Radiological Hazard Indices of Hollow Aggregate Filled Stone-Dust Blocks and Sandcrete Blocks Produced in Jos, Plateau State, Nigeria

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Abstract

Measurement of gamma radiation emanating from hollow sandcrete and aggregate filled stone-dust blocks across major block industries in Jos North Central Nigeria was carried out using RS-230 Gamma Spectrometer. The purpose of the investigation is to determine the uranium (^{238}U), thorium (^{232}Th) and potassium (^{40}K) contents in them for assessment of radiological hazard indices. Results obtained show that concentrations of ^{238}U, ^{232}Th and ^{40}K in the two major types of blocks vary from 3.95-9.67 ppm, 14.93-30.20 ppm, and 0.62-4.16% respectively. Higher values were recorded in the aggregate filled stone-dust blocks compared with the sandcrete blocks. Activity concentration of the sandcrete blocks comprises 62.79 Bq/Kg for ^{238}U, 71.83 Bq/Kg for ^{232}Th, and 447.02 Bq/Kg for ^{40}K, while it is 110.16 Bq/Kg, 114.15 Bq/Kg, and 1194.88 Bq/Kg for ^{238}U, ^{232}Th and ^{40}K respectively for the aggregate filled stone-dust blocks. Consequently, the values of indoor absorbed dose rate, annual effective dose equivalents (indoor and outdoor), radium equivalent activity, internal hazard index (indoor and outdoor) as well as excess lifetime cancer risk (ELCR) are higher among the aggregate filled stone-dust blocks compared to the values recorded for the sandcrete blocks. Radiological hazard indices are not only higher in the aggregate filled stone-dust blocks but are much higher than the recommended limits in most cases. With excess lifetime cancer risk (ELCR) of up to 2.99 x10^{-3}, it is recommended that radiological safety be given priority over and above strength and durability in the choice of blocks for residential building.

Keywords: Aggregate filled stone-dust block; Sandcrete block; Uranium; Thorium; Potassium; Activity Concentration; Radiological Hazard indices; Jos Metropolis.

1. Introduction

Hollow sandcrete blocks are masonry units made from a mixture of sand, cement and water. They are largely used as walling materials in the construction of shelter and other infrastructures (Sholanke *et al*. 2015). Sandcrete blocks are commonly used in building construction in many countries, including Nigeria (Oyekan & Kamiyo 2011; Dashan & Kamang, 1999; Al-Khalaf & Yousif 1984; Morenikeji *et al*. 2015). They are reputed to have adequate strength and stability, provide good resistance to weather and ground moisture; and are durable, easy to maintain, as well as resistant to fire and heat among others (Anwar *et al*. 2000, Nair *et al*. 2006). Construction of load bearing and non load bearing structures (roof gutters, drainage ditches and strip foundations) are also done using sandcrete blocks.

The principal component of hollow sandcrete block is sand. Sand is a naturally occurring granular material composed essentially of silica. It is produced from weathering and decomposition of rocks. Sand is usually deposited along the banks and bed of major rivers and streams through erosion and deposition processes. For construction, sands must be clean and coarse, free from organic matters and silt coatings, chemically inert, and contain no salt which attracts moisture from the atmosphere. The preference of aggregate filled stone-dust block (Figure 1) over ‘normal’ sandcrete block is becoming popular in many cities in Nigeria, including Jos. People are more reassured of the strength and durability of the block they buy if it contains aggregates and stone-dust. However, the addition of aggregates and stone-dust originating from Jos and environs in the block mix invariably increases radiological hazard from such blocks. This is because the aggregates and stone-dust are derived from rocks relatively rich in naturally occurring radioactive materials (NORM) which increases the uranium (^{238}U), thorium (^{232}Th) and potassium (^{40}K) concentrations in the blocks.

According to Sholanke *et al.* (2015), standardization and regulation of quality for all products including blocks is vested in the Standards Organization of Nigeria (SON). However, no standard has been set for natural radioactivity in materials for building construction. The Federal Building Code of Nigeria also stipulates what all materials and components used in the construction of buildings must achieve, but no reference was made to radiation dose from these materials and components. According to Afolayan *et al*. (2008); Anosike (2011), the Nigerian Federal Building Code of 2006 stipulates that application of all materials and components used in the construction of buildings must provide aesthetics; it should be durable, functional, and affordable. The code also stated that locally available building materials should be integrated for the additional advantages of availability, identity, job creation and affordability. The aim of this study, therefore is to determine radiological hazard indices from both ordinary sandcrete blocks and aggregate filled stone-dust blocks produced by major block industries in Jos Metropolis and to assess the level of radiation safety of the users.

Figure 1. Composition and completion of aggregate filled stone-dust block.

2.0 Materials and Methods

2.1 The study area

The study area which focuses on metropolitan Jos, is located in north central part of Nigeria (Figure 2) at an elevation of about 1200 metres above mean sea level. The city has a population of about 1,500,000 residents. It is the administrative capital of Plateau State and thus the need for shelter is increasing at a fast rate.

The Jos area is underlain by rocks of the Nigerian Basement Complex, the Younger Granites and the Newer Basalts (Figure 3) Kinnaird *et al.* (1981). The Basement Complex rock found within the area of interest is mainly migmatite while the Jos Bukuru Complex, the Rukuba Complex and the Shere Complex constitute the Younger Granites suite. The sequence of magmatic events of the Jos Bukuru Complex can be classified into three namely the early granite, the central granite, and the volcanic cycles. The early granite cycle consists mainly of biotite granite, quartz pyroxene fayalite porphyry and granite porphyry.

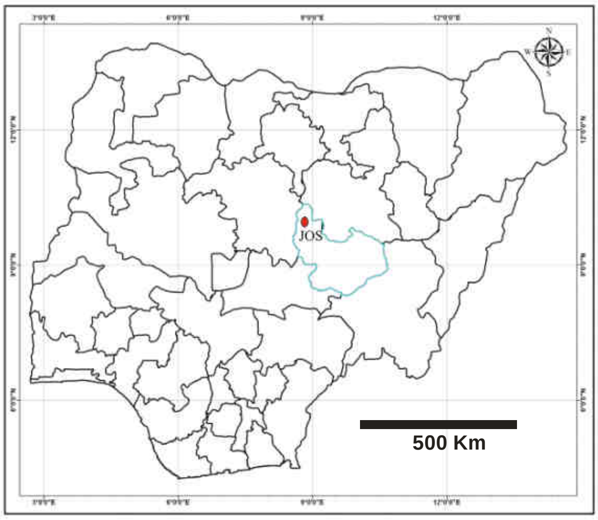

Figure 2. Location of Jos Plateau State Nigeria.

The central granite cycle consists of microgranite, biotite granites and hornblende fayalite granite, while the volcanic cycle is made up of rhyolite and pyroclastics as well as felsites and dykes. It is generally believed that the richest and most extensive alluvial deposit of tin and columbite in the Younger Granite Province was derived from the Jos-Bukuru Complex**.** The Rukuba Complex consists of two overlapping plutons of biotite granite, and covered by large basalt flow at the central part. The sequence of granite intrusion here includes the northern pluton and the southern pluton (Macleod et al. 1971). The northern pluton comprises of Timber Creek biotite granite while the southern plutons consists of Dutse Kura biotite granite, Rukuba biotite granite and hornblende biotite granite. The rocks of the Rukuba Complex are generally medium to coarse grained. The Shere Complex is located next to the Jos-Bukuru Complex. It is made up of monzogabbro, fayalite granite, biotite granite, arfvedsonite aegirine granite, riebeckite annite granite, arfvedsonite albite granite and granite porphyry. Rocks of these three complexes represent a major source for stone aggregates and stone-dust production within the Jos Metropolis. Newer and lateritized basalts are found around Rukuba Complex to the north west of Jos. The basalts are believed to be products of volcanic activities which took place intermittently from Tertiary (65 Ma) to Recent time (~1 Ma).

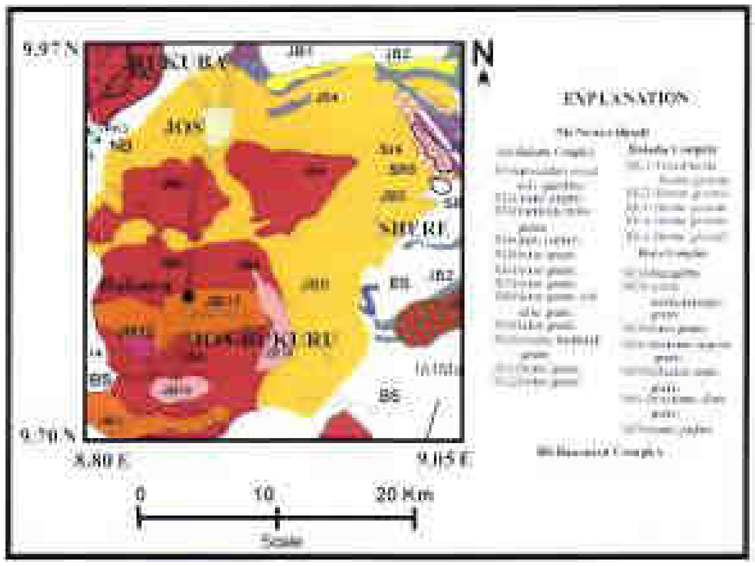

Figure 3. Geological map of Jos and Environs.

2.2 *Determination of concentration of naturally radioactive elements*

Measurement of gamma radiation emanating from the naturally radioactive constituents of both sandcrete blocks and aggregate filled stone-dust blocks was carried out using RS-230 Gamma Spectrometer (Figure 4). The spectrometer is a handheld auto-stabilized 1024 channel piece of equipment which uses a large (103 cm^3) BGO (Bismuth Germanate Oxide) detector for improved level of system sensitivity and accuracy. The use of a BGO gives very significant increase in performance over the normal NaI detector. A preset time of 120 seconds was used for the measurement per point to allow for better accuracy, while the assay mode provided the concentrations of Potassium (K %), equivalent Thorium (eTh) in ppm, and equivalent Uranium (eU) in ppm for each point of measurement. The energy response of the equipment is 30–3000 kev. Measurement of gamma radiation was carried out on each of the sampled block over a production period of seven (7) days, and the average value for each of the block type calculated. The values were then converted into activity concentrations in Bq/kg with which the levels of radiological hazard were determined.

Figure 4. RS-230 BGO Handheld

Gamma-Ray Spectrometer.

3. Results and discussion

Radionuclide concentration, activity concentration, absorbed dose rate in air, annual effective dose equivalent (AEDE), radium equivalent activity (Ra_{eq}), hazard indices, and excess lifetime cancer risk (ELCR) were determined in this study.

3.1 Radionuclide concentration

Concentrations of ^{238}U, ^{232}Th and ^{40}K in sampled blocks vary from 3.95-9.67ppm, 14.93-30.20 ppm, and 0.62-4.16% respectively (Table 1). Generally, higher values were recorded within the aggregate-filled stone-dust blocks compared to 'ordinary' sandcrete blocks. This is because the stone aggregates and stone-dust from which the blocks were made have higher concentration of these radionuclides in them. It is recognized that granitic rocks (the source of the stone aggregates and stone-dust) are commonly enriched in Thorium (Th) and Uranium (U), with an average 15 µg/g of Th and 5 µg/g of U(Faure 1986; Mènager *et al.* 1993).

Table 1. Concentrations of ^{238}U, ^{232}Th and ^{40}K in the hollow blocks from the block industries in the study area.

SNo	BLOCK INDUSTRY	LOCATION		BLOCK TYPE	U (ppm)	Th (ppm)	K%
		LAT°N	LON°E				
1	Carsely Ventures, Tudunwada	9.876	8.863	Sandcrete	6.10	24.37	0.89
2	Nantum, Federal Low Cost	9.879	8.851	Sandcrete	5.63	19.88	0.84
3	Kundung, Zaramaganda	9.847	8.866	Sandcrete	5.24	16.60	0.62
4	Kwang, Lamingo	9.872	8.928	Sandcrete	6.63	16.54	1.48
5	Haske 1, Lamingo Road	9.888	8.947	Sandcrete	4.73	17.43	1.41
6	Haske 2, Lamingo Road	9.888	8.948	Aggregate /Stone dust	7.54	23.76	3.81
7	Nwobodo, Zaria Road	9.967	8.833	Sandcrete	4.31	16.28	2.56
8	Don, Lamingo Junction	9.903	8.903	Sandcrete	4.96	16.66	1.47
9	Excellence, Odus	9.946	8.907	Sandcrete	3.95	14.93	1.63
10	A. S. Mohammed 1, Feringada	9.959	8.873	Aggregate /Stone dust	9.05	28.80	3.40
11	A. S. Mohammed 2, Feringada	9.960	8.873	Sandcrete	4.26	19.23	1.74
12	Peniel, Rayfield	9.848	8.882	Aggregate /Stone dust	9.67	30.20	4.16
13	Smid Engineering, Rayfield	9.818	8.875	Aggregate /Stone dust	9.42	29.70	3.90
14	Retsat, Rayfield	9.824	8.881	Sandcrete	5.34	16.56	1.53
15	Oye, Rukuba Road	9.786	8.858	Sandcrete	4.78	16.12	1.54
SUMMARY				AVERAGE	6.11	20.47	2.07
				MINIMUM	3.95	14.93	0.62
				MAXIMUM	9.67	30.20	4.16

3.2 Activity concentration

Activity concentration was calculated by multiplying the radionuclides concentrations presented in Table 1 with the conversion factors shown in Table 2. Results obtained vary from 48.78-119.42 Bq/Kg for ^{238}U, 60.62-122.61 Bq/Kg for ^{232}Th, and 194.06 -1302.08 Bq/Kg for ^{40}K (Table 3). Average values of activity concentration for the three radionuclides in the 'ordinary' sandcrete blocks are 62.79 Bq/Kg for ^{238}U, 71.83 Bq/Kg for ^{232}Th, and 447.02 Bq/Kg for ^{40}K, while for the aggregate-filled stone-dust blocks, the values are 110.16, 114.15, and 1194.88 Bq/Kg for ^{238}U, ^{232}Th and ^{40}K respectively. Clearly, the values of activity concentration are higher within aggregate-filled stone-dust hollow blocks compared to 'ordinary'sandcrete hollow blocks. The implication of this trend is that radiological hazard will be higher in building constructed with aggregate-filled stone-dust hollow blocks.

3.3 Absorbed Dose Rate in Air

The absorbed dose rate in the air due to gamma rays from the blocks 1 metre above the ground was calculated according to UNSCEAR (2000), using Equation 1.

$D\ (nGy/h) = 0.462A_U + 0.621A_{Th} + 0.0417A_K$ (*1*)

Where 0.462, 0.621 and 0.0417 are the conversion factors for ^{238}U, ^{232}Th and ^{40}K respectively. The assumption here is that other natural radionuclides contributes negligible amount to the absorbed dose rate. Results obtained (Table 3) varies from 79.84 – 185.61 nGy/h. For the sandcrete blocks, the value varies from 79.84-107.86 nGy/h with an average of 92.26 nGy/h, while for the aggregate-filled stone-dust blocks, it varies from 152.65-185.61 nGy/h with an average value of 171.61 nGy/h.

3.4 Annual Effective Dose Equivalent (AEDE).

Annual (indoor and outdoor) effective dose equivalent was calculated for the two types of block under study using Equation 2 and 3.

$$AEDE_{Indoor}\ (mSvy^{-1}) = D\ (nGyh^{-1})\ x\ 8760\ hy^{-1}\ x\ 0.75\ x\ 0.7SvGy^{-1}x\ 10^{-6} \quad (2)$$

$$AEDE_{Outdoor}\ (mSvy^{-1}) = D\ (nGyh^{-1})\ x\ 8760\ hy^{-1}\ x\ 0.75\ x\ 0.7SvGy^{-1}x\ 10^{-6} \quad (3)$$

Table 2. Conversion factors from equivalent concentration(ppm, %) to activity in Bq/kg (IAEA 1989).

1% K	313 Bq/kg	^{40}K
eU (ppm)	12.35 Bq/kg	^{238}U or ^{226}Ra
eTh (1ppm)	4.06 Bq/kg	^{232} Th

Table 3. Activity concentrations of ^{238}U, ^{232}Th, ^{40}K and absorbed dose in air for the blocks under investigation.

SNo	BLOCK INDUSTRY	LOCATION		BLOCK TYPE	U (Bq/kg)	Th (Bq/kg)	K (Bq/kg)	D (nGy/h)
		LAT °N	LON °E					
1	Carsely Ventures Tudunwada	9.876	8.863	Sandcrete	75.34	98.94	278.57	107.86
2	Nantum, Federal Low Cost	9.879	8.851	Sandcrete	69.53	80.71	262.92	93.21
3	Kundung, Zaramaganda	9.847	8.866	Sandcrete	64.71	67.40	194.06	79.84
4	Kwang, Lamingo	9.872	8.928	Sandcrete	81.88	67.15	463.24	98.85
5	Haske 1, Lamingo	9.888	8.947	Sandcrete	58.42	70.77	441.33	89.34
6	Haske 2, Lamingo	9.888	8.948	Aggregate /Stone dust	93.12	96.47	1192.53	152.65
7	Nwobodo, Zaria Road	9.967	8.833	Sandcrete	53.23	66.10	801.28	99.05
8	Don, Lamingo Junction	9.903	8.903	Sandcrete	61.26	67.64	460.11	89.49
9	Excellence, Odus	9.946	8.907	Sandcrete	48.78	60.62	510.19	81.45
10	A. S. Mohammed 1, Feringada	9.959	8.873	Aggregate /Stone dust	111.77	116.93	1064.20	168.63
11	A. S. Mohammed 2, Feringada	9.960	8.873	Sandcrete	52.61	78.07	544.62	95.50
12	Peniel, Rayfield	9.848	8.882	Aggregate /Stone dust	119.42	122.61	1302.08	185.61
13	Smid, Engineering, Rayfield	9.818	8.875	Aggregate /Stone dust	116.34	120.58	1220.70	179.53
14	Retsat, Rayfield	9.824	8.881	Sandcrete	65.95	67.23	478.89	92.19
15	Oye, Rukuba Road	9.786	8.858	Sandcrete	59.03	65.45	482.02	88.02
SUMMARY				AVERAGE	75.43	83.11	646.45	113.42
				MINIMUM	48.78	60.62	194.06	79.84
				MAXIMUM	119.42	122.61	1302.08	185.61

Where D is the absorbed dose in air, 8760 (*24x365)* is the number of hours in a year, 0.75 is the indoor occupancy factor, which represents the fraction of time spent indoor, and $0.7SvGy^{-1}$ is the conversion coefficient from absorbed dose in air to effective dose received by adults. Although UNSCEAR (1993) recommended 0.8 (19.2 hrs) as the indoor occupancy factors, 18 hours is estimated to be the average time spent indoors per day by adults within the study area. It implies that the indoor occupancy factor is 0.75. Value of annual outdoor effective dose equivalent obtained ranges from 0.12-0.28 mSv/y and 0.37-0.85 mSv/y for indoor (Table 4). Also high values with average of 0.79 mSv/y (indoor) and 0.26 mSv/y (outdoor) was recorded for the aggregate-filled stone-dust blocks.

3.5 Hazard Indices

The Internal and external hazard indices are reflections of exposure to radiation. The hazard indices were calculated using Equation 5 and 6 according to Shoeib & Thabayneh (2014).

$$H_{In} = A_U/185 + A_{Th}/259 + A_K/4810 \quad (4)$$

$$H_{Ex} = A_U/370 + A_{Th}/259 + A_K/4810 \quad (5)$$

Where A_U, A_{Th} and A_K are the specific activity concentrations of ^{238}U, ^{232}Th and ^{40}K respectively. The mean internal and external hazard indices should be less than 1 to provide a level of safety for the individuals living in such dwellings. The Internal and external hazard indices for the two major types of block (Table 4) vary from 0.60-1.39 and 0.47-1.07 respectively. The values for sandcrete block ranges from 0.60-0.85 (internal) and 0.47-0.64 (external) while for aggregate-filled stone-dust blocks, it ranges from 1.12-1.39 (internal) and 0.87-1.07

(external). Radiological hazard index from aggregate-filled stone-dust blocks is greater than 1, and therefore radiologically significant.

3.6 Radium Equivalent Activity (Ra_{eq})

In order to assess the level of gamma radiation hazards that is associated with the use of both sandcrete and aggregate filled stone-dust blocks in the study area to human, radium equivalent activity was calculated. This is a single index which sums up the gamma output from different mixture of ^{238}U, ^{232}Th and ^{40}K in the blocks.

Table 4. Annual effective dose equivalents and hazard index in the hollow blocks from the study area

SNo	BLOCK INDUSTRY	LOCATION		BLOCK TYPE	$AEDE_{(int)}$ (mSv/yr)	$AEDE_{(ext)}$ (mSv/yr)	Hazard Index (internal)	Hazard Index (External)
		LAT °N	LON °E					
1	Carsely, Ventures Tudunwada	9.876	8.863	Sandcrete	0.50	0.17	0.85	0.64
2	Nantum, Federal Low Cost	9.879	8.851	Sandcrete	0.43	0.14	0.74	0.55
3	Kundung, Zaramaganda	9.847	8.866	Sandcrete	0.37	0.12	0.65	0.48
4	Kwang, Lamingo	9.872	8.928	Sandcrete	0.45	0.15	0.80	0.58
5	Haske 1, Lamingo	9.888	8.947	Sandcrete	0.41	0.14	0.68	0.52
6	Haske 2, Lamingo	9.888	8.948	Aggregate /Stone dust	0.70	0.23	1.12	0.87
7	Nwobodo, Zaria Road	9.967	8.833	Sandcrete	0.46	0.15	0.71	0.57
8	Don, Lamingo Junction	9.903	8.903	Sandcrete	0.41	0.14	0.69	0.52
9	Excellence, Odus	9.946	8.907	Sandcrete	0.37	0.12	0.60	0.47
10	A. S. Mohammed 1, Feringada	9.959	8.873	Aggregate /Stone dust	0.78	0.26	1.28	0.97
11	A. S. Mohammed 2, Feringada	9.960	8.873	Sandcrete	0.44	0.15	0.70	0.56
12	Peniel, Rayfield	9.848	8.882	Aggregate /Stone dust	0.85	0.28	1.39	1.07
13	Smid, Engineering, Rayfield	9.818	8.875	Aggregate /Stone dust	0.83	0.28	1.35	1.03
14	Retsat, Rayfield	9.824	8.881	Sandcrete	0.42	0.14	0.72	0.54
15	Oye, Rukuba Road	9.786	8.858	Sandcrete	0.40	0.13	0.67	0.51
SUMMARY				AVERAGE	0.52	0.17	0.86	0.66
				MINIMUM	0.37	0.12	0.60	0.47
				MAXIMUM	0.85	0.28	1.39	1.07

The radium equivalent activity was calculated in line with the proposition of Beretka & Matthew (1985); and UNSCEAR (2000) as follows:

$$Ra_{eq}\ (Bq/kg) = A_{Ra} + 1.43A_{Th} + 0.077A_K \qquad (6)$$

Where A_{Ra}, A_{Th} and A_K are the specific activity concentrations of uranium (^{238}U), thorium (^{232}Th) and potassium (^{40}K) respectively. This equation is based on the estimation that 370 Bq/kg of ^{238}U, 259 Bq/kg of ^{232}Th and 4810 Bq/kg of ^{40}K produce the same gamma ray dosage. Maximum value of Ra_{eq} is set at 370 Bq/kg for safety. This is equivalent to a maximum permissible dose of 1.5mSv/y to human from exposures to natural radiation. Result of radium equivalent activity from the hollow blocks is presented in in Table 5. The value ranges from 174.75-395.02 Bq/kg. For the sancrete blocks, it ranges from 174.75-238.27 Bq/kg with an average of 199.92 Bq/kg, while for the aggregate-filled stone-dust blocks, it varies from 322.89-395.02 Bq/kg with an average of 365.40 Bq/kg. In two of the block making industries where stone aggregate are mixed with stone-dust and sand to make blocks, average values in excess of 370Bq/Kg maximum allowable limit were recorded thus suggesting that radiation safety may become a major concern in buildings constructed with such blocks.

3.7 Excess Lifetime Cancer Risk (ELCR)

Excess lifetime cancer risk estimates the additional or extra risk of developing cancer due to exposure to a toxic substance incurred over the lifetime of an individual. In line with the position of Ramasamy *et al*. (2009), and Emelue *et al*. (2014), the excess lifetime cancer risk (ELCR) was calculated based on the values of annual effective dose equivalents using the following equation:-

$$ELCR_{(indoor)} = AEDE(indoor) \times DL \times RF \qquad (7)$$

$$ELCR_{(outdoor)} = AEDE(outdoor) \times DL \times RF \qquad (8)$$

Where AEDE is the annual effective dose equivalent, DL is the average duration of life (70 years), and RF is the risk factor or fatal cancer risk per Sievert. The International Committee on Radiation Protection ICRP (1991) peg RF at 0.05 for the public.

The excess lifetime cancer risk (ELCR) obtained for indoors for the sandcrete blocks range from 1.26 $x10^{-3}$- 1.74 $x10^{-3}$, while for outdoor, it ranges from 0.43 $x10^{-3}$- 0.58 $x10^{-3}$(Table 5). For aggregate-filled stone-dust blocks, ELCR (indoor) varies from 2.46 $x10^{-3}$- 2.99 $x10^{-3}$ while for the outdoor, it ranges from 0.82 $x10^{-3}$-1.00 $x10^{-3}$. The risk of developing cancer is therefore much higher for dwellers of buildings constructed with aggregate filled stone-dust blocks compared to ‘ordinary’ sandcrete blocks.

Table 5. Radium equivalents and excess lifetime cancer risks for the hollow blocks in the study area.

SNo	BLOCK INDUSTRY	LOCATION		BLOCK TYPE	RaEq. (Bq/kg)	ELCR (indoor)	ELCR (Outdoor)	ELCR (Total)
		LAT °N	LON °E					
1	Carsely,Ventures Tudunwada,	9.876	8.863	Sandcrete	238.27	1.74	0.58	2.32
2	Nantum, Federal Low Cost	9.879	8.851	Sandcrete	205.19	1.50	0.50	2.0
3	Kundung, Zaramaganda	9.847	8.866	Sandcrete	176.03	1.29	0.43	1.72
4	Kwang, Lamingo	9.872	8.928	Sandcrete	213.58	1.59	0.53	2.12
5	Haske 1, Lamingo	9.888	8.947	Sandcrete	193.59	1.44	0.48	1.92
6	Haske 2, Lamingo	9.888	8.948	Aggregate /Stone dust	322.89	2.46	0.82	3.28
7	Nwobodo, Zaria Road	9.967	8.833	Sandcrete	209.45	1.59	0.53	2.12
8	Don, Lamingo Junction	9.903	8.903	Sandcrete	193.41	1.44	0.48	1.92
9	Excellence, Odus	9.946	8.907	Sandcrete	174.75	1.31	0.44	1.75
10	A. S. Mohammed 1, Feringada	9.959	8.873	Aggregate /Stone dust	360.92	2.71	0.90	3.61
11	A. S. Mohammed 2, Feringada	9.960	8.873	Sandcrete	206.19	1.54	0.51	2.05
12	Peniel, Rayfield	9.848	8.882	Aggregate /Stone dust	395.02	2.99	1.00	3.99
13	Smid, Engineering, Rayfield	9.818	8.875	Aggregate /Stone dust	382.76	2.89	0.96	3.85
14	Retsat, Rayfield	9.824	8.881	Sandcrete	198.97	1.48	0.49	1.97
15	Oye, Rukuba Road	9.786	8.858	Sandcrete	189.74	1.42	0.47	1.89
SUMMARY				AVERAGE	244.05	1.83	0.61	2.43
				MINIMUM	174.75	1.29	0.43	1.72
				MAXIMUM	395.02	2.99	1.00	3.99

4. Conclusion

Using the RS-230 Gamma Spectrometer, the concentration and specific activity of ^{238}U, ^{232}Th and ^{40}K from hollow sandcrete blocks and aggregate filled stone-dust blocks have been determined across major block industries in Jos, North Central Nigeria. Radiological parameters which include absorbed dose rate in air, annual effective dose equivalent, radium equivalent activity, internal hazard index and excess lifetime cancer risk were found to be generally higher among the aggregate filled stone-dust blocks compared to ordinary sandcrete hollow blocks. Also, radiological hazard indices among the aggregate filled stone-dust blocks are not only high but are in some cases above the recommended limits. The implication of this is that dwellers in buildings constructed with such blocks are at higher risk of developing radiation related health problems in the long term. It is therefore strongly recommended that radiological safety rather than extra strength and durability be given priority in the choice of blocks for residential building, since strong blocks can still be obtained through the use of clean sharp sand provided that the recommended composite mixture of sand to cement ratio is maintained.

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