EK 8	31.940 ± 3.085	0.157 ± 0.015	65.114 ± 7.008	0.219 ± 0.025	0.176 ± 0.019
EK 9	24.403 ± 1.443	0.120 ± 0.007	48.215 ± 3.200	0.158 ± 0.014	0.130 ± 0.009
EK 10	18.603 ± 1.239	0.091 ± 0.006	37.535 ± 2.763	0.123 ± 0.010	0.101 ± 0.007
EK 11	19.124 ± 1.213	0.094 ± 0.006	38.033 ± 2.615	0.122 ± 0.011	0.103 ± 0.007
EK 12	23.826 ± 2.439	0.117 ± 0.012	49.330 ± 5.403	0.162 ± 0.022	0.133 ± 0.015
EK 13	21.592 ± 1.127	0.106 ± 0.006	43.260 ± 2.463	0.139 ± 0.010	0.117 ± 0.007

EK 14	18.712 ± 1.033	0.092 ± 0.005	37.649 ± 2.232	0.116 ± 0.008	0.102 ± 0.006
EK 15	21.100 ± 1.492	0.104 ± 0.007	41.345 ± 3.219	0.133 ± 0.014	0.112 ± 0.009
EK 16	22.562 ± 1.519	0.111 ± 0.007	45.068 ± 3.361	0.138 ± 0.011	0.122 ± 0.009
EK 17	17.919 ± 1.939	0.088 ± 0.010	35.810 ± 4.213	0.115 ± 0.020	0.097 ± 0.011
Range	42.137 ± 2.549 17.919 ± 1.939	0.207 ± 0.013 0.088 ± 0.010	86.125 ± 5.548 35.810 ± 4.213	0.314 ± 0.018 0.115 ± 0.020	0.233 ± 0.015 0.097 ± 0.011
Mean	28.363 ± 1.775	0.139 ± 0.009	57.234 ± 3.887	0.193 ± 0.015	0.155 ± 0.105

Table 4: Estimated Results of Radiological Parameters of Ogun State

Sample Id	ADR (nGy/h)	AEDE (mSv/y)	Ra_{eq} (Bq/kg)	H_{in} (Bq/kg)	H_{ext} (Bq/kg)
OG 1	45.518 ± 2.551	0.223 ± 0.013	92.678 ± 5.640	0.321 ± 0.021	0.250 ± 0.015
OG 2	37.320 ± 1.884	0.183 ± 0.009	75.313 ± 4.095	0.250 ± 0.015	0.203 ± 0.011
OG 3	42.950 ± 1.63	0.211 ± 0.008	87.437 ± 3.578	0.307 ± 0.013	0.236 ± 0.010
OG 4	33.623 ± 1.621	0.165 ± 0.008	67.542 ± 3.580	0.223 ± 0.013	0.182 ± 0.010
OG 5	40.048 ± 2.033	0.196 ± 0.010	82.613 ± 4.440	0.312 ± 0.017	0.223 ± 0.012
OG 6	33.987 ± 1.861	0.167 ± 0.009	67.831 ± 3.990	0.233 ± 0.016	0.183 ± 0.011
OG 7	26.798 ± 1.645	0.131 ± 0.008	54.758 ± 3.660	0.175 ± 0.013	0.148 ± 0.010
OG 8	19.117 ± 0.993	0.094 ± 0.005	38.201 ± 2.207	0.125 ± 0.008	0.103 ± 0.006
OG 9	21.322 ± 1.552	0.105 ± 0.008	42.919 ± 3.431	0.145 ± 0.014	0.116 ± 0.009
OG 10	17.768 ± 1.009	0.087 ± 0.005	35.050 ± 2.111	0.111 ± 0.008	0.095 ± 0.006
OG 11	19.376 ± 0.827	0.095 ± 0.004	38.647 ± 1.751	0.123 ± 0.006	0.104 ± 0.005
OG 12	27.116 ± 2.292	0.133 ± 0.011	55.880 ± 5.216	0.171 ± 0.017	0.151 ± 0.014
OG 13	17.420 ± 1.263	0.085 ± 0.006	34.425 ± 2.726	0.110 ± 0.012	0.093 ± 0.007
Range	42.950 ± 1.63 17.420 ± 1.263	0.211 ± 0.008 0.085 ± 0.006	87.437 ± 3.578 34.425 ± 2.726	0.307 ± 0.013 0.110 ± 0.012	0.236 ± 0.010 0.093 ± 0.007
Mean	29.413 ± 1.628	0.144 ± 0.008	59.484 ± 3.571	0.201 ± 0.013	0.161 ± 0.10

The chart of the radiological parameters of the two states as shown in Figure 1, the mean values of the estimated radionuclide hazards of Ogun State is slightly higher than that of Ekiti State, though the values are below the recommended limit in indicating that the quarry workers, dwellers built with the product samples from quarries are safe.

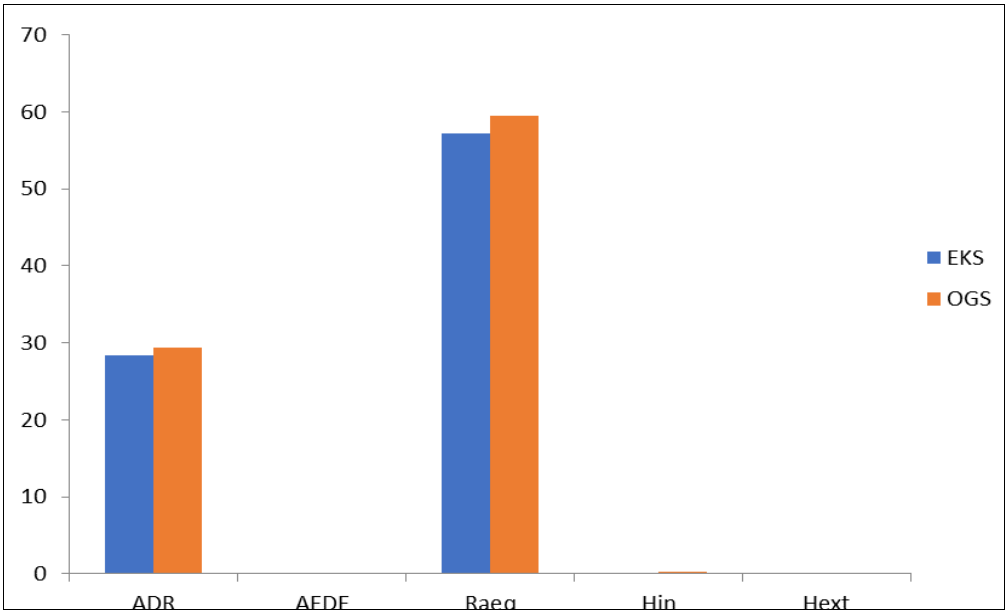

Fig 1: Mean Radiological Parameters for Ekiti and Ogun States

Conclusion

This study has presented the results of the activity concentrations and radiological parameters for samples from Ekiti and Ogun States, Southwestern Nigeria. The obtained results indicated that, samples from the studied areas have activity concentrations of ^{238}U, ^{232}Th and ^{40}K ranging from 32.10 ± 2.18 to 5.48 ± 0.89, 15.09 ± 1.32 to 3.92 ± 0.53 and 512.38 ± 10.21 to 264.31 ± 3.38 Bq/kg; and 32.71 ± 2.03 to 6.02 ± 0.92, 15.17 ± 2.01 to 4.21 ± 0.42 and 581.23 ± 9.56 to 286.42 ± 4.48 Bq/kg as presented. The values of absorbed dose rates in samples ranged from 41.257 ± 2.036 to 17.919 ± 1.939 nGy/h and 45.518 ± 2.551 to 17.420 ± 1.263 nGy/h with mean values of 28.363 ± 1.775 and 29.413 ± 1.628 nGy/h respectively. The annual effective dose equivalent in the air varied from 0.207 ± 0.013 to 0.088 ± 0.010 mSv/y with average values of 0.139 ± 0.009 and 0.144 ± 0.008 mSv/y respectively. The obtained values of natural radioactivity and gamma absorbed dose rates because of the activity concentrations of ^{238}U, ^{232}Th and ^{40}K of samples show that none of the studied samples is considered a radiological hazard and products of quarries assayed can be safely used in construction without any significant radiological threat to the general public users.

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