Assessment of radiological health hazard in building materials in Ijebu North LGA, Ogun State Nigeria

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ABSTRACT

The gamma ray spectrometry carried out using Sodium lodide (doped with Thallium (Nal(Tl)) detector on building sample materials of two (2) different samplesof cement blocks (9inches and 6inches blocks), from four blocks making industry under Ijebu North Local Government were collected for analysis with samples of sharp sand, soft sand, stony sand (gravel), two different brands of cement , floor tiles and wall tiles were analyzed for the radioactivity counts of Thorium (Th-232), Uranium(U-238),and Potassium K-40. The results obtained from these samples after gamma ray spectrometry showed that the radium equivalents calculated from Specific Activities of the samples are all very low at the range of 24.58Bq/Kg to108.38Bq/Kg and the mean radium equivalent is 63.17Bq/Kg which is very low compared to370Bq/Kg as the upper safety limit recommended by World Health Organization (WHO) and International Atomic Energy Agency (IAEA). All the safety hazard indices such as Alpha index, Gamma index, External hazard index and Internal hazard index are all very well below unity which is the recommended maximum limits. Hence all the building materials in the study area are safe for use.

Keywords**:** Specific Activity, Building materials, Health hazard, Gamma ray spectrometry, Ijebu-North .

INTRODUCTION

A building is an edifice or a structure with a roof and walls standing more or less permanently in one place, to serve as a shelter to live in such as a house or to serve other purposes like working place such as an office or factory. A building come in a variety of sizes, shapes and function and have been adapted throughout history of mankind for a wide number of factors ,ranging from caves to sky scrappers. The building materials available to individuals vary in choices of buildings desired and are determined by available fund, weather conditions ,land prices, ground location /conditions, specific use and aesthetic reason. Building serve several societal needs, primarily as shelter from weather, security, living spaces, privacy, to store belongings (warehouse) and for comfort ability, live and work. A building could be erected/constructed chiefly with any or combinations of either clay brick, cement brick, wood(planks), stone, stucco, aluminum, glass, plaster and vinyl. Actually stucco and plaster offer built-in insulation (McAulay and McLaughlin,1985). Among several other materials and products used in building are cement, sand, water, roofing sheet, nails and tiles etc.

Since it is asserted that human indoor occupancy factor is 80% (Abdulrahman, Abdelhakim, and Benamar, 2013), it is necessary to evaluate the human exposures to radioactivity due to building materials and its components specifically so as to know the dose limits of public exposure combined with the natural environmental radiation level provided by ground, water, air, foods etc.

Radiation exposure is known to increase the incidence of cancer in high doses. Epidemiological investigations on people living in high radiation areas have shown cancer incidences in these areas which are not statistically different from nearby populations who have much lower does and similar socio economic condition (Jibiri, Alausa and Farai, 2009).

The public should therefore be kept to low dose exposure as possible since high exposure cause undesired biological effects to human beings. It is therefore essential that activities involving radiation exposure is subjected to certain standard of safety in order to protect the individuals, who are expose to radiation, be it occupationally, medical diagnostic or therapeutic. (IAEA, 1994)

MATERIALS AND METHODS

Description of Materials

All the materials used in the study were collected from the local brick block factories/manufacturers builders/building materials merchants in the towns and locations within the ljebu North local government area/council .

Cement

Cement is a building material which is made up by wet process. Cement is made from Calcium carbonate ($CaCo_3$) salt and clay. It provides strength to structure. A cement is also a binder, a substance used for construction that sets, hardens and adheres to other materials, binding them together. Cement is seldom used on its own, but rather to bind sand and gravel together (Kplegoet al, 2011).

Type of Cements

Ordinary PortLand Cement: Portland cement is a product obtained by the calcinations at a very high temperature, an intimate mixture of correctly proportioned calcareous and argillaceous materials.

Rapid hardening Cement: it is also known as high early strength cement. It is manufactured with such adjustments in the proportion of raw materials.

Portland cement is the most commonly used and they are mostly graded in terms of their bonding strength in codes such as 32.5, 42.5 and 52.5 in increasing strength respectively (Solific, Barasic, Solific and Durokovic, 2011) . It is the type collected for sampling in this study. The raw materials included in the cement are; calcareous materials and argillaceous materials. The calcareous materials include compounds of calcium and magnesium such as limestone and argillaceous which include mainly silica, alumina and oxide such as clay and shale.

Sand

Sand is a mixture of small grain so frock and granular materials which is mainly define by size, being finer than gravel and coarser than slit. Sand can be also considered as a textural class of soil or soil type. Soil containing more than 85 percent particles whose average diameter is lower than 0.002mm is referred to as clay. Soil with average diameter between 0.002mm and 0.02mm are termed silt. The one between 0.02mm-0.2mm is fine or soft sand, while 0.2mm-2.0mm is coarse or sharp sand. All soils with average diameter above 2.0 mm are referred to as stony sand or gravel. Sand is made by erosion or broken pebble sand weathering of rocks, which is carried by sea sore rivers (Mehdizadeh, Faghihi, and Sina ; 2011). The sand materials used in this study were categorized locally as sharp sand, soft sand and stony sand (Gravel) .

Brick

Brick is as mall rectangular block typically made or fired or sun dried clay; used in building a large and relatively heavy mobile home; typically a nearly model with limited functionality, fired bricks are most numerous types and are laid in course and numerous pattern known as bonds, collectively known as brick work and may be laid in various kinds of mortar to hold the bricks together to make a durable structure. Bricks are provided in numerous classes, types, materials and sizes which vary with region and time period; and produce in bulk quantities. Two most basic categories of bricks are fired and non–fired bricks (Nooreldin,Osiman and Mobark;2017).

Type of Bricks

Chemical Set Bricks: Chemical set bricks are not fired but may have the curing process accelerated by the application of heat and pressure in an autoclave. The chemical process involved in chemical set bricks are hydrolysis; hydration; dehydration; halogenations; dehalogenation, distillation and crystallization.

Calcium silicate bricks are also called sand lime or flint limebricks depending on their ingredients. Rather than being made with clay they are made with lime binding the silicate material. The raw materials for calcium silicate bricks include lime in a population of about 1 to 10 with sand; quartz; crushed flint or crushed siliceous rock together with minerals colourants. The materials are mixed and left until the lime is completely hydrated; the mixture is then pressed into moulds are in an autoclave for three to fourteen hours to speed the chemical hardening. The finished brick are very accurate and uniform, although the sharp a rises need care ful handling to avoid damage to bricklayer.

Concrete Bricks (Blocks): Bricks of concrete with sand aggregate can be made with a simple machine and a basic assembly line. A convey or belt adds the mixture of concrete and sand aggregate to a machine which pour a measure amount of concrete into a form. The for misvibrated to remove bubbles after which it is then raised to rave the wet bricks spread out on a plier wood sheet. A small elevator then stacks the palettes; after which a fork lift operator moves then to the brickyard for drying. They are made to three standard dimensions in Nigeria which are 9inches, 6inches and 4inches. The dimensions are as follows:-for 9inches; breadth =23.0cm; length =46.0cm; height =23.3cm; hollow segment =17.5cmX13.5cmX14.5cm for 6inches;breath =13.5cm; length =45.5cm; height =23.5cm; hollow segment =16.5cmX8.0cmX8.5cm. Most of the operations are done manually whereby the concrete brick is moved from the machine by labourers to drying ground or the blocks are set with a mould onto the drying ground. (See plates 1&2).

This concrete brick is the type used as sample for the study because it is the prevalent chief building material in the study area.

Tiles

Tiles are products of processed kaolin clay, quartz, other earthen soil, feldspar, limestone and some chemicals grounded separately and mixed together. lt is usually cut into shapes and sizes while wet and then fired in a kiln up to temperatures of about 1800°C to 2000°C. The sizes vary from the smallest 20mm by 20mm size used for checker drought games to any squared or rectangular dimension less or equal to 1mby 1m (Ogunobi, 2018). Most beautifully glazed tilescontains Zircon components which are the major sources of radioactivity in the tiles (Bruzzi,Barroni, Mazzotti,Mele and Righi; 1999). Tiles are used for wall decorations, floor covering and roofing of a house.

Woods, Roofing sheet, Water and others

The wood materials used in the building of houses are different types depending on the functions. Woods are used in planks for doors, window panels and panes, as well as the rafters for the roofing coverage by corrugated iron sheet. The wood materials are gotten from plant trees by lumbering processes.The samples of wood should be the saw dusts from the different woods processed at the saw mill. However their different separate saw dusts were not readily available for collection at the saw mill due to combine processes done by the millers. The radioactivity of woods are not expected to be high because the uptake of Uranium and Thorium into plants are very low and as such their radioactivity would not significantly increase the radioactive dose (Mustonen, 1984)

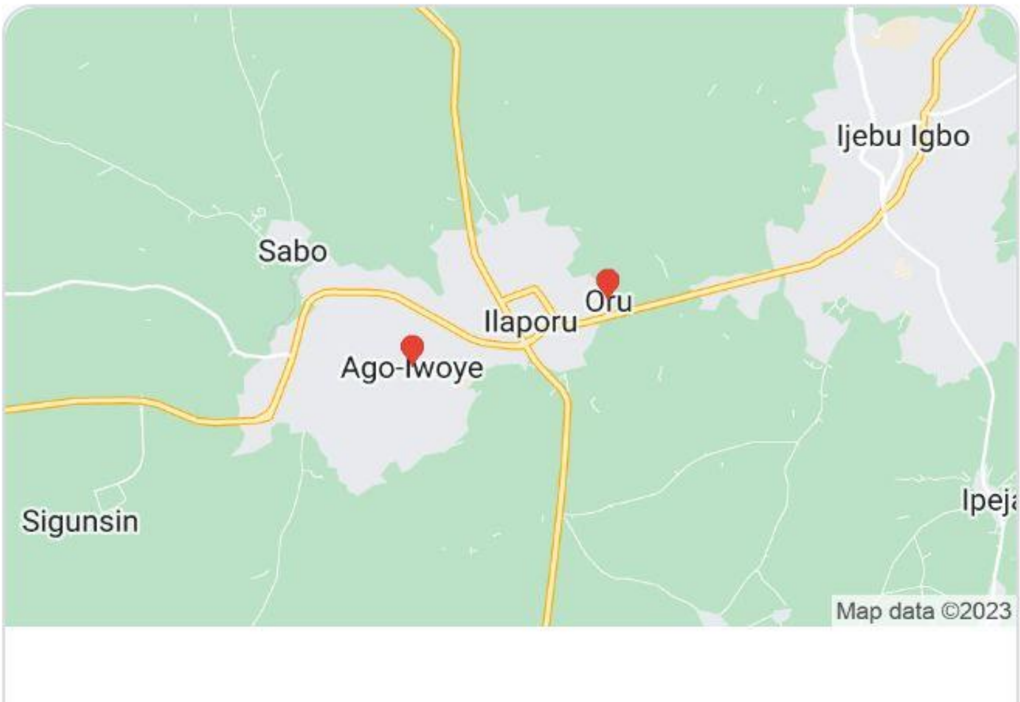
Roofing sheets are another brand of materials that could not be obtained for analysis, due to the method of spectrometry to be used. Same goes for nails and water. The radioactivity of water in building material is not a major concern, considering that water is used in drinking , cooking, bathing and more (Alausa and Ogunobi, 2019).

Description of the Study Area

All the materials used in the study were collected from town sand locations with in the ljebu North local government area/council of Ogun state such as Awa, Oru, Ago-lwoye, llaporu, with the headquarters in ljebu lgbo.

Ijebu-Igbo Town and its environ, are in the Ogun East senatorial district. The towns lie in the area between latitudes 6°55'N to 7°.35'N and longitudes 3° 50'E to 4°55''E. ljebu- lgbo alone has a land mass of 967 km^2 and estimated population of 284,336 in habitants (NPC, 2006)

The geology of the areas within and surrounding the ljebu North local government area are of basement rock complex of Precambrian age; composed primarily of metamorphic and igneous rock, such as schist, older granite, folder gneisses, quartzites and migmatites which are rich in natural radio nuclide like ^{40}K, ^{238}U, ^{226}Ra and ^{232}Th (Alausa,andOdusote,2013 ; Alausa, 2014).



Geological map of Ogun State showing Towns in Ijebu-North

Sample Collection, soft sand, sharp sand, nine inches block, six inches block were collected from, selected concrete block factories such as

Hasbunallahi block factory (Oru)

Psalm121 block factory (Oke-Agbo)

Agbomabiwon block factory (Ago-Iwoye)

Labo block factory (Atikori)

The samples to be analyzed include

a).nine inches block (500g)

b).six inches block (500g)

c).Dangote/Lafarge cement (500g)

d) sharp sand (500g)

e).stony sand (500g)

f) soft sand (500g)

g). floor tiles (500g)

h). wall tiles (500g)

Sample Preparation and Measurement

The samples were all crushed individually and separately in a mortal by its pestle and sun dried. Then it was sieved with a 150micrometer(□m) mesh (except for the cement samples which is already in fine particles) to have very fine particles of each samples. These samples were each weighed by electronic scalar to a value of 500g in a marinelli container, then coded and labelled. The prepared standard samples in the labeled marinelli beakers were then placed on the shelf in the laboratory for stability and were left there for thirty days(30) for each one of them to achieve secular equilibrium. This will allow the rate of decay of the daughter radionuclides to equal that of the parent and ensure that radon gas is confined within the volume (El-Taher and Makhluf, 2011)

After the period of secular equilibrium, the samples were taken to the environmental laboratory of the Nigerian Nuclear Regulatory Agency located inside the University of Ibadan for the gamma ray spectrometry tests, using the Sodium lodide doped with Thallium (Nal(Tl)) detector.

LITERATURE REVIEW

Natural occuring radionuclides (NORs) abound in the earth crust, environment and under ground and together with the cosmic radiations forms about 90%proportions of human exposure to radioactivity (McAulay and Moran, 1989) . It was discovered that ^{238}U and ^{232}Th are present in the earth crust in parts per million (ppm) levels. Potassium is also present in parts per million and about 0.0118% of total amount of natural potassium is ^{40}K (Tufail*et al*. 1991). These radionuclides occur more in tested samples than other ones, including their daughters.

Humans are also exposed toradiations from artficialsources due to technological activities(TENORs) in which radio isotopes and gamma rays could cause both internal and external exposures (ICRP, 1991). Artificial radionuclides such as Caesium-137(^{137}Cs) results from nuclear activities, weapon testing and accidents such as the Chernobyl disaster (McAulay and Moran, 1989).

The natural radionuclides in building materials usually cause external exposure by direct gamma radiations while internal exposure results from inhalation of radon gas (UNSCEAR, 1988). Radon, being a noble gas is inert and can move freely without any interactions through porous building materials to the surface and enter the lungs from indoor air (Fasae, 2013).

In Sudan, Nooreldin et.al. (2017) recorded mean activity concentration values of 23.58$\pm$7.86, 36.14$\pm$5.17, 381.88$\pm$127.43, for ^{226}Ra, ^{232}Th and ^{40}K respectively in Bq/Kg for building materials.

In India,Viruthagiri and Ponnarasi (2011) recorded mean activity concentration values of 46.78, 19.57, 349.87 for ^{232}Th, ^{226}Ra and ^{40}K respectively in Bq/Kg for red bricks.

Though records of specific activities involving tiles as building materials are not common, in Serbia, Jankovicetal (2013) showed that the specific activity for ^{238}U ranged from 43±17 to 114±32 Bq/kg for floor tiles, and 43±17 to 143±36Bq/kg for wall tiles. While the specific activity for ^{232}Th ranges from 53±5 to 72±6Bq/kg for floor tiles and 50±5 to 101±9Bq/kg for walltiles. The activity for ^{40}Klies between 560±40 and 1030±70Bq/kg for floor tiles and 590±40 to 1070±80Bq/kg for walltiles

Similarly in Nigeria, Ademola (2009), recorded a Radium equivalent which ranged between 194 to 328Bq/Kg for imported ceramic wall tiles and 176 to 306Bq/Kg for the floor tiles, the specific activities for wall tiles are 72±14,84±18 and 629±198Bq/Kg for ^{226}Ra, ^{232}Th and ^{40}K respectively, while for the floor tiles, the specific activities are 70±31, 82±24 and 618±231Bq/Kg for ^{226}Ra,^{232}Th and ^{40}K respectively

Radiometric Measurements

The gamma-ray spectrometry counting was done using a well calibrated NaI (TI) and well shielded detector couple to a computer resident quantumMCA2100R Multichannel analyzer for 36,000s. An empty container under identical geometry was also counted for the same time to make room for the background radioactivity counts. The 1460KeV gamma-radiation for ^{40}K was used to determined the concentration of ^{40}K in the sample. The gamma transition energy of 1764.5KeV ^{214}Bi was used to determine the concentration of ^{238}U while the gamma transition energy of 2614KeV ^{208}TI was used to determine the concentration of ^{232}Thwhile ^{137}Cs was detected by its 661.6KeV gamma transition

The efficiency calibration of the detector was done using a reference standard mixed source traceable to Analytical Quality Control Service (AQCS, USA), which has certified activities of the selected radionuclide and has a geometrical configuration identical to sample container. The standard sources contained ten known radionuclide. The energy calibration was also performed by using the peak of the radionuclide present in the standard sources . The channel number is proportional to energy, the channel scale was then converted to an energy scale. This produces an energy calibration curve i.e. energy versus channel.

The activity concentration (A_{sp}) was determined by using the formular

$$A_{sp} = \frac{N_{sam} \exp(\lambda T_d)}{P_E \times \varepsilon(E\gamma) \times Tc \times M} \quad \text{(ii)}$$

Where,

N_{sam} = Background corrected net counts of radionuclide in the sample

T_d = Delay time between sampling and counting.

$\exp(\lambda T_d)$ = Correction factor between sampling and counting

P_E = Gamma ray emission probability (gamma yield)

$\varepsilon(E\gamma)$ = Counting efficiency of the detector

Tc = Sample counting time

M =Mass of sample (Oresegun, *et al*, 1993)

Calculation of activity

The building materials collected from the locations in Oru, OkeAgbo, Atikori, and Ago-Iwoye were prepared and taken to the environmental laboratory of nuclear regulatory authority at the University of Ibadan. The samples were subjected to gamma ray spectrometry and the results are presented in tables I to VII.

Table 1: Natural Radioactivity of Cements

S/N	Samples	^{40}K(Bq/Kg)	^{238}U(Bq/Kg)	^{232}Th(Bq/Kg)
1	HAS1	97.24±9.54	11.67±2.61	3.78±0.31
2	PSA1	148.96±12.11	34.17±5.95	3.22±0.28
3	AGB1	40.92±3.63	3.85±0.89	1.20±0.10
4	LAB1	192.18±14.96	BDL	BDL
	Mean±SD	119.83±10.07	12.42±2.36	2.05±0.17

Table 2. Natural radioactivity of nine inches block

S/N	Samples	^{40}K(Bq/Kg)	^{238}U(Bq/Kg)	^{232}Th(Bq/Kg)
1	HAS2	574.49±36.84	34.92±5.60	0.96±0.092
2	PSA2	309.43±21.86	13.08±2.61	3.62±0.30
3	AGB2	268.73±18.52	6.77±1.50	2.69±0.24
4	LAB2	271.49±19.08	22.59±5.05	12.52±1.10
	Mean±SD	356.04±24.08	19.34±3.69	4.95±0.43

Table 3. Natural radioactivity of six inches block

S/N	Samples	^{40}K(Bq/Kg)	^{238}U(Bq/Kg)	^{232}Th(Bq/Kg)
1	HAS3	471.50±30.15	36.90±5.91	9.06±0.72
2	PSA3	261.61±17.72	10.54±2.14	0.52±0.04
3	AGB3	430.12±28.69	10.54±2.31	1.77±0.15
4	LAB3	707.36±42.53	21.46±4.38	BDL
	Mean±SD	467.65±29.77	19.86±3.69	2.84±0.23

Table 4. Natural radioactivity of sharp (coarse) sand

S/N	Samples	^{40}K(Bq/Kg)	^{238}U(Bq/Kg)	^{232}Th(Bq/Kg)
1	HAS4	511.27±33.30	0.65±0.16	7.08±0.63
2	PSA4	-	-	-
3	AGB4	334.94±25.60	BDL	16.95±1.37
4	LAB4	463.45±30.31	27.20±5.22	4.63±0.38
	Mean±SD	436.55 ±29.74	9.28±1.79	9.55±0.79

Table 5. Natural radioactivity of soft (fine) sand

S/N	Samples	^{40}K(Bq/Kg)	^{238}U(Bq/Kg)	^{232}Th(Bq/Kg)
1	HAS5	347.82±22.63	BDL	BDL
2	PSA5	263.68±19.77	7.62±1.70	BDL
3	AGB5	644.37±40.34	18.73±3.83	BDL
4	LAB5	172.41±13.24	4.04±0.99	6.52±0.54
	Mean±SD	357.07±24.00	7.60 ±1.63	1.63±0.14

Table 6. Natural radioactivity of stony sand (gravel)

S/N	Samples	^{40}K(Bq/Kg)	^{238}U(Bq/Kg)	^{232}Th(Bq/Kg)
1	HAS 6	367.13±24.70	17.32±3.61	12.72±1.03
2	PSA 6	1135.19±64.32	33.04±5.66	9.62±0.87
3	AGB 6	-	-	-
4	LAB 6	892.88±51.93	27.67±4.59	7.01±0.58
	Mean±SD	798.40±46.98	26.01±4.62	9.78 ± 0.83

Table 7. Natural radioactivity of Ceramic Tiles

S/N	Samples	^{40}K(Bq/Kg)	^{238}U(Bq/Kg)	^{232}Th(Bq/Kg)
1	WLT 1	1026.27 ± 54.77	7.98 ± 1.24	BDL
2	WLT 2	1619.75 ± 85.00	64.31 ± 8.66	2.84 ± 0.15
3	FLT 1	BDL	11.79 ± 1.84	0.18 ± 0.01
4	FLT 2	1102.56 ± 57.78	50.59 ± 5.59	4 11 ± 0.24
	Mean±SD	937.15 ± 49.39	33.67 ± 4.33	1.78 ± 0.10

Radium equivalent

The radium equivalent gives the value of a singular quantity (index) which can take into account the radiation hazards contribution from ^{40}K,^{238}U,^{226}Raand^{232}Th.Radium and its daughter products are responsible for about 98.5% of radiological effects of uranium decay series (El-TaherandMakhluf,2011). Hence the radium equivalent is calculated using equation (ii) according to Beretka and Matthew(1985) and (Akpolile and Ugbede, 2019) as follows :

$Ra_{eq} = A_u + 1.43A_{Th} + 0.077A_k$ (ii) Where A_u, A_{Th}, and A_k represent the specific activities of ^{238}U , ^{232}Th and ^{40}K .

Gamma lndex (I□□

This is the value which indicates the conversion of specific radioactivity of the sample of building material to a measure of dose the occupant in a room receives. European Commission proposed this index to verify if the guidelines of EC for building material usage are met. Gamma index is calculated using equation (iii)

Gamma index I□□□□□□$A_k/3000 + A_u/300 + A_{Th}/200 \leq 1$ (iii)

Hazard lndices for alpha radiation

Alpha Index (□□□

The first is the alpha index which gives the proportion of alpha particle radiation in the activity of the radionuclide. This was proposed by Krieger (1981) and Stoulos et al (2003) to be given by equation (iv) as :

Alpha index □□ $=A_u/200$ (iv)

This value should be less than unity. Values calculated are recorded in table 8.

External Hazard Index (Hex)

This is the measure of radiation the human body is exposed to as received on the skin surface. lt is calculated using equation (v) as follows :

$$Hex = AU/370 + A_{Th}/259 + A_K/4810 \leq 1 \qquad (v)$$

This presupposed that 370Bq/kg of ^{238}U, 259Bq/kg of ^{232}Th and 4810Bq/kg of ^{40}K, produces the same gamma dose rate. This imply that the index value must be less than unity in order to keep the radiation hazard in significant, (Kpeglo*etal*,.2011). The calculated values for the Hex are recorded in table VIII.

Internal Hazard Index (H_{in})

This is the internal exposure to car cinogenicradon ^{222}Rn and its short lived progeny through the respiratory organs. The lnternal Hazard lndex (H_{in}) is calculated by reducing the normal limit of ^{226}Ra, by half from 370 to 185Bq/Kg (Mujahid etal 2008). The lnternal hazard index is given by equation (vi) and the calculated values for the samples are recorded in table VIII.

$$H_{in} = AU/185 + A_{Th}/259 + A_K/4810 \leq 1 \qquad (vi)$$

Absorbed Dose Rate

The Monte Carlo method adopted in NewYork (UNSCEAR,1998) considered conversion factors to transform specific activities into absorbed dose rate at 1m above the ground in nano Gray (nGy) perhour by Bq/kilogram with equation (vii) (El-Taher and Makhluf, 2011). Thus, assuming that contributions from all other naturally occurring radio nuclidesto the absorbed dose are not really significant, then, the actual dose rates is;

$$D\ (nGyhr^{-1}) = 0.462A_U + 0.604A_{Th} + 0.0417A_K \qquad (vii)$$

The world average is 55 $nGyhr^{-1}$ (ElTaher,2012). The values calculated for these samples are shown in table 8.

The Annual Effective Dose DE

Ln order to estimate the annual effective dose rates, we need to consider the 80% indoor occupancy and the conversion coefficient from absorbed dose in air to effective dose 0.7 Sv/Gy (UNSCEAR,2008). The annual effective time used is given by 365.25 days multiplied by 24hours which amounts to8766h/y (El-Taher and Makhluf, 2011 ; Medhizadeh et al 2011) .Hence the annual effective dose is as calculated using equation viii.

$$DE = D\ (nGyhr^{-1}) \times 10^{-9} \times 8766h/y \times 0.8 \times 0.7Sv/Gy \qquad (viii)$$

The calculated annual effective dose for the samples are recorded also in table VIII .

RESULTS AND DISCUSSION

The specific activities for the radio nuclides in each sample are as recorded in the coulums bearing AU, A_{Th} and A_K of table viii.

All the hazard indces calculated are lower than the upper safety limits individually and collectively. The mean radium equivalent for all the building samples studied is 63.17Bq/Kg which is very low to 370Bq/Kg as the upper safety limit, with range of 24.58Bq/Kg to 108.38Bq/Kg for cement and ceramic tiles respectively.

The alpha index has a mean of 0.091 and a range of 0.038(soft sand) to 0.168(cement) which is very much less than unity. The gamma index values are all, also very much less than unity, with a mean of 0.250 and range of 0.092 (cement) to 0.434 (ceramic tiles). Similarly the external hazard(Hex) and internal hazard (H_{in}) indices are less than unity with mean values 0.171 and 0.220 respectively. The range for H_{ex} is between 0.066 for cement to 0.293 for tiles . Likewise for H_{in} the range is 0.10 for cement to 0.384. All these are very much below the safety value of unity (1.0).

The dose rate for the samples has mean of 31.96 nGy/hr which is less than the world average of 55nGyhr^{-1}and the range lies between 11.97nGyhr^{-1} and55.71nGyhr^{-1}.The Annual effective dose recorded for the samples ranged between 0.059mSv/yr for cement and 0.273mSv/yr for tiles with the mean being 0.157mSv/yr. The upper safety limit is 1.0 mSv/yr (UNSCEAR, 2008 ; El-Taher,2012). The most important fact here is that the risk of exposure to carcinogenic radiation is very low.

Table 8. Calculated Hazards lndices for the samples

Building Material	AU (Bq/kg)	A_{Th} (Bq/kg)	A_K (Bq/kg)	Ra_{eq} (Bq/kg)	□□ -•--	I□□□ •-	H_{ex} -•--	H_{IN} .-(	Dose(D) nGyhr^{-1})	AED (mSv)
Cement	12.42	2.05	119.83	24.58	0.062	0.092	0.066	0.10	11.97	0.059
9" Block	19.34	4.95	356.04	53.83	0.097	0.208	0.145	0.198	26.77	0.131
6" Block	19.86	2.84	467.65	59.93	0.099	0.236	0.162	0.216	30.39	0.149
Sharp Sand	9.28	9.55	436.55	56.55	0.046	0.224	0.153	0.178	28.26	0.139
Soft Sand	7.60	1.63	357.07	37.43	0.038	0.153	0.101	0.122	19.39	0.095
Gravel	26.01	9.78	798.40	101.47	0.130	0.402	0.274	0.344	51.22	0.251
Tiles	33.67	1.78	937.15	108.38	0.168	0.434	0.293	0.384	55.71	0.273
Mean±SD	18.31	4.65	496.10	63.17	0.091	0.250	0.171	0.220	31.96	0.157

This study recorded the highest radio activity for building materials from the ceramic tiles with radium equivalent of 108.38Bq/Kg and the lowest from cement with 24.58Bq/Kg.The cement samples in the study recorded the lowest among all other studies from other countries considered for comparison in table IX. However the gravel (stony sand) recorded the highest radio activity among the works compared with it. Other samples studied compared favourably with the world average values. Literatures show that cement brick (concrete block) has more radio activity than the clay brick (Fasae, 2013; Amrani et al, 2001 and Abdulrahman etal, 2013).

Materials to be used for homes and residential apartments have recommended maximum limit value for safety of 370Bq/Kg while those for factories and industrial buildings are pegged at a maximum limit of 740 Bq/Kg (NEA-OECD, 1979).

Table 9. Comparison between radioactivity of this study and other Countries

Country [Author]	Building Materials	^{238}U (Bq/kg)	^{226}Ra (Bq/kg)	^{232}Th (Bq/kg)	^{40}K (Bq/kg)	l ___	Ra_{eq} (Bq/kg)	H_{EX} ___	H_{IN}	Dose (nGyhr^{-1}) ___
CROATIA[42]	Sand	---	11.3	17.6	225.4	---	53.8	--	--	----
C. Block	___	11.8	14.0	147.2	43.0	___	-_____-	__	-____-	_____
Cem(52.5)	---	29.6	23.3	256.8	---	182.6	---	----	----	___
Cem(32.5)	---	28.0	23.1	307.3	---	185.7	----	-----	-----	
Cem(42.5)	__	31.6	25.4	252.4	---	187.4	----	----	----	
GHANA[23]	Cement __	39.94	25.44	233.0	---	90.12	0.25	0.34	41.60	
EGYPT[10]	R.Brick ---	33.4	27.7	284.0	---	0.69	---	---	------	
	C. Block	---	10.6	3.1	54.1	---	0.13	----	----	------
[13]	Cement __	19.73	39.04	61.16	0.56	79.85	0.16	__	35.25	
[11]	Cement __	36.6	43.2	82.0	__	103.0	__ ---	__---	__	----
	Sand	---	11.7	18.8	248.0	----	57.65	--_	----	----
	Gravel	---	13.4	23.0	193.0	----	62.4	----	----	-----

Marble ---- 15.9 12.3 60.0 --- 37.76 --- --- -----
ITALY[9] Wall Tile ___ 79±3 ---- 66±3 890±39 --- --- ---- --- -----
FloorTile 58±2 ---- 52±2 830±35 --- --- ---- --- -----
[41] Cement --- 38±14 22±14 218±248 --- 92±60 --- --- ---
Marble --- 4.0±12 0.9±3.6 16±20 ---6.0±7.0 --- --- ---
PAKISTAN[45]Gravel --- 24.8 9.9 51.3 --- 42.9 --- --- ----
[15]R.Brick ---- 23.0 35.0 431.0 --- --- --- --- ----
[22]Cement ---- 26.1 28.6 272.9 ---- --- ---- --- ----
CHINA[49] R.Brick ---- 59.0 50.0 714.0 ---- ---- ---- ---- ----
[50] Cement ---- 39.7 34.3 189.0 ---- -------- ---- ----
GREECE
[39] R.Brick ---- 35.0 45.0 710.0 ---- ---- ---- --- ----
[43] Cement ---- 20.0 13.0 241.0 ---- ---- ---- --- ----
BRAZIL[26] Cement ---- 41.0 27.0 422.0 ---- ---- ---- ---- ----
Gravel ---- 10.3 ND 933.0 ---- 82.1---- ---- ----
[27] Cement ---- 61.7 58.5 564.0 ---- 188.8 ---- ---- -----
Sand ---- 14.3 18.0 807.0 ---- 102.2 ---- ---- ----
ALGERIA[7] Cement --- 41±7 27±3 422±3 ---- 112±8.2 --- ---- ---
Sand --- 12±1.0 7±1.0 74±7.0 --- 28±7.1 --- ---- ---
Marble --- 23±2 18±2 310±3 ---73±4.1 --- ---- ---
C.Block --- 65.0 51.0 675.0 --- ---- --- --- ---
[1] R.Brick1 --- 13.0 10.0 183.00.31 41.31 0.11 0.15 19.64
R.Brick2 --- 18.0 12.0 211.0 0.38 51.41 0.14 0.19 24.36
lNDIA[25] Cement --- 37.0 24.1 432.2 --- 104.7 --- --- ----
: Sand --- 43.7 64,4 455.8 --- 170.8 --- ---- ----
[40] R.Brick --- 18.3 19.4 238.4 --- 45.94 --- ---- ----
[40] R.Brick --- 19.57 46.78 349.87 0.84 113.54 --- --- ----
lRAN[30] R.Brick --- 37.0 12.2 851.4 0.47 120.0 0.32 0.42 53.72
C.Block --- 20.7 3.0 436.00.2358.58 0.16 0.21 26.48
Gravel --- 20.4 6.3 450.7 0.25 64.11 0.17 0.23 28.67
Cement --- 39.6 28.9 290.8 0.37 103.32 0.28 0.39 41.90
SAUDI ARABIACement --- 38.4 45.3 86.0 --- 108.23 0.19 --- 48.94
[12] Sand --- 12.3 19.7 260.0 --- 59.88 0.17 --- 29.49
Gravel --- 14.7 24.2 195.0 --- 65.51 0.28 --- 37.64
Marble --- 12.7 13.2 64.0 --- 39.64 0.07 --- 18.17
NIGERIA R.Brick --- 18.7 39.8 351.1 --- ----- 0.28 --- 49.4
16] C.Block --- 47.9 63.8 572.6 --- ----- 0.50 --- 87.4
[21] Tiles --- 61.1 70.2 514.7 __--- 204.42 0.55 0.77 177.6
(This work) Cement 12.42 -2.05 119.83 0.092 24.58 0.066 0.100 11.97
9"Block 19.34 -- 4.95 356.04 0.208 53.83 0.145 0.198 26.77
6"Block 19.86 -- 2.84 467.65 0.236 59.93 0162 0.216 30.39
Sharp sand 9.98 --- 9.55 436.55 0.224 56.55 0.153 0.178 28.26
Soft sand 7.60 --- 1.63 357.07 0.153 37.43 0.101 0.122 19.39
Gravel 26.01 --- 9.78 798.40 0.402 101.47 0.274 0.344 51.22
Tiles 33.67 --- 1.78 937.15 0.434 108.38 0.293 0.384 55.71

CONCLUSION

The natural radioactivity measurements and estimated/calculated hazard indices from the samples through the gamma ray specrometry of the radionuclides ^{40}K, ^{238}U and ^{232}Th,show that all the building materials samples are safe for use in construction of houses for residential as well as industrial purposes. The radioactivity level was highest in the ceramic tiles, followed by gravel (stony sand), 6" concrete(cement)block, sharp sand, 9" concrete (cement) block, soft sand and cement in that order respectively.

The hazard indices recorded for all samples are all below the safety limit standard except for the dose rate in ceramic tile which was 55.71nGyhr^{-1}which was just slightly above the world average of 55.0nGyhr^{-1}

The safety limit for public exposure in Annual Effective Dose (AED) is 1mSvyr^{-1} (ICRP, 1991; UNSCEAR, 1988). The samples had values so much lower than the maximum safety limit of AED at mean value of 0.157 mSvyr^{-1}, with the range of 0.059 mSvy^{-1} to 0.273 mSvyr^{-1}.

Recommendations

Further studies still be needed to be carried out to involve more regions in the whole Ogun state to get more information on the radioactivity levels.

REFERENCES

Abdulrahman,K., Abdelhakim, H.B. and Benamar D. (2013) Natural Radioactivity in red clay bricks manufactured in Tlemcen-Algeria, using well-shape NaI(Tl) Detector. Advances in Physics Theories and Applications, IISTE, Vol.25: 120-128 . ISSN2225-0638.

Ademola, J. A. (2009). Natural radioactivity and hazard assessment of imported ceramic tiles in Nigeria; African Journal of Biomedical Research. Vol. 12, No. 3. 112-117.

Akpolile, F.A. and Ugbede, F.O. (2019). Natural radioactivty study and radiological risk assessment in surface water and sedeiments from Tuomo river in Burutu, Deltastate.Journal of the Nigerian Association of Mathematical Physics. 50: 267-274. ISSN 1116-4336

Alausa, S.K. and Ogunobi,S.G. (2019) Radiometric impact assessment of raw water from river Osun purified for public consumption in ljebu-lgbo , south western Nigeria. Journal of the Nigerian Association of Mathematical Physics. 50: 259-266. ISSN 1116-4336

Alausa, S. K. and Odusote, O. O. (2013). Radiological health impact due to activity concentrations of radionuclides in the soil from two major areas in Ijebu-North Local Government, Ogun State, Nigeria, The Nucleus 60 no4, 293-299

Alausa, S.K. (2014) Radiological Assessment of Soils on the Way sides of the Road under construction in Ijebu-Ode, Ogun State, South western Nigeria Journal of Natural Sciences Research Vol.4,No.1580-84

Amrani,D., and Tahtat, M. (2001). Natural Radioactivity in Algerian building materials, Appl. Radia. & lsot. 54 ; 687-689.

Beretka,J.and Mathew,P.J.(1985).Natural radio activity of Australian building materials, industrial waste and by-products.*HealthPhys*.48,87–95.

Bruzzi,L.,Baroni,M.,Mazzotti,G., Mele, R. and Righi, S (1999). Radio activity in raw material sand and products in the Italian ceramics industry. *Journal of Environmental Radioactivity*. 47(2000) 171–181.

El Tahawy, M.S. and Higgy, R.H. (1995) Appl. Radiat. Isot. 46: 401-406

El-Taher, A., (2010). Gamma spectroscopic analysis and associated radiation hazards of building materials used in Egypt. Radiat.Prot.Dos.138(2):158-165.

El-Taher, A., (2012). Assessment of natural radio activity levels and radiation hazards for building matrerials used in Qassim area. Saudi Arabia. Rom.Journ. of Phys, Vol. 57., Nos. (3-4): 726-735 . Bucharest.

El-Taher, A. and Makhluf, S. (2011). Radiological Significance of Egyptian Limestone and alabaster used for construction of dwellings. Indian Journal of Pure and Applied Physics, 49, 157 – 61.

European Commission (1999) Radiological protection principles concerning the natural radioactivity of building materials. Radiation Protection 112. EC, Brussels.

Faheem, M.,Mujahid, S.A. and Mtiuallah, M (2008) . Assessment of radiological hazards due to natural radioactivity in soil and building material samples collected from six distrcts of the Punjab province, Pakistan. Radiat. Meas. 43; 8: 1443-1447.

FasaeK.P. (2013) Natural radio activity in building materials in Ekiti State, south Western Nigeria. Civil and Environmental ResearchVol.3(11) , 109-114.

IAEA (1994). International Basic Safety Standard for Protection Against Ionizing Radiation for the safety of radiation sources, Safety series No. 115-1 (IAEA Vienna).

ICRP (1991).Recommendations of the International Commission on Radiological Protection, Pergamon Press, Oxford, ICRP Publication 60.

Jankovic, M.M., Rajacic,M.M.,Rakic,T.M.,Todorovic,D.J.(.2013). Natural radio activity in imported ceramic tiles used in Serbia, *Processing and Applications of Ceramics.*7(3),123–127, 2nd Conference of the Serbian Ceramic Society-2CSCS.. DOI:10.2298PAC13803123J

Jibiri,N.N.,Alausa, S. K.andFarai,I.P., (2009). Radiological Hazard lndices Due to Activity Concentration of Natural Radionuclides in Farm soils from two background radiation areas in Nigeria. international Journal of low radiation. 6 : 79-95 .

Joel, E.S., Maxwell,O.,Adewoyin, O.O, Ehi-Eromosele, C.O.,Embong, Z and Oyawoye, F. 2018. Assessment of Natural Radioactivity in various comercial ceramic tiles used for Building purposes in Nigeria . Methods X, Environmental Sciences, Medicine . 5. 8-19 ., doi.org/10.1016/j.mex.2017.12.002.

Khan,K.,and Khan, H.M. (2001). Natural gamma-emitting radionuclides in Pakistani Portland cement. Appl. Radiat. Isot 54: 861-865.

Kpeglo,D.O., Lawluvi,H., Faanu,A., Awudu,A.R., Deatanyah,P., Wotorchi,S.G., Arwui,C.C. Emi-Reynolds, GandDarko, E.O. (2011). Natural radio activity and its associated Radiological Hazards in Ghanaian Cement. *Research Journal of Environmental and Earth Sciences.*3(2),160–166

Krieger, V.R., (1981) Radioactivity of construction materials. Betonwerk Fertigteil Tech 47: 468-473.

Kumar, V., Ram, Achandran, T.V.,and Prasad, R. (1999). Natural Radioactivity of lndian building materials and by products. Appl. Radiat. Isot. 51: 93-96.

Malanca, A.,Pessina, V., and Dallara, G.,(1993) Radionuclide content of building materials and gamma ray dose rates in dwellings of Rio-Grande Do-Norte, Brazil. Radiat. Prot. Dosim ; 48 ; 199-203.

Malanca, A.,Pessina, V., and Dallara, G., Luce, C.N., and Gaidol, L. (1993)Natural Radioactivity in building materials fromthe Brazillian state of Espirito Santo. Appl.Radiat. Isot. ; 46: 1387-1392.

McAulay, I.R.andMoran, D.(1989) Radiocaesium falloutin lreland from the Chernobyl accidents. Journ. Radiol. Prot.9: 29-32.

McAulay,I.R. and McLaunghlin, J.P. (1985) Indoor Natural Radiation Levels in lreland. Sci.Total Environ.45: 319-325

Mehdizadeh,S., Faghihi, R.andSina, S(2011) Natural radioactivity in building materials in lran. NUKLEONIKA; 56 (4) : 363-368

Mujahid,S.A.,Rahim,A.Hussain, S. and Farooq, M.(2008).Measurements of natural radio activity and radon exhalation rates from different brands of cement used in Pakistan, *Radiat.Prot.Dosim*.130;206–212.

Mustonen, R (1984) Natural Radioactivity in and Radon exhalation from Finnish Building Materials Health Physics . 46 : 1195-1203

National Population Commission (NPC) (2006) Population distribution by sex, state, LGAs and senatorial districts : Census priority tables . Vol. 3.http///wwwpopulation.gov.ng./index.php/censuses

No oreld in Fadol.,OsimanBeelly and Mobark Tagabo (2017), Natural radio activity concentration and Radiological Assessment in Soil Samples around Abujubauha; Eastern Nubamountain. Saudijournal of Engineering and Technology10.110-117

Nuclear Energy Agency-Organization for Economic Cooperation and Development (NEA-OECD). (1979) Exposure to radiation from natural radioactivity in building materials; Report by a group of Experts. Paris. France.

Ogunobi,Steven.Gbenga.,(2018).Natural Radioactivity of Nigerian Ceramic tiles and assessmentoftheEnvironmentallmpactsandHealthHazardinAbeokuta,ASUPjournaloflnnovative ResearchandTechnology.ISSN2682-50311(1)21-27.

Oresegun, M. O., Decker, K. M. and Sanderson, C. G. (1993).Determination of self absorption correction by computation in routine gamma-ray spectrometry for typical environmental samples. J. Radioact. Radiochem. 4(1): 38 – 45.

Papaefthymiou, H., and Gouseti O. (2008) Natural radioactivity and associated radiation hazards in building materials user in Peloponnese, Greece.Radiat. Meas. 43; 8: 1453- 1457

Ravisankar, R., Vanasundari, K., Chandrasekaran, A.,Suganya, M., Eswaran,P., Vijayagopal, P. and MeenakshiSundaram, V. (2011). Measurement of natural radioactivity in brick samples of Namakkal, Tamilnadu,India using gamma-ray spectrometry. Archives of Physixs library, Scholars Research Library. 2(2) : 95-99 ISSN 0976-0970

Risso,S.,Brai,M., Basile,S., Belia, SVand Hauser, S. (2001) . Gamma activity and geochemical features of building materials : estimation of gamma dose rate and indoor radon levels in Sicily. Appl. Radiat.lsot. 55: 259-265.

Solific, T.,Barasic,D.,Solific, U andDurokovic,M., (2011). Radioactivity of Some Building and Raw Materials used in Croatia. Polish Journal of Chemical Technology. Vol. 13. 3: 23-27.

Stolous, S., Manolopoulo, M and Papastefanou,C (2003) Assessment of natural radiation exposure and radon exhalation from building materials in Greece. Jour. Enviro. Radiaoact. 69; 225-240.

Tufial, M., Ahmad, N., Khan, H. A. and Zafar, M. S. (1991). Gamma activity in the bricks used for construction of dwellings in Rawalpindi and Islamabad areas of Pakistan, Radiation protection Dosimetry, Vol. 37, pp. 197 – 200.

Tufial,M.,Ahmad,N.,Mirza, S.M. and Khan,H.A.(1992).Natural radioactivityfrom building mterials usedinRawalpindiandIslamabad, Pakistan. Sci. Total. Environ. 121: 282-291.

United Nations Scientific Committee on the Effect of Atomic Radiation(UNSCEAR) (1988).Sources, effect and risks of ionizing radiation, UNSCEAR (A/43/45), New York.

United Nations Science Committee on the Effect of Atomic Radiation–UNSCEAR(2008).*Sources and effects of ionizing radiation:Report to the General Assembly with Scientific Annexes,VolumeI*, NewYork: United Nations,

Viruthagiri G. and PonnarasiK.(2011) Measurement of Natural radio activity in brick samples in Indian. Advances in Applied Science Research; Pelagia Research library;2(2):. 103 - 108. ISSN : 0976-8610

Xinwei, L. (2005). Natural radio activity in some building materials of Xi'an, China. Radiat. Meas.,40; 94–97.

Xinwei,L.(2007).Natural radio activity in some building materials of Shaanxi, China.J. Nucl. IEEETrans.,54(2);327–332.