Gamma Ray Spectroscopy Study of the Radiological Hazards of Pottasium-40 Radionuclide Found in Cement Block in Some Selected Local Government Areas of Katsina State Northern Nigeria

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Abstract:- Twenty Concrete Blocks each from one of the selected Local Government Areas of Katsina state were investigated. The activity concentration of ^{40}K radionuclide in each of the block sample was measured by means of Gamma-Ray Spectroscopy using Sodium Iodide Thallium [NaI (Tl)] detector and was found to range from 46.11±8.55 to 826.59±4.82Bq/kg with the calculated mean concentration value of 229.98±5.22Bq/kg, which is less than the International permissible values of activity concentration of 4810Bq/kg. The mean Radium Equivalent value was found to be 17.71±0.40 from the measurement ranged from (3.55±0.66 to 63.65±0.37 Bq/kg) which is lower than the maximum permissible value of 370Bq/kg. The absorbed dose rate in air (D) with its mean value was obtained as 95.00 ±2.18, ranges from (19.23±3.57 to 344.69±2.01 nGy/h). The annual effective dose equivalent (AEDE) obtained, ranges from 0.07±0.0041 to 0.50±0.003mSv/y, with mean value of 0.18 ± 0.004mSv/y, which is less than the world average value of 1 mSv/y for Public exposure. When these values are compared with the internationally permissible values, it shows that, the values of the radiometric parameters of K-40 radionuclide found in cement blocks in Katsina state are below the recommended limit.

Keywords:- *Gamma-Ray Spectroscopy, radium equivalent, absorbed dose rate, annual effective dose equivalent.*

I. INTRODUCTION

Cement, sand and gravels used in block manufacturing are building materials of natural origin that contain some amounts of Naturally Occurring Radioactive Materials (NORM), mainly radionuclides from ^{226}Ra and ^{232}Th decay chains and ^{40}K (Pesequilo, 2015). These radionuclides are sources of the external and internal radiation exposures in dwellings (Aku, 2015). Among all building materials, the highest concentration of radionuclides are found in mineral based materials such as stone, sand, bricks and cement (Jonathan., 2013). The radioactive isotope of Pattasium-40 (^{40}K) with half-life = 1.251×10^9 years is unstable and is the most abundant radionuclide found in those materials (Yang, 2005). In 89.14% of transition, ^{40}K emits a β^- particle with a maximum energy of 0.560 MeV, and in 10.66%of transition, it emits a γ photon of 1.461 MeV (Strom, 2009). From a total of 130g of potassium in an average person weighing 70kg, there is about 0.0157g of ^{40}K (Rafique, 2011). Pottasium-40 produces ionizing radiation that causes cellular damage which includes DNA breakage, accurate or inaccurate repair, apoptosis, gene mutations, chromosomal damage, and genetic instability. The specific activities of ^{40}K in building materials and products mainly depend on geological and geographical condition as well as geochemical characteristics of those materials (UNSCEAR, 1993).

The long time people spend indoor, shows the enormous importance of building to human life, and most of these buildings, are made using cement blocks in most town an urban areas of the state.

The main objective of this work is to find the concentration of the K-40 radionuclide in those blocks as well as the environment were those blocks are manufactured and compare it with the world recommended dose limit of public exposure for the safety of the people working in the industries or living in those areas and those that use the blocks for construction

II. MATERIALS AND METHOD

➢ *Materials*
- Cement blocks (That was made from cement, water, sand and gravels)
- Polythene bag
- Rubber container (cylindrical container 7cm in diameter)
- Crushing machine (crusher)
- Candle wax and Masking tape

➢ *Samples collection*

Twenty (20) samples of building blocks were collected randomly from some block making industries in 20 different local government areas in Katsina State, one from each local government. The table below list the name of the local government visited as well as the block manufacturing industries:

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S/N	SAMPLE ID	NAME OF INDUSTRY	ADDRESS	LOCAL GOVERNMENT AREA
1	BS 01	Umkha Block Industry	Along Zango Road, Daura	Daura
2	BS 02	A.I.B. Block Industry	G.R.A. Katsina	Katsina
3	BS 03	Alheri Block Industry	Zaria Road, Funtua	Funtua
4	BS 04	Albarka Block Industry	Along Katsina road, Jibia	Jibia
5	BS 05	Alheri Block Industry	Near NNPC Mega Station	Dutsin-ma
6	BS 06	Albarka Block Industry	Katsina Road, Kankia	Kankia
7	BS 07	Commander Block Industry	Funtua Road, Malumfashi	Malumfashi
8	BS 08	Musawa Block Industry	Matazu Road, Musawa	Musawa
9	BS 09	A.G Block Industry	Matazu	Matazu
10	BS 10	Kafur Block Industry	Kafur	Kafur
11	BS 11	Dandume Block Industry	Dandume	Dandume
12	BS 12	Faskari Block Industry	Faskari	Faskari
13	BS 13	Bakori Block Industry	Funtua Road, Bakori	Bakori
14	BS 14	Kankara Block Industry	Dutsin-ma Road, Kankara	Kankara
15	BS 15	Danja Block Industry	Zaria Road,	Danja
16	BS 16	Madugu Block Industry	Jibia Road, Batsari	Batsari
17	BS 17	Danmusa Block Industry	Yantumaki Road	Danmusa
18	BS 18	Kaita Block Industry	Dankama Road	Kaita
19	BS 19	Bindawa Block Industry	Bindawa	Bindawa
20	BS 20	Al-Amin Block Industry	Katsina Road	Charanchi

Table 1:- Sample collection Industries and their respective locations

➢ *Sample preparation*

All the samples collected were air dried at room temperature of 27℃ – 30℃ and mean relative humidity of about 70% for fourteen days in order to avoid loss of radionuclides (Taiwo A. O., 2014). The samples were then ground into fine powder and then subjected to analysis in the laboratory with a spectrometer. The analysis was carried out at the Centre for Energy Research and Training (CERT), Ahmadu Bello University, Zaria. The spectrometer consists of a highly-shielded Canberra [NaI(Tl)] detector enclosed in a 100mm thick lead blocks. The spectrometer is a 7.6cm x 7.6cm NaI (TI) detector (model No. 802-series by Canberra Inc.) with a resolution of about 8.0% at 0.662 MeV of gamma ray energy from 137Cs and 1.33MeV, 1.173 of 60Co which are capable of distinguishing the gamma ray energies used for the measurement. The detector was placed inside a lead shielded counting chamber and was coupled to a Canberra Series 10 plus multichannel analyser (MCA) with a PC via an interface. The samples were then counted for 29,000 seconds. The gamma energies of 1.46, 1.7 and 2.62 MeV were used in the analysis of ^{40}K. The peaks obtained were reasonably strong and clean, the peak area A for the radionuclides was computed using the algorithm of the MCA, which subtracts the background spectrum from the total peak counts

The Energy and Efficiency calibration of the gamma spectrometer was carried out using the International Atomic Energy Agency (IAEA) reference source material. Accurate energy and efficiency of the gamma spectroscopy system were made quantity radionuclides present in the sample since the accuracy of all quantitative results depend on the attainable accuracy of the systems calibration. Before the counting commenced, the two gamma standard sources (137Cs and 60Co) were placed into the shield NaI (TI) detector chamber and closed to exclude laboratory background interference. The acquire display was click on from the MAESTRO window. The limit was pre-set and the live time typed (i.e. 1024). The micro ace amplifier gain

III. RESULT AND DISCUSSION

➢ *Experimental Results*

The specific radioactivity concentration values of ^{40}K (C_K) measured in the building block samples collected are presented in table 2. The activity concentration of the K-40 radionuclide was measured in count per second (CPS) and then converted to Becquerel per kilogram (Bq/kg). Count per second is defined as:

$$Count\ per\ second\ (CPS) = \frac{Live\ time}{Net\ count} \text{ --------------------1}$$

Were the live time is the period at which counting was carried out which was set at 29,000s.

The net count is the activity of each sample under selected photo peaks. The photo peaks observed with regularity in each sample were identified to belong to natural radioactive decay series headed by ^{226}Ra, ^{232}Th as well as the single occurring natural radionuclide ^{40}K. Although, other radionuclides were present and appeared rather infrequent at low levels or levels below the minimum detectable limits (MDL).

$$Becquerel\ per\ kilogram\ (Bq/kg) = \frac{count\ per\ second}{callibration\ factor} \text{ -2}$$

S/N	SAMPLE	C_K (CPS)	C_K (Bq/kg)
1	BS 01	0.1856 ± 0.0053	288.65 ± 8.25
2	BS 02	0.4968 ± 0.0027	772.63 ± 4.19
3	BS 03	0.1895 ± 0.0031	294.71 ± 4.82
4	BS 04	0.2328 ± 0.0006	367.05 ± 0.93
5	BS 05	0.5315 ± 0.0003	826.59 ± 4.82
6	BS 06	0.3173 ± 0.0047	67.51 ± 7.30
7	BS 07	0.3940 ± 0.0041	97.18 ± 0.01
8	BS 08	0.2478 ± 0.0015	165.20 ± 2.33
9	BS 09	0.2536 ± 0.0055	46.11 ± 8.55
10	BS 10	0.2623 ± 0.0025	104.92 ± 3.89
11	BS 11	0.2956 ± 0.0049	60.23 ± 7.62
12	BS 12	0.1884 ± 0.0028	293.00 ± 4.35
13	BS 13	0.2565 ± 0.0011	233.18 ± 1.71
14	BS 14	0.3453 ± 0.0048	71.94 ± 7.46
15	BS 15	0.1290 ± 0.0029	200.59 ± 4.51
16	BS 16	0.3997 ± 0.0041	97.49 ± 6.37
17	BS 17	0.4345 ± 0.0041	81.98 ± 8.24
18	BS 18	0.3886 ± 0.0055	70.65 ± 8.55
19	BS 19	0.2040 ± 0.0033	317.26 ± 5.13
20	BS 20	0.4856 ± 0.0034	142.82 ± 5.29
MEAN		0.3119 ± 0.0034	229.98 ± 5.22

Table 2:- Activity concentration of radionuclide in concrete block measured in CPS and Bq/kg

As seen from the table, the activity concentration of Potassium (C_K) ranges from 46.11±8.55Bq/kg to 826.59 ± 4.82Bq/kg. The highest value was obtained in sample BS 05 and the lowest value in sample BS 09.

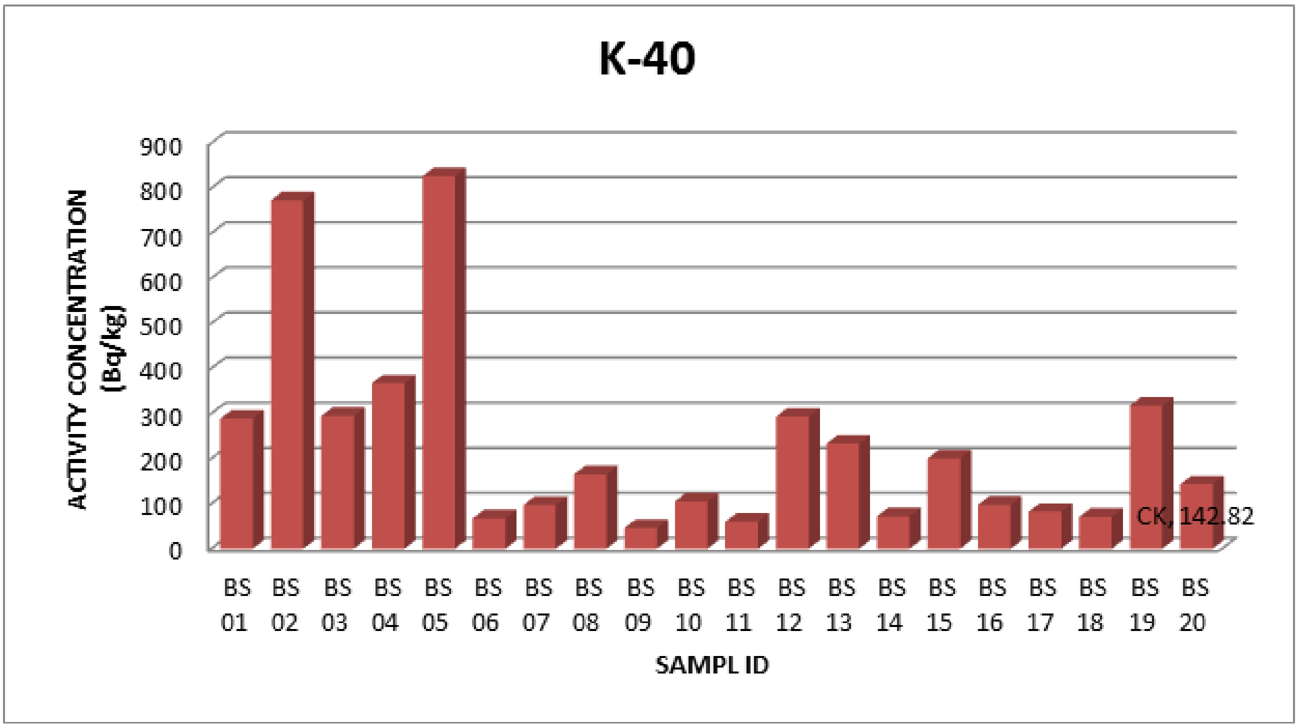

Fig 1

➢ *Activity analysis*

The radium equivalent

It is found that distribution of K-40 in the analyzed samples is not uniform. The actual activity level of the K-40 in the samples and the radiation hazard associated with it is found from Radium equivalent activity (Ra_{eq}) which is an index that has been introduced to represent the specific activities of ^{226}Ra, ^{232}Th and ^{40}K by a single quantity, which takes into account the radiation hazards associated with them (Aku, 2015). This first index can be calculated using the equation described by (Baretka, 1985) as:

$$Ra_{eq} = 0.077C_K \text{ -- } 3$$

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- *Absorbed dose in Air*

The absorbed dose in air (D) in nGy/h, resulting from the natural specific activity concentration of ^{40}K, in Bq/kg, at a height of 1 m above the ground was calculated using the equation

$D(nGyh^{-1}) = 0.417C_K$ --------------------------------------4

Where C_K is concentration of K-40.

- *Annual Effective Dose Rate (AEDR)*

To estimate annual effective doses the following must be considered:

The annual, estimated, average, and effective – doses equivalent received by a member of the public is calculated using a conversion factor of 0.7SvG/y, which is used to convert the absorbed dose rate to human effective – dose equivalent with an outdoor occupancy of 20% and 80% for indoors (UNSCEAR, 1993). The calculation was made by using the conversion coefficient of 0.7SvG/y and the outdoor occupancy factor of 0.2 as defined in equation

$E = D(nGyh^{-1}) \times 8760hy^{-1} \times 0.2 \times 0.7(SvGy^{-1} \times 10^{-6})$ -------- 5

- *External and Internal Hazard Indices (H_{ex})*

The external hazard index or indoor radiation hazard index measures the radiation exposure due to radionuclides. It can be calculated using this equation

$H_{ex} = \frac{C_{Ra}}{370} + \frac{C_{Th}}{259} + \frac{C_K}{4810}$---------------------------------------6

S/N	Sample ID	Radium Equivalent Raeq (Bq/kg)	Absorbed Dose (D) (nGy/h)	Annual Effective Dose Rate (E) (mSv/y)	H_{ex}
1	BS 01	22.23 ± 0.64	120.37 ± 3.44	0.20 ± 0.0084	0.060 ± 0.002
2	BS 02	59.49 ± 0.32	322.19 ± 1.75	0.50 ± 0.00087	0.161 ± 0.001
3	BS 03	22.69 ± 0.37	122.89 ± 2.01	0.30 ± 0.0073	0.061 ± 0.001
4	BS 04	28.26 ± 0.07	153.06 ± 0.39	0.30 ± 0.0055	0.076 ± 0.000
5	BS 05	63.65 ± 0.37	344.69 ± 2.01	0.50 ± 0.003	0.172 ± 0.001
6	BS 06	5.20 ± 0.56	28.15 ± 3.04	0.10 ± 0.001	0.014 ± 0.002
7	BS 07	7.48 ± 0.00	40.52 ± 0.00	0.10 ± 0.0055	0.020 ± 0.000
8	BS 08	12.72 ± 0.18	68.89± 0.97	0.10 ± 0.0043	0.034 ± 0.000
9	BS 09	3.55 ± 0.66	19.23 ± 3.57	0.04 ± 0.001	0.096 ± 0.002
10	BS 10	8.08 ± 0.30	43.75 ± 1.62	0.10 ± 0.002	0.022 ± 0.001
11	BS 11	4.64 ± 0.59	25.12 ± 3.18	0.08 ± 0.0052	0.013 ± 0.002
12	BS 12	22.56 ± 0.33	122.18 ± 1.81	0.20 ± 0.0055	0.061 ± 0.001
13	BS 13	17.95 ± 0.13	97.24 ± 0.71	0.20 ± 0.0021	0.048 ± 0.000
14	BS 14	5.54 ± 0.57	30.00 ± 3.11	0.08 ± 0.0054	0.015 ± 0.001
15	BS 15	15.45 ± 0.35	83.65 ± 1.89	0.20 ± 0.0001	0.042 ± 0.001
16	BS 16	7.51 ± 0.49	40.65 ± 2.66	0.08 ± 0.0053	0.020 ± 0.001
17	BS 17	6.31 ± 0.63	34.19 ± 3.44	0.08 ± 0.0053	0.017 ± 0.002
18	BS 18	5.44 ± 0.66	29.46 ± 3.57	0.07 ± 0.0041	0.015 ± 0.002
19	BS 19	24.43 ± 0.40	132.30 ± 2.14	0.20 ± 0.0053	0.066 ± 0.001
20	BS 20	11.00 ± 0.41	59.56 ± 2.21	0.10 ± 0.0033	0.030 ± 0.001
MEAN		17.71 ± 0.40	95.00 ± 2.18	0.18 ± 0.0040	0.052 ± 0.001

Table 3:- Calculated values of radium equivalent, absorbed dose rate and annual effective dose rate from each block sample

It is found that the Radium equivalent is higher in sample BS 05 and least in sample BS 09 with the mean value of 17.71±0.40Bq/kg.

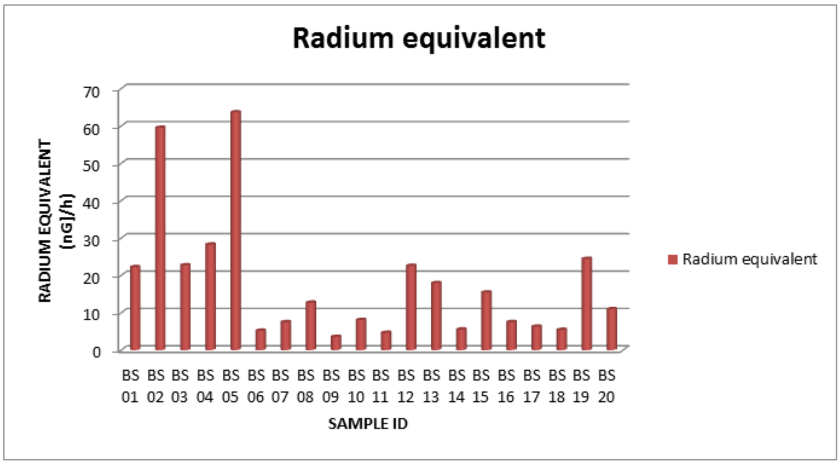

Fig 2

The absorbed dose rate for the block sample range from 19.23 ± 3.57 to 344.69 ± 2.01 nGy/h

With a mean value of 95.00 ± 2.18 nGy/h, as indicated in table 3. Some samples have absorbed dose rate higher than estimated average global terrestrial radiation range 24 to 160nGy/h (UNSCEAR, 2000).

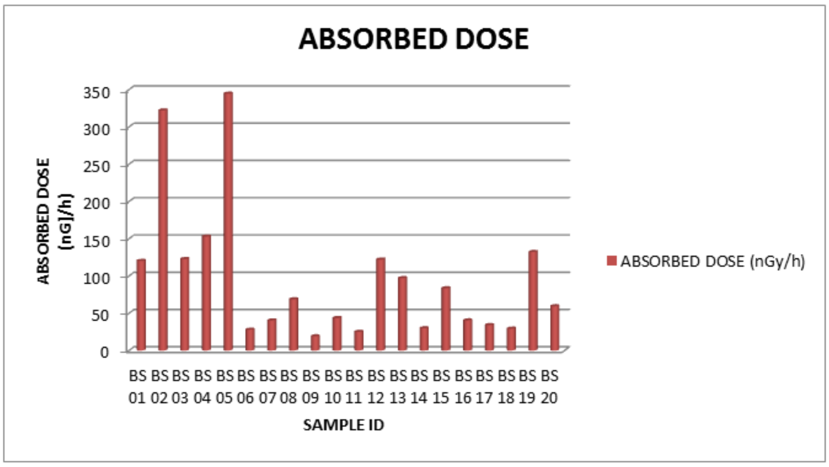

Fig 3

The Values of E obtained from the block samples range from 0.040±0.001 to 0.20±0.0001mSv/y, with mean value 0.187±0.00055mSv/y as indicated in 5. When compared with (UNSCEAR, 2000) limit of 0.460mSv/y for terrestrial radionuclides for area of normal background radiation, it is evident that the data obtained from block samples gives a values that are lower than the internationally permissible value.

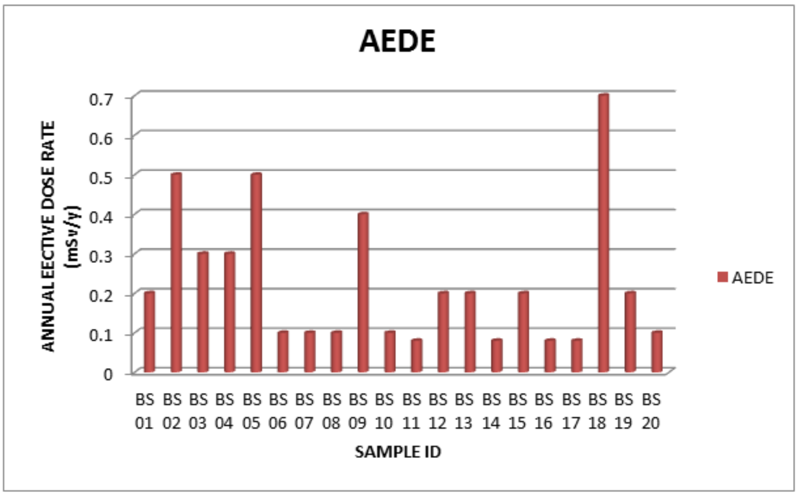

Fig 4

IV. CONCLUSION

The result showed that the mean activity concentration of ^{40}K level in the twenty (20) block samples analyzed is 229.98$\pm$5.22 with the highest value of 826.59±4.82 and the lowest value of 46.11±8.55 are within the world range of 140 to 850Bq/kg as reported by UNSCEAR 2000. The radium equivalent indexes calculated are also below the recommended maximum value allowed of 370Bq/kg. The other calculated radiometric parameters like the mean absorbed doses rate were found to be below the maximum world recommended value of 55nGy/h, and also the annual effective doses equivalent were also found to be less than the maximum value recommended of 1mSv/y (UNSCEAR, 2000). The external hazard index is also found to be less than unity. The findings show that people living or working in those local government areas are not facing any significant radiation hazard due to Pottasium-40 (K-40) radionuclide.

RECOMMENDATION

Although the research is restricted to only twenty out of the thirty four local government areas of the state, there is need for the investigation to be carried out in the remaining local government areas because the variations in the radiation parameters observed may not be unconnected to the topography as well as mining and or agricultural activities practiced in the areas investigated.

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