



# Activity Concentration of Gamma Emitting Natural Radionuclides in Building Materials

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## ABSTRACT

In this work, the natural radionuclide contents of some building materials widely used in Nigeria were measured by the means of gamma-ray spectrometry using Na(I)TI detector. A total of 15 samples were assayed from different materials. The mean of <sup>226</sup>Ra, <sup>232</sup>Th and <sup>40</sup>K concentrations determined are  $30.35 \pm 8.69 \text{ BqKg}^{-1}$ ,  $20.12 \pm 6.00 \text{ BqKg}^{-1}$  and  $241.95 \pm 76.31 \text{ BqKg}^{-1}$  respectively. These values were lower than permissible global values except for potassium which is higher than that of global permissible value of 52.2, 41.0 and 230.0 ( $\text{BqKg}^{-1}$ ) respectively by UNSCEAR. The obtained mean absorbed dose rate for all the collected building materials samples is  $39.90 (\text{nGh}^{-1})$ . These results, along with the results of the estimated annual effective dose rates, radium equivalent ( $\text{Ra}_{\text{eq}}$ ), external hazard index ( $H_{\text{ex}}$ ) are presented and they are found below the internationally accepted safe limits. It suffices to say therefore the analyzed samples could be used for building and construction purposes. It is safe to say that there is no threat pose to any users of the materials.

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## Introduction

Every person, animal and objects on our planet is subjected to radiation and may indeed contain it. Though it could not be smelt, seen or felt but it is with us at all times. Radionuclides are present always in the natural environment and man is continually exposed to ionizing radiation from Naturally Occurring Radionuclides Materials (NORM). The origin of these materials is the earth crust, but they find their way into building materials, air, water, food, and the human body itself. It is well known that radioactive nuclides in the uranium and Thorium decay chains do occur with varying degrees of concentration in the earth's crust. While radioactive nuclides such as radium (<sup>226</sup>Ra), radon (<sup>222</sup>Rn) and bismuth (<sup>214</sup>Bi) are the product in the decay chain of uranium (<sup>238</sup>U), other radioactive nuclides, such as actinium (<sup>228</sup>Ac), bismuth (<sup>212</sup>Bi) and lead (<sup>212</sup>Pb) do occur in the decay chain of the thorium element (<sup>232</sup>Th). In addition, the radionuclide (<sup>40</sup>K) does also occur in construction materials. These radioactive elements can be found almost in all types of building materials containing naturally occurring radionuclides are the main source of exposure. The knowledge of natural radioactivity in these materials is then important for determining the amount of public exposure because people spend most of their time (about 80%) indoors (Stoulos et al). Such information is essential in understanding human exposure from natural and man-made sources of radiation and necessary in establishing rules and regulations relating to radiation protection (Quindos et al., 1994). Elevated indoor external dose rates may arise from high activities of radionuclides in building materials. Large-scale surveys of concentrations of radioisotopes in construction materials were summarized by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). Monitoring of any release of radioactivity to the environment is important for environmental protection. Rapid and accurate

methods for the assay of radioactivity are essential. Low level gamma-ray spectrometry is suitable for both qualitative and quantitative determinations of gamma-ray emitting nuclides in the environment (IAEA, 1989).

## Materials and Methods

### Sample Description and Preparation

A total of 15 samples of 5 different building materials. Three (3) samples for each type of materials were collected. The samples collected were Sand, Concrete, Bricks and Batches of Cement samples, all the sample were collected from the suppliers and masons popularly known as (brick layers) in this part of the world. The samples were collected from Ogbomoso, south western Nigeria. The samples were air dried to remove the moisture, crushed and sieved so that heavy particles could be removed. The powdered samples were stored in airtight plastic containers for period of 28 days to allow the samples to attain a state of secular radioactive equilibrium where the rate of decay of the progeny becomes equal to that of the parent (radium and thorium) within the volume and the progeny will also remain in the sample (ASTM 1983, ASTM 1986). The samples were then analyzed to determine the radioactivity concentration in the samples.

### Measurement

In this work activity concentration were determined by gamma ray spectrometer with a highly shielded Canberra NaI(Tl) detector enclosed in a 100mm thick lead blocks coupled to a Canberra Multichannel Analyzer (MCA) with a PC via a preamplifier base. The collector is located in the centre of the lead shield in order to minimize the effect of scattered radiation from the shield. Energy and efficiency calibration of gamma spectrometer were carried out using the International Atomic Energy Agency (IAEA) reference source material. Counting was carried out for a period of 36000s, first for the empty beaker of identical geometry as the sample to determine the background

spectrum. Thereafter the sealed samples were counted for the same period of 36000s. The geometry of the beaker used in this work plays an important role because it covers almost all the detector sensitive volume. It presented the largest surface area to the detector hence, sustained the greatest solid angle at the detector. Each sample was measured several times. The transmission line of 1460Kev for  $^{40}\text{K}$ , 1764Kev for  $^{214}\text{Bi}$ , 2614Kev for  $^{218}\text{Ti}$  were use to determine the concentrations of  $^{40}\text{K}$ ,  $^{238}\text{U}$  and  $^{232}\text{Th}$  respectively.

### Result and Discussion

Activity concentrations of  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  in controlled samples of building materials are shown in Table 1.

**Table 1. Activity concentrations range of  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  in different samples**

Samples	$^{226}\text{Ra}$ (BqKg <sup>-1</sup> )	$^{232}\text{Th}$ (BqKg <sup>-1</sup> )	$^{40}\text{K}$ (BqKg <sup>-1</sup> )
Bricks	30.25±2.85	23.40±8.09	389.83±107.57
Gravel	25.88±6.93	22.49±5.17	123.42±20.35
Concrete	23.83±8.46	23.35±6.90	278.93±20.35
Sand	27.01±4.93	13.46±6.03	364.22±218.38
Cement	44.78±20.28	17.88±3.80	58.38±25.08
Mean values	30.35±8.69	20.12±6.00	241.95±76.31

Activity concentration of  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  in the samples of the building materials are presented in the Table 1. The Obtained results highlight the presence of natural radionuclides for each batch of building materials measured. The specific activity determined for  $^{226}\text{Ra}$  vary from 23.83±8.46 BqKg<sup>-1</sup> to 44.78±20.28 BqKg<sup>-1</sup> with a mean value of 30.35±8.69 BqKg<sup>-1</sup>, also for  $^{232}\text{Th}$  ranges from 13.46±6.03 BqKg<sup>-1</sup> to 23.40±8.09 BqKg<sup>-1</sup> with an average of 20.12±6.00 BqKg<sup>-1</sup> while for  $^{40}\text{K}$  ranges from 58.38±25.08 BqKg<sup>-1</sup> to 389.83±107.57 BqKg<sup>-1</sup> with an average value of 241.95±76.31. From the result obtained it was indicated that  $^{40}\text{K}$  is the highest contributor to the radionuclide while  $^{232}\text{Th}$  is the least contributor. It was also observe that the potassium in cement is much lower than that of other samples measured.

### Radium Equivalent Activity( $R_{eq}$ ) and External Hazard Index( $H_{ex}$ )

The natural radionuclides present in the samples are not uniformly distributed in the building materials, therefore in order to assess the hazards associated with the materials that contain  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  the equation 1 is used

$$R_{eq} = ARa + 1.43A_{Th} + 0.077AK \dots \dots \dots (1)$$

Where  $ARa$ ,  $A_{Th}$  and  $AK$  are the mean activity in Bqkg<sup>-1</sup> of  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$ , respectively. The values of  $R_{eq}$  for the selected building materials ranges from 66.68 Bqkg<sup>-1</sup> in Gravel to 91.00 Bqkg<sup>-1</sup> in bricks with a mean value of 76.12 Bqkg<sup>-1</sup>. Thus all materials will no present a significant radiological hazard when they are used in building constructions. These values are smaller than the suggested maximal admissible values

of 370 Bqkg<sup>-1</sup>, which is equivalent to annual dose of 1.5mSv, but the European commission report set the limit as 0.3-1.0 msvy<sup>-1</sup> for safety use. While the external hazard index ( $H_{ex}$ ): is given by the following equation (UNSCEAR 2000), (European Commission 1999).

$$(H_{ex}) = 0.0027C_{Ra} + 0.00386C_{Th} + 0.000208C_K \dots \dots \dots (2)$$

Where  $C_{Ra}$ ,  $C_{Th}$  and  $C_K$  are the concentration in BqKg<sup>-1</sup> of radium, thorium and potassium, respectively. The value obtained in this work is lower than the unity; the value must be lower than or equal to unity in order to limit external gamma dose of 1.5msvy<sup>-1</sup> therefore there is no radiological threat to the users of the materials in the studied area. The soil in the studied area could be used for Agricultural practices and other samples could be used for building construction without posing any threat to lives. The investigated materials meet the criterion.

### Absorbed dose Rate

The calculated absorbed dose rate of the samples materials are presented in the Table 2. The absorbed dose was calculated by using the equation 3. Since the radionuclide concentrations of the samples are known.

$$D(\text{nGhy}^{-1}) = (R_k \times Q_k) + (R_U \times Q_U) + (R_{Th} \times Q_{Th}) \dots \dots \dots (3)$$

Where  $R_k$  (0.0417),  $R_U$  (0.462) and  $R_{Th}$  (0.604) are the conversion factor for  $^{40}\text{K}$ ,  $^{238}\text{U}$  and  $^{232}\text{Th}$  respectively (UNSCEAR 2000).  $Q_k$ ,  $Q_U$  and  $Q_{Th}$  are the activity concentrations of  $^{40}\text{K}$ ,  $^{238}\text{U}$  and  $^{232}\text{Th}$  respectively in Bq/Kg. The absorbed dose rate for the materials investigated ranges from 30.69 nGhy<sup>-1</sup> to 44.37 nGhy<sup>-1</sup> with a mean value of 39.90 nGhy<sup>-1</sup> as shown in the Table 2. Gravel has the lowest value (30.69) nGhy<sup>-1</sup> and where the highest value is found in bricks 44.37(nGhy<sup>-1</sup>). The value Obtained is lesser than the world average value of 55 nGhy<sup>-1</sup>.

### Annual effective dose

In order to access the health effect of the absorbed dose rate, the annual effective dose rate was calculated using the equation 4. The calculation was made by using the conversion coefficient of 0.73 SvGh<sup>-1</sup> and the indoor occupancy factor of 0.8 as described in the equation4.

$$E (\text{mSvy}^{-1}) = D (\text{nGyh}^{-1}) \times 8760(\text{hy}^{-1}) \times 0.8 \times 0.7(\text{SvGy}^{-1}) \times 10^{-6} \dots \dots \dots (4)$$

The value of E obtained for the sample investigated ranges from 0.15 to 0.22 mSvy<sup>-1</sup> with mean value of 0.18 mSvy<sup>-1</sup> when the result is compared with the value of (UNSCEAR 2000) limit of 0.46 mSvy<sup>-1</sup> for terrestrial radionuclides for area of normal back ground radiation. It is evident that the data obtained is much lesser.

Comparing the result obtained from this work it could be seen that the  $R_{eq}$  in cement is lower that of (Ademola 2008) and the values of sand is in average from that of other countries.

**Table 2. below shows comparison of activity and Radium equivalent in building materials used in Ogbomos o with those of other countries**

Material	Country	Activity(Bq/kg)			$R_{eq}$	Reference
		$^{238}\text{U}$	$^{232}\text{Th}$	$^{40}\text{K}$		
Sand	Ireland	20.20	23.50	550.20	-----	Zikovsky and kenedy,1992
	Brazil	10.2	12.6	51	34	Malanca et al. (1995)
Brick	Germany	59.00	67.00	670.00	-----	Schmier et al 1982
Granite	Canada	15.30	9.20	1030.30	-----	Zikovsky and kenedy,1992
Cement	-----	-----	-----	-----	88.9	Ademola 2008
Gravel	Canada	10.00	12.00	222.00	-----	Zikovsky and kenedy,1992
Concrete	Finland	53.00	38.00	838.00	-----	UNSCEAR, 1982
Sand	Ogbomos	27.01	13.46	364.22	71.75	This work
Brick	Ogbomos	30.25	23.40	389.83	91.00	This work
Cement	Ogbomos	44.78	17.88	58.38	74.43	This Work

**Table 3.  $R_{eq}$ , D,  $H_{ex}$  and E values for some selected building materials in Nigeria**

Samples	$R_{eq}$	D( $nGy h^{-1}$ )	$H_{ex}$	E( $msv y^{-1}$ )
Bricks	91.00	44.37	0.25	0.22
Gravels	66.68	30.69	0.18	0.15
Concrete	76.75	36.74	0.21	0.18
Sand	71.75	35.80	0.20	0.18
Cement	74.43	33.90	0.21	0.18
Mean Value	76.12	39.90	0.21	0.18

**Conclusion**

The activity concentration of building materials has been analyzed. There is variation in the Radionuclides presents in the samples analyzed which vary from for  $^{226}Ra$  vary from  $23.83 \pm 8.46 \text{ BqKg}^{-1}$  to  $44.78 \pm 20.28 \text{ BqKg}^{-1}$  with a mean value of  $30.35 \pm 8.69 \text{ BqKg}^{-1}$ , also for  $^{232}Th$  ranges from  $13.46 \pm 6.03 \text{ BqKg}^{-1}$  to  $23.40 \pm 8.09 \text{ BqKg}^{-1}$  with an average of  $20.12 \pm 6.00 \text{ BqKg}^{-1}$  while for  $^{40}K$  ranges from  $58.38 \pm 25.08 \text{ BqKg}^{-1}$  to  $389.83 \pm 107.57 \text{ BqKg}^{-1}$ . The radium equivalent was also calculated and found to be the acceptable limit. The result obtained can be used as baseline for the studied area.

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