MEASUREMENT OF GAMMA RADIOACTIVITY LEVEL IN ROCK AND SOIL OF SAUNDER QUARRY SITE, ABEOKUTA NORTH, SOUTH-WESTERN, NIGERIA.

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ABSTRACT

Crystalline rocks have been observed to be rich in Naturally Occurring Radionuclides (NOR) which are the primary terrestrial sources of radiation in the environment. This study determined the activity concentrations of NOR in rock and soil from Saunder quarry site, Abeokuta North, South-Western, Nigeria using NaI(Ti) gamma spectrometer. The average activity concentrations of ^{40}K, ^{238}U and ^{232}Th in rock samples were 605.62±83.29, 39.69±12.57 and 62.64±22.47 Bq kg^{-1}, respectively. The calculated average Absorbed Dose Rate(ADR) and Annual Effective Dose (AED) were 84.00 nGy h^{-1} and 103.03 µSv y^{-1}. The mean activity concentration of the sampled soils were ^{40}K (145.10±12.64 and 236.08±17.34 Bq kg^{-1}), ^{238}U (13.36±3.53 and 23.99±6.80 Bq kg^{-1}) and ^{232}Th (15.09±5.48 and 19.74±7.22 Bq kg^{-1}). Similarly, the corresponding average ADR and AED were 28.99 nGy $h^{-1}$and 35.56 µSv y^{-1} as well as 33,32 nGy h^{-1} and 40.87 µSv y^{-1}, respectively at the two depths of soil sampling. The average values of the sampled rock were higher than 70 µSv y^{-1} UNSCEAR recommended dose value. Hence, the granite rock used for building and construction purpose from the study area will be rich in NOR. There will be need for routine assessment of radionuclide contents of the rocks of the quarry site before supply for commercial purposes.

Key words: Gamma ray, Radioactivity, NOR, Abeokuta

INTRODUCTION

The naturally occurring radionuclides include the primordial radionuclide such as uranium (^{228}U), thorium (^{232}Th) and potassium (^{40}K) (Carlson, 2003). Studies of radionuclides distribution in the immediate environment provide vital information on human exposures to natural and man made source of radiation (Quindos et. al.,1994; Steinhausler, 1992). Terrestrial sources of radiation contribute for most of man's exposure to radiation and the average annual effective dose arising from natural source of radiation is 2.4mSv (UNSCEAR, 2000).

Quarrying activities can enhance the natural radiation background levels by bringing out large amount of otherwise buried materials containing Naturally Occurring Radionuclides (NOR) on to the surface of the environment ((Saleh et. al., 2007; Karangelos et. al., 2004). Equally, IAEA, 2003 revealed that plants grown on the aggregate dust of quarrying and mining activities, which are rich in NOR are environmental pathways. This study determined the distribution and presence of ^{40}K, ^{238}U and ^{232}Th and their potential hazards in rock and soil of Saunder quarry site, Abeokuta South-Western, Nigeria

MATERIALS AND METHODS

Study area: The study area is within latitude 7^0 13^1 N and 7^0 20^1 N and Longitudes 3^0 33^1E and 3^0 40^1 E. Three rock samples were collected randomly from the quarry site. Similarly, a total of ten (10) soil samples which comprised five (5) surface (0-5 cm) and five (5) subs – surface (20-25 cm) soil samples collected within and radialy around the quarry site were used for this study. Each soil sample was collected by pitting the soil to depth of interest in each location and then packed in a nylon made of non- radioactive material. The samples were sealed and labelled to avoid contamination. The soil samples were air dried and sieved with a < 2 mm mesh sieve while the rock samples were grounded into fine powder of < 2 mm size.

Measurement technique: The counting system used in the determination of natural radionuclide contents of the soil samples consists of a 7.6 x 7.6 cm NaI (Tl) scintillation detector (Model Bircom) and a multichannel spectroscopic analyzer (Canberra series 10). The detector, which interfaced with the electronic system through 50W coaxial cable, is placed in a lead castle to reduce signals from external background radiation. The Multi Channel Analyzer (MCA) electronic system consists of an internal spectroscopic amplifier and a 100 mHz Wilkinson type of Analogue to Digital Converter. For the purpose of this work, three Regions of Interest were defined for ^{40}K, ^{238}U and ^{232}Th, respectively.

Three Regions of Interests were created for the purpose of this research using the channel numbers corresponding to their gamma ray energies. The background radiation due to the naturally occurring radionuclides in the environment around the detector was measured by using an empty

plastic container; the empty plastic container was counted in the same manner as the rock and soil samples for the same counting time (36000 sec). ^{40}K content of the samples was obtained from the intensity of 1.461 MeV gamma ray peak followed by the ^{238}U content from 1.761 MeV peak of ^{214}Bi and the ^{232}Th content from the 2.614 MeV gamma ray peak from ^{208}Tl. The mean specific activity per kilogram of dried mass of the samples (rock and soil) at the beginning of the measurement in this study was calculated as follows:

$$\frac{A_S}{A_{st}} = \frac{N_S}{N_{st}}$$

$$A_S = A_{st} \left(\frac{N_S}{N_{st}}\right)$$

Where: A_S = Specific activity concentration of radionuclides (Bq Kg^{-1}) in unknown sample

A_{st} = Specific activity concentration of radionuclides (Bq Kg^{-1}) in reference Material

N_s = Net count rate under region of interest for unknown sample

N_{st} = Net count rate under region of interest for reference material

Quality Assurance Procedure

The method of gamma ray spectroscopy adopted in this analysis followed those reported by Ajayi and Ajayi (1999) and Jibiri et. al., (1999). However, the gamma counting equipments used consists of a 7.6 x 7.6 cm NaI (Tl) crystal (Model Bircom) placed in a Lead castle. The detector was properly connected to a Multi- Channel Analyzer (MCA) (Knoll, 1998). A well calibrated standard source supplied by the IAEA and available at the Centre for Energy Research and Development Ile-Ife, Nigeria were used for energy and efficiency calibrations and corrected for the counting losses due to coincidence summing effects (Olomo et. al., 1994). Accurate energy and efficiency of the gamma spectroscopy system were made to quantify radionuclide's present in a sample.

RESULTS AND DISCUSSION

The activity concentrations of the naturally occurring radionuclides in the sampled rock and soil are shown in Table 1- 3. The results revealed that ^{40}K, ^{238}U and ^{232}Th mean activity in rock (Table 1) were 605.62 $\pm$ 83.29, 39.69$\pm$ 12.57 and 62.64$\pm$ 22.47 Bq kg^{-1} respectively. Similarly, ^{40}K, ^{238}U and ^{232}Th mean activity concentration in surface and sub- surface soil (Table 2 and 3) were 145.10$\pm$ 12.64 and 236.08$\pm$ 17.34 Bq kg^{-1} for ^{40}K, 13.36$\pm$ 3.55 and 23.99$\pm$ 6.80 Bq kg^{-1} for ^{238}U as well as 15.09$\pm$ 5.48 and 19.74$\pm$ 7.22 Bq kg^{-1} for ^{232}Th respectively, at the two depth of soil sampling.

The results revealed that, the mean activity concentrations of the Naturally Occurring Radionuclides (NOR) were higher in the sampled rocks compared to the sampled soil. It was equally observed that, all values of the activity per unit mass are in the ranges of the corresponding typical world values (UNSCEAR, 2000), which are 50,50 and 500 Bq kg^{-1} for ^{238}U, ^{232}Th and ^{40}K, respectively with exception of ^{238}U. The result also shows that, the mean activity concentration of NOR in the soil samples were lower than world recommended values.

Table 1: Radioactivity Concentration, Absorbed Dose rate, Annual effective dose in rock sample

Radionuclide concentrations (Bq kg^{-1})				Dose Rate (nGy h^{-1})	Annual effective dose (µSv y^{-1})
Sample	^{40}K	^{238}U (^{226}Ra)	^{232}Th (^{228}Ra)		
Sample 1	392.32± 78.81	16.71 ± 6.74	46.81 ± 20.71	54.64	67.01
Sample 2	1353.82 ± 157.17	30.18 ± 8.21	61.22 ± 9.78	110.55	135.59
Sample 3	64.72 ± 13.90	72.20± 22.75	79.90 ± 31.65	86.83	106.49
Mean	**605.62± 83.29**	**39.69± 12.57**	**20.22 ± 8.2**	**84.00**	**103.03**

Table 2: Radioactivity Concentration, Absorbed Dose rate, Annual effective dose in surface (0-5cm) soil samples

Sample	Radionuclide concentrations (Bq kg^{-1})			Dose Rate (nGy h^{-1})	Annual effective dose (µSv y^{-1})
	^{40}K	^{238}U (^{226}Ra)	^{232}Th (^{228}Ra)		
Sample 1	629.80±44.09	19.59±5.85	27.74±8.97	53.31	65.38
Sample 2	6.48±2.04	7.85±2.03	7.54±2.05	8.65	10.61
Sample 3	29.40±4.98	6.25±12.08	5.69±5.54	43.33	53.14
Sample 4	52.93±9.98	12.75±3.45	11.98±3.87	15.66	19.20
Sample 5	6.90±2.11	20.37±4.25	22.54±6.95	24.02	29.46
MEAN	**145.10±12.64**	**13.36±3.53**	**15.09±5.48**	**28.99**	**35.56**

Table 3: Radioactivity Concentration, Absorbed Dose rate, Annual effective dose (20-25cm) samples

Sample	Radionuclide concentrations (Bq kg^{-1})			Dose Rate (nGy h^{-1})	Annual effective dose (µSv y^{-1})
	^{40}K	^{238}U (^{226}Ra)	^{232}Th (^{228}Ra)		
Sample 1	421.67±39.08	16.75 ±4.25	14.63±5.20	34.62	42.46
Sample 2	29.40±4.98	6.25±2.08	14.63±5.20	7.69	9.44
Sample 3	693.13 ±32.67	74.71±21.67	5.69± 1.87	101.44	124.41
Sample 4	28.10 ±6.65	6.90 ±2.03	4.74 ± 1.76	7.29	8.94
Sample 5	8.09 ±3.31	15.32 ±3.97	13.03±14.31	15.57	19.10
MEAN	**236.08±17.34**	**23.99±6.80**	**19.74±7.22**	**33.32**	**40.97**

The total air absorbed dose rate: The absorbed dose at 1 m above soil or rock containing the naturally occurring radionuclide is calculated from (UNSCEAR, 2000):

$$D(nGy\ h^{-1}) = 0.604C_{th} + 0.462C_u + 0.042C_k$$

Where C_{th}, C_u, C_k are the activity concentrations (Bqk g^{-1}) of ^{232}Th, ^{238}U and ^{40}K, respectively in the soil/ rock sample, and 0.604, 0.462 and 0.042 (nGy h^{-1} per Bq kg^{-1}) are the activity concentration – to-dose conversion factors. The annual effective dose resulting from the absorbed dose is also obtained from: E = D (nGy h^{-1}) x (8760h y^{-1}) x 0.2 x 0.7 (Sv/G y^{-1})

Where: D ($nGy\ h^{-1}$) is the dose rate in air from outdoor terrestrial gamma radiation and 0.7($Sv\ Gy^{-1}$) is the dose conversion factor and 0.2 is the outdoor occupancy factor.

The average gamma Absorbed Dose Rate (ADR) in air and Annual Effective Dose (AED) of the rock sample were calculated as 34.00 nGy h^{-1} and 103.03 μSv y^{-1} (Table 1). Similarly, the average ADR and AED of the surface soil were calculated as 28.99 nGy h^{-1} and 35.56 μSv y^{-1} (Table 2), while the average values of 33.32 nGy h^{-1} and 40.87 μSv y^{-1}, respectively were recorded at sub-surface level of the soil sampling (Table 3).These values are similar to 77.40 nGy h^{-1} and 88.70 μSv y^{-1} earlier reported by Kurnaz et. al., (2007) and 124.00 nGy h^{-1} and 152.00 μSv y^{-1} reported by Yang et. al., (2005). However, the average annual effective doses recorded at the two depths of the sampled soil of this study were lower than the worldwide average value (70 μSv y^{-1}) recommended by UNSCEAR, (2000).

CONCLUSIONS

This study determined the distribution and presence of NOR in rock and soil of saunder quarry site, Abeokuta, south-western Nigeria. The study confirmed the presence of ^{40}K, ^{238}U and ^{232}Th in appreciable amount in the rock samples. The activity concentrations of natural radionuclides and dose rate were observed to be higher in the rock of the study area than the worldwide average value of 70 μSv y^{-1}, which put the end users of the aggregate rocks and people around the area on a radiological hazard.

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