RADIOACTIVITY ASSESSMENT ON SOME SELECTED BUILDING MATERIALS IN JOS, PLATEAU STATE- NIGERIA

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ABSTRACT

This work was carried out on some selected building materials in Jos Plateau State, Middle belt of Nigeria to determine their radionuclide's contents. The sole objective of this work was to determine the concentration of radionuclides in some building material samples and the radiological implication to the dwellers of Jos, Plateau State. The machine used was a very sensitive Thallium activated Sodium Iodide Na (Ti) scintillation detector that is interface with a series of 10plus Canberra Multi-channel analyzer. The MCA (multi-channel analyzer) was used to qualify the concentration of the naturally occurring radionuclides namely: ^{40}K (potassium-40), ^{226}Ra (Radium-226) and ^{232}Th (Thorium-232). The counting system was calibrated using standard reference source from IAEA, Vienna, Austria. Results showed that the radioactivity concentrations of ^{40}K, ^{226}Ra, ^{232}Th in the sample ranged from 13.941 ± 11.120 to 54.52 ± 3.438, 10.025 ± 1.360 to 86.31 ± 2.802, 16.217 ± 1.464 to 748.10 ± 17.011Bqkg^{-1} respectively. The average of ^{40}K, ^{226}Ra, ^{232}Th were calculated as 236.94 ± 11.52Bqkg^{-1} ,35.779±.81Bq/kg and35.70±3.30 Bq/kg respectively, while the mean of the radium equivalent, external hazard, internal hazard and absorbed dose rate were 0.34Bqkg^{-1}, 0.26Bqkg^{-1} and 0.33nGyh^{-1} respectively. This shows that the radionuclides present in the building materials may be harmful to the survival of the people living in the environment.

KEYWORDS: Radioactivity, building material, Samples, Radium Equivalent and Radionuclides

INTRODUCTION

Man is continuously exposed to radiation from naturally occurringradioactive materials (NORM). Natural radioactivity is widely spread in the earth's environment and it exist in various geological formation e.g soil, rock, plant, water, air and in building material (Absalom, 2001, Ahmed, 2005). Measurement of activity concentrations of radionuclide in building materials is important in the assessment of population exposure as most individuals spend 80% of their time indoors (Mcaulay, 1988). Naturally occurring radionuclide in building materials are source of external radiation exposure in dwellings. This radiation is caused by gamma radiation originating from the Uranium and Thorium series and from ^{40}K (Amrani and Tahtat, 2001). The population weight average indoor absorbed dose rate in air from terrestrial source of radioactivity is estimated to be 84nGyh^{-1}(UNSCEAR, 1997 & 1993). The average activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K in the earth's crust are 35, 30 and 400Bqkg^{-1}respectively. However, elevate level of natural radionuclide's causing annual doses of several mSv have been identified in some building materials. All materials derived from rocks and soils contain mainly natural radionuclides of the Uranium, Thorium series and potassium – 40.Construction materials and interior finish products should be chosen with low or zero emissions to improve indoor airquality. Many building materials and cleaning maintenance products emit toxic gases such as formaldehyde and Radon (Kamal *et al*, 2011). These gases can have a detrimental effect on the occupant's health and productivity. Another source of Radon is the radiation in the environment, which is either natural or artificial. All exposure from natural background radiations except for direct cosmic radiation is produced by radiation emanating from natural radionuclide in the environment. Thorium and Uranium in their natural occurrence undergo radioactive decay in three different series headed by ^{238}U, ^{235}U and ^{232}Th. Without chemical or physical separation each of three series attains a state of secular radioactive equilibrium (Barakat, 2008).

Naturally occurring radioactive materials (NORMs) are the major sources which cause exposure to people by ionizing radiation of about 2.3mSv/year on the average (UNSCEAR, 1993). These radionuclides pose exposure risks externally due to their gamma-ray emissions and internally due to radon and its progeny which emit alpha particles with the contributions of 46% and 54% respectively to the total annual effective dose caused by the NORMs.

To minimize the exposure of the population to ionizing radiation, there is the need to control and limit the content of radiative materials in constructions. The objective of this work is to determine the specific activity of ^{226}Ra, ^{232}Th and ^{40}K some types of building materials used in Jos, Plateau State – Nigeria.

MATERIALS AND METHOD

Samples Collection/Preparation

The materials were obtained from suppliers or gathered directly in demolished houses or building under construction and each of these materials were put together for preparation.The organic and absorbed water needs to be dried off, so each samples were spread under direct sunlight of about 40^{0}C temperature before, pulverizing utmost care was maintained in the process in order to avoid sample mix-up. The samples were left to dry up for several days under intense sunlight in which they were grinded to powder and sieved through a 200µm, which is the optimum size enriched in heavy minerals. Weighted samples were placed and packed into a cylindrical plastic container of uniform base diameter of about 6.0cm which could sit on the 7.60cm x 7.60cm Na (Ti) detector and well labelled. The plastics were tightly sealed and left for about 28 days to reach secular equilibrium between radium -226 and its radon daughters (Jwanbot, 2012).

Method of Monitoring and Calibration

Activity measurements were performed by gamma ray spectrometer employing a Thallium activated sodium iodide Na (Ti) scintillation detector interface with a series of 10plus Canberra multi-channel analyzer. To reduce gamma ray background, a cylindrical lead shield (100m thick) with a fixed bottom and movable cover shielded the detector. The lead shield contains inner concentric cylinders of copper (0.3mm thick) in order to absorb x-rays generated in the lead. In order to determine the background distribution in the environment around the detector, an empty scaled beaker was counted in the same manner and in the same geometry as the samples.

The measurement time of activity or background was 27200s. The background spectra were used to correct the net peak area of gamma rays off measured isotopes. A delicate software program, from Canberra has carried out the online analysis of each measured gamma ray spectrum.The ^{232}Th concentration was determine from the average concentrations of ^{212}Pb (238.6KeV), and ^{288}Ac (911.1) in the samples and that of ^{226}Ra was determined from the average concentrations of the ^{214}Pb (351.9keV) and ^{214}Bi (609.3KeV and 1764KeV) decay products.

RESULTS AND DISCUSSION

Activity Concentrations in the Samples

The radioactivity concentration levels of the collected building materials used are presented in the Table 1. The three primordial radionuclide's ^{40}K, ^{226}Ra, ^{232}Th have been detected and measured in the building materials in Jos, Plateau State.

The activity concentration level in each of the sample was calculated using the expression:

$$Activity = \frac{N_0 C}{N} \qquad (1)$$

Where $N_0$is the standard values of ^{40}K, ^{226}Ra, ^{232}Th respectively, N is the Net Area values and C is their concentration values.

We calculated the error using:

$$E = \sqrt{\varepsilon B^2 + \varepsilon G^2} \qquad (2)$$

Where B is their background values and G is the Gross values respectively.

From Table 1, it can be seen that ^{40}K always contributes to the most specific activity compared to ^{226}Ra and ^{232}Th. For the different samples, the highest activity of ^{226}Ra is 53.601 ± 3.402Bqkg^{-1} for Asbestos ceiling; which is four times greater than that of the lowest value 13.941 ± 3.402Bqkg^{-1} obtained in laterite. ^{232}Th is in the wide range from 10.025 ± 1.360Bqkg^{-1} in clay bricks to 58.50 ± 3.220Bqkg^{-1} in Asbestos ceiling. The concentration of ^{40}K values range 3.438 ± 15.07 in laterite to 748.10 ± 17.011Bqkg^{-1} in Asbestos ceiling. Thus the activities in Asbestos ceiling were higher than all other building materials. This may suggest that it advisable to monitor the radioactivity levels of the materials from a new source before adopting it for use as building material.

Table 1: Activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in different samples.

S/NO	SAMPLES	ACTIVITY CONCENTRATION (Bqkg^{-1})		
		^{40}K	**^{226}Ra**	**^{232}Th**
1	Sand	37.820 ± 13.03	37.997 ± 9.561	13.205 ± 1.744
2	Clay bricks	21.289 ± 13.82	51.142 ± 9.426	10.025 ± 1.360
3	Ceramic tiles	284.10 ± 7.280	48.71 ± 2.88	86.31 ± 2.802
4	Gravel	207.11 ± 5.025	35.11 ± 2.190	11.33 ± 0.92
5	White cement	480.00 ± 11.18	25.55 ± 1.803	28.44 ± 1.602
6	Marble	124.18 ± 12.03	32.10 ± 2.10	10.18 ± 1.02
7	Gypsum	17.02 ± 0.44	14.42 ± 1.08	40.83 ± 0.22
8	Laterite	3.438 ± 15.07	13.941 ± 11.120	21.348 ± 13.50
9	Brown bricks	16.217 ± 14.64	33.484 ± 9.658	23.950 ± 13.03
10	Wood (teak)	82.92 ± 5.20	45.551 ± 3.311	29.71 ± 2.45
11	Asbestos ceiling	748.10 ± 17.011	53.601 ± 3.402	58.50 ± 3.220
12	Cement (gray)	436.62 ± 20.21	21.90 ± 3.80	29.68 ± 3.201
13	POP (plaster of Paris)	587.08 ± 3.130	46.92 ± 2.801	21.400 ± 1.600
14	Filler (Calcium Carbonates)	3.08.08 ± 8.01	27.33 ± 2.302	14.11 ± 1.708
15	Cement blocks	121.05 ± 13.99	29.98 ± 2.09	18.402 ± 1.098
16	Acrylic paint (dry)	285 ± 14.18	54.52 ± 3.438	65.820 ± 3.348
	Mean	**236.94 ± 11.52**	**35.77 ± 9.81**	**35.70 ± 3.30**

Radium Equivalent (BqKg^{-1})

The radium equivalent of the sample was calculated using the following relation (Barakat, 2008):

$$Ra_{eq} = C_{Ra} + 1.43C_{Th} + 0.07C_k \quad (3)$$

Where C_{Ra}, C_{Th} and C_k are the activity concentrations of ^{40}K, ^{226}Ra, ^{232}Th in BqKg^{-1} respectively. To assess the radiological risk building materials it is useful to represent the activities, due to ^{226}Ra, ^{232}Th and ^{40}K by a single quality, which takes into account the associated radiation hazard. A common index called radium equivalent activity has been introduced by Beretka and Mathew (Anjos *et al*, 2005) for radiation risk from building material to be negligible, the maximum value of Radium equivalent must be less than 370Bqkg^{-1}.

Table 2 summarizes that Ra_{eq} results for all the samples studied. These values range from 55.35Bq/kg in marble to 192.01Bq/kg in ceramic Tiles. Thus, all materials will not present a significant radiological hazard when they are used for building construction. However, from the results (Ra_{eq}) obtained in Table2 where all the values are less than 370 Bq/kg; there is no cause for alarm at present.

Table2: Radium equivalent activity in the building material samples

Samples	Radium Equivalent (Bqkg^{-1})
Sand	59.53
Clay bricks	66.97
Ceramic tiles	192.01
Gravel	65.81
White cement	99.77
Marble	55.35
Gypsum	72.93
Laterite	46.98
Brown bricks	68.87
Wood (teak)	93.84
Asbestos ceiling	189.63
Cement (gray)	94.90
POP (plaster of Paris)	118.62
Filler (Calcium Carbonates)	69.13
Cement blocks	64.76
Acrylic paint (dry)	168.6
Mean	**0.34**

External Hazard Index (Bqkg^{-1})

The value of the index must be less than unity in order to keep radiation hazard in significant.

The external hazard index can be calculated using the following equation

$$H_{ext} = \frac{C_{Ra}}{370} + \frac{C_{Th}}{259} + \frac{C_k}{4810} \leq 1 \qquad (4)$$

Table 3: External hazard index in building materials sample

Samples	External Hazard ($Bqkg^{-1}$)
Sand	0.10
Clay bricks	0.18
Ceramic tiles	0.52
Gravel	0.17
White cement	0.29
Marble	0.16
Gypsum	0.20
Laterite	0.12
Brown bricks	0.18
Wood (teak)	0.25
Asbestos ceiling	0.53
Cement (gray)	0.26
POP (plaster of Paris)	0.33
Filler (Calcium Carbonates)	0.18
Cement blocks	0.18
Acrylic paint (dry)	0.46
mean	**0.26**

From Table 3:

$$H_{ext} = \frac{C_{Ra}}{370} + \frac{C_{Th}}{259} + \frac{C_k}{4810} \leq 1 \qquad (5)$$

From the formulae, the index must be less than unity so that the annual effective dose due to radioactivity in the materials will be less or equal to 1.5mSv indicated in Table 3, it appears that all investigated materials meet this criterion.

Internal Hazard Index

The internal index was calculated using the relation

$$H_{in} = \frac{C_{Th}}{370} + \frac{C_{Ra}}{259} + \frac{C_k}{4810} \leq 1 \qquad (6)$$

Table 4: Internal hazard index in building materials sample.

Samples	Internal Hazard (Bqkg^{-1})
Sand	0.22
Clay bricks	0.26
Ceramic tiles	0.72
Gravel	0.24
White cement	0.37
Marble	0.21
Gypsum	0.28
Laterite	0.61
Brown bricks	0.26
Wood (teak)	0.36
Asbestos ceiling	0.79
Cement (gray)	0.33
POP (plaster of Paris)	0.42
Filler (Calcium Carbonates)	0.35
Cement blocks	0.25
Acrylic paint (dry)	0.63

From Table 4, the investigated materials fall within the range of 0.21Bqkg^{-1} in marble to 0.79Bqkg^{-1} in Asbestos ceiling. This again shows that virtually all the building materials surveyed are within the safety limit. This suggests that since H_{in} is supposed to be less than unity for the safe use of a material in the construction of dwellings.

Absorbed Dose Rate (D,nGyh^{-1})

The absorbed dose rate of ^{40}K, ^{226}Ra, ^{232}Th, measured in each of the samples is only an indication of the radionuclide present and does not relate the effect of such level on bio-system especially when the soil samples are dispersed into the environment and are potential source of gamma radiation exposure to the population. The important quantity to access when considering radiation risk in the bio-system is the absorbed dose rate.

The absorbed dose rate in air at 1m above ground level due to the concentration of the radionuclides in the sample was calculated using the following equation:

$$D_o = (0.00333C_{Ra} + 0.005C_{Th} + 0.000333C_k)(D, nGyh^{-1}) \quad (7)$$

Table 5: Absorbed dose rate in analyzed samples

Samples	External Hazard ($Bqkg^{-1}$)
Sand	0.21
Clay bricks	0.22
Ceramic tiles	0.29
Gravel	0.25
White cement	0.39
Marble	0.30
Gypsum	0.24
Laterite	0.21
Brown bricks	0.23
Wood (teak)	0.33
Asbestos ceiling	0.72
Cement (gray)	0.37
POP (plaster of Paris)	0.58
Filler (Calcium Carbonates)	0.26
Cement blocks	0.23
Acrylic paint (dry)	0.60

Table 5 gives the results for absorbed dose rate in air for the building materials under investigation. It is observed that Asbestos ceiling show the highest value ($0.72nGyh^{-1}$), where the lowest value is found in Marble ($0.21nGyh^{-1}$).

Annual Effective Dose (DE)

The annual effective dose DE was calculated using the relation below:

$DE = 0.7SvGy^{-1}$ 700h. D_0Where D_0 must be taken in μGyh^{-1} and 0.7 $SvGy^{-1}$ is effective absorbed dose conversion factor and the outdoor occupancy factor of 0.2 and 7000h is annual exposure time. Results are represented in Table 6 below.

Table 6: The annual effective dose in the samples analyzed

Samples	Annual Effective Dose DE (μSv)
Sand	1.03
Clay bricks	1.08
Ceramic tiles	1.42
Gravel	1.22
White cement	1.91
Marble	1.47
Gypsum	1.18
Laterite	1.03
Brown bricks	1.13
Wood (teak)	1.62
Asbestos ceiling	3.53
Cement (gray)	1.81
POP (plaster of Paris)	2.84
Filler (Calcium Carbonates)	1.27
Cement blocks	1.13
Acrylic paint (dry)	2.94

Results are presented in Table 6 and the values lied between 1.03 and 5.53μSvy^{-1}. According to reference of (UNSCEAR, 2000), the annual effective dose of those samples doesn't exceed the average worldwide exposure of 2.4mSv due to natural sources. This shows that all the building materials may not pose any danger to the inhabitance in this area.

CONCLUSION

The average value of the activity concentration for ^{226}Ra, ^{232}Th and ^{40}k have been found within the range 13.941 ± 11.120 to 54.52 ±3.438, 10.025±1.360 to 86.31 ±2.802, 16.217 ±1.464 to 748.10 ±17.011Bqkg^{-1} respectively. The lowest ^{226}Ra were found in Laterite and highest in acrylic paint (Dry), ^{232}Th lowest were found in clay bricks and highest in asbestos ceiling. The absorbed dose rate indoor was found to vary from 0.3 to 0.72nGyh^{-1} and the corresponding annual effective dose ranging from 1.03 to 3.53μSvy^{-1} set by OECD report which lies within the acceptable are used for both domestic and industrial construction purposes.

RECOMMENDATIONS

Owing to the fact that all the samples used for the purpose of this work are mainly internationally produced building materials, I therefore recommend the use of locally produced building materials in Jos for further work and more samples can also be added for a wider and critical assessment.

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