Natural Radioactivity Levels in Some Building Materials and their Radiological Implications in Pankshin, Plateau State, North Central, Nigeria

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Abstract: **- This study aimed to measure the activity concentration of 226Ra, 232Th, and 40K in some selected building materials of Pankshin, Plateau State, North Central Nigeria, using a thallium-doped sodium iodide scintillator detector. The activity concentrations range from 86.8089Bq/kg to 158.6369Bq/kg, 53.7883Bq/kg to 229.5046Bq/kg, and 262.8164Bq/kg to 475.3861Bq/kg with average values of 106.3379Bq/kg, 110.1520Bq/kg, and 354.9511Bq/kg for 226Ra, 232Th, and 40K, respectively. The activity concentration and average values of 226Ra and 232Th in this study were higher than the world average values of 35 Bq/kg and 30 Bq/kg given by UNSCEAR in 2000. In contrast, 354.9511 Bq/kg was reported as the average value of 40k, which is less than the world's average of 400Bq/kg. However, the activity concentration of 40K in Dene (Gravel), Kor (Mud Block), and Katambiri (Cement Block) were higher than the recommended world average of 400Bq/kg. As a result, the general public's risk of developing cancer complications over time in these areas reported to be higher than the world average cannot be overlooked. The Radiation dose and radiation hazard index were calculated for Radium equivalent (Raeq), absorbed Dose rate (Dr), Annual Effective Dose (AED), Annual Gonadal Dose Equivalent (AGDE), Hazard indices (Hex and Hin), Activity Concentration index (Iγ) and Excess Lifetime Cancer Risk (ELCR).**

Keywords: **Activity concentration, radiation dose, radiation hazards indices, building materials.**

I. INTRODUCTION

All living things need a place to call home. Humans and animals use various shelters to shield themselves from the sun's rays, hot or cold temperatures, rain, and so on. This enhances human well-being and the will to live. We now spend about 90% of our time indoors, with almost 70% of that time spent at home. We should be mindful that spending a significant amount of time indoors may have a negative impact on our health and well-being. (Whitney Gray & Stephanie Timm, 2019). The materials used to build this house, such as concrete, marble, and granite, contain extremely low levels of naturally occurring radioactivity. However, when these materials degrade, they can release radon in your home. (Environmental Protection Agency of the United States, 1999). The natural radio nuclides of the nuclear decay chain of uranium-238, thorium-232, and radioactive isotopes of potassium-40 are present in the building materials obtained from rock and soil. As a result, human activity has increased background radiation by developing and utilizing artificial radiation sources such as medical X-rays, toxic fallout from nuclear weapons tests, and radioactive waste from nuclear power plants are all examples of these.

Knowing the geology of the study field, which is made up of Syenite and younger granite rock, can lead to ~~severe~~ cancers and cause death in extremely high doses of radiation. However, in developed countries, radionuclide evaluation is part of determining the quality of building materials, while in developing countries, such as Nigeria, especially the Pankshin local government area in Plateau state, north central Nigeria, it is not. Although the area is known for its distinctive hills of varying heights, which may account for radioactive elements in drinking water rocks and sands, radioactivity measurements are rare. As a result, this study aims to look into the activity levels of uranium, thorium, and potassium in some building materials in the Pankshin local government area of plateau state north-central Nigeria to evaluate the radiation dose and radiation hazard indices of the building material.

II. THE STUDY AREA'S GEOLOGY

Pankshin in plateau state North central Nigeria having a landmass of about 1,524km2 and bounded by latitude 9° 19″ 31″ N and longitude 9° 26′ 6″ E (Figure 1). The rock is made up of migmatite, granite gneiss, basalt, syenite and younger Granite. Tin, niobium, and tantalum are all found in the younger granite around Jos plateau. The younger granite is one of the most common rock types in the region, covering roughly three-quarters of the area from northeast to southeast (Bolanrinwa and Adeola, 2000). (2017). The lack of bauxite minerals in the profiles around Pankshin may be due to the terrain roughness, which aided run-off but prevented alternative water table movement up and down. Rather than the predicted aluminium accumulation (bauxitization), the profile's weathering trend is toward iron enrichment (lateralization) (Aleva,1994: Bolarinwa,2001: 2006)

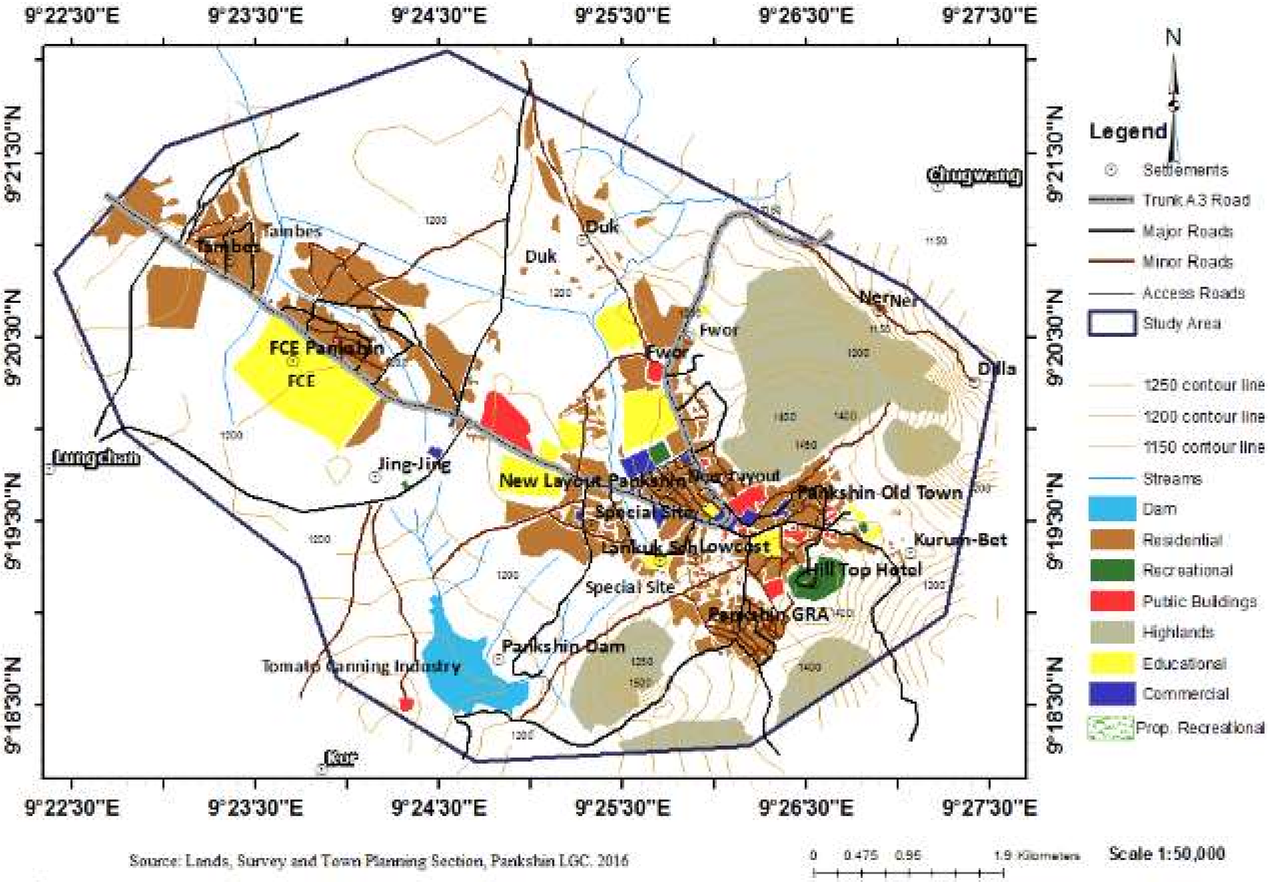

Figure 2: map of the study area (lands survey and Town planning, 2016)

III. MATREIALS AND METHOD

Sample Collection

Ten samples of different building materials were collected from various locations. Two quarry sites (Gravels), three cement blocks (two and hand make block), mud block, saw dust from timber shade, two cement of different companies, Brazilian ceiling and titles. Each of the building samples collected was dried and crushed to fine powder with agate mortar and pestle The samples were also packaged into radon-impermeable cylindrical plastic containers chosen based on the space distribution of the detector vessel, which is 7.6cm by 7.6cm in size (geometry). Every case's packaging was triple sealed to prevent radon-222 from escaping. Smearing Vaseline jelly on the inner rim of each jar lid, filling the lid assembly gap with candle wax to block the gaps between lid and container, and tight-sealing lid-container with masking adhesive tape were all part of the sealing process. By storing the samples for 30 days prior to gamma spectroscopy, radon and its short-lived progenies were able to achieve secular radioactive equilibrium prior to gamma spectroscopy measurements, the samples were stored for 30 days.

Activity concentration analysis

A 76x76mm NaI (Tl) detector crystal optically coupled to a photomultiplier tube was used for the study (PMT). A preamplifier and a 1kilovolt external source are built into the assembly. A 6cm lead shield with cadmium and copper sheets surrounds the detector this setup aims to reduce the effects of background and dispersed radiation.

The data acquisition software is **Maestro** by Camberra Nuclear Products. The samples were measured for a period of 29000 seconds, for each sample. The peak area of each energy in the spectrum was used to compute the activity concentrations in each sample by the use following equation:

$$\mathbf{C\ (Bq.kg^{-1})} = \frac{C_n}{C_{fk}}$$

Where,

C = activity concentration of the radionuclides in the sample given in $BqKg^{-1}$

C_n = count rate (counts per second)

$$\textbf{Count per second (cps)} = \frac{\textbf{Net Count}}{\textbf{Live Time}}$$

C_{fk} = Calibration factor of the detecting system.

Calibration of the system for energy and efficiency done with two calibration point **sources, Cs-137 and Co-60. These were done with the amplifier gain that gives 72% energy** resolution for the 661.16KeV of Cs-137, and counted for 30 minutes The IAEA gamma Spectrometric reference materials RGK-1 for K-40, RGU-1 for Ra-226 (Bi-214 peak), and RGTh-1 for Th-232 were used to verify the calibration (Ti-208).

For 226Ra, 232Th, and 40K, the spectral energy windows used in the study have gamma energies of 1764.0, 2614.5, and 1460.0 Kev, respectively, and energy windows of 1620-1820, 2480-2820, and 1380-1550 Kev.

Assessment of Radiological Risk

The effects of radiation on the health of people exposed to radiation and the atmosphere are measured using standard radiation indices. The indices that were looked at were as follows:

Radium Equivalent Activity (Raeq)

This is used to measure the hazards associated with materials that contain 226Ra, 232Th, and 40K in Bq kg-1 (UNSCEAR 1982), which is calculated on the assumption that 370 Bq kg-1 of 226Ra, 259 Bq kg-1 of 232Th, or 4810 Bq kg-1 of 40K generate the same gamma dose rate (Beretka& Mathew, 1985). The Raeq of the sample in Bq kg^{-1} was achieved using the equation (ICRP1990):

Raeq=(ATh1.43)+ (AK 0.0077) + (AR) (1)

Where ATh, AK, and A stand for 232Th, 40K, and 226R activity concentrations, respectively.

The radium equivalent is the most practical guideline for regulating radiation safety requirements for the general public (UNSCEAR 1982).

Air- absorbed dose rate (D)

Based on guidance given by Yu.K,N, et al 1992, the absorbed dose concentrations in outdoor (D) due to gamma radiations in air at 1m above the ground surface for uniform distribution of the naturally occurring radionuclides 232Th, 40K, and 226Ra were determined. The conversion factors for calculating absorbed - dose rate (D) in air per unit activity concentration in Bq/kg (dry-weight) are as follows 0.427 $nGyh^{-1}$for 226_{Ra} (of u-series), 0.662 $nGyh^{-1}$ for 232_{Th} and 0.043 $nGyh^{-1}$for 40_{K}

$$D= 0.0427C_{Ra} + 0.662C_{Th} + 0.043C_{K}\ nGyh^{-1} \quad (2)$$

Where CRa,CTh, and CK are the radium, thorium, and potassium concentrations in Bq/kg, respectively.

Annual Gonadal Dose Equivalent

M. Faheem and S. A. Mujahid (2008) measured the annual gonadal dose equivalent (AGDE) due to the specific activities of 226Ra, 232Th, and 40K using the following formula:

3.09ARa +4.18ATh +0.314AK AGDE (Sv yr-1) (3).

Annual Effective Dose (AED)

The annual effective dose is a measure of a whole organism's cancer risk ~~i~~onizing radiation administered non-uniformly to part(s) of its body. With an outdoor occupancy of 20% and an indoor occupancy of 80%, a conversion factor of 0.7svGy-1 was used to translate the absorbed rate to human effective dose equivalent (UNSCEAR 1993). The AED is calculated as follows:

Annual effective dose rate= D ×T×F (4)

Where D is the calculated dose rate in nGyh-1, T is the outdoor occupancy time (0.8 ×24h × 365.25d ≐7013hy-1) and F is the conversion factor (0.7 ×10-6 svGy-1)

External Hazard Index (Hex)

A model proposed by Beretka and Mathew (1985) was used to calculate the external hazard index (Hex). This index assesses the risk posed by natural gamma radiation (Amrani and Tahtat 2001). However, the primary goal of this index is to keep the radiation dose below the acceptable dose equivalent limit of 1 mSv/y. The formula for calculating Hex is as follows:

$$H_{ex} = \frac{AR}{370} + \frac{ATh}{259} + \frac{AK}{4810} \leq 1 \quad (5)$$

This model's criterion assumes that the material's external gamma-ray hazard corresponds to a cumulative radium-equivalent operation of 370 Bq kg-1 (ICRP 1990; Friedrich 2009).

Internal Hazard index (H_{in})

The internal hazard index (Hin), established by Abbay A.G.E. 2005 and Papadopoulos.A. 2010, quantifies the internal exposure to radon and its daughter products in addition to the external hazard.

$$H_{in} = \frac{ARa}{185} + \frac{ATh}{259} + \frac{AK}{4810} \leq 1 \quad (6)$$

For the safe use of a material in the construction of dwelling, H_{in} should be less than unity.

Activity Concentration Index ($I\gamma$)

In Europe, the activity concentration index (I) is a well-established screening method for identifying potentially hazardous materials. Radium-226, Thorium-232, and Potassium-40 measurements are important for calculating the activity concentration index (I) using the formula below (EC,1999) ,

$$I\gamma = \frac{CRa}{300Bq/kg} + \frac{CTh}{200Bq/kg} + \frac{CK}{300Bq/kg} \quad (6)$$

Where CRa, Cth and CK are activity concentration of 226Ra, 232Th and 40K respectively

The European Commission recommends that gamma doses for bulk materials be I 1 or I 6 for superficial materials (e.g. tiles), with an annual effective dose of less than 1mSv.

Excess Life Cancer Risks (ELCR)

This study looks at the chances of developing cancer over the course of a lifetime at a given level of exposure, with a lifespan of 70 years as the average. It's written as (Taskin et.al., 2009)

$$ELCR = AEDE \times DL \times RF \quad (7)$$

Where AEDE = Annual Effective Dose Equivalent

DL = Average Duration of life (estimated to be 70 years)

RF = the risk factor (Sv^{-1}) i.e fatal cancer risk per Sievert for stochastic effects,

ICRP 60 use value of 0.05 for the public (Taskin*et.al*., 2009; US-EPA, 1991; Keled and Mohamad, 2012).

IV. RESULTS AND DISCUSSIONS

Tables 1 and 2 summarize the measured results for ten building materials collected at various locations around Pankshin, Plateau State, North Central Nigeria.

Activity concentration of ^{226}Ra, ^{232}Th, and ^{40}K have been measured for some building materials. The measured activities with their errors are presented in Table 1, which ranged from 86.8089Bq/kg to 158.6369Bq/kg, 53.7883Bq/kg to 229.5046Bq/kg and 262.8164Bq/kg to 475.3861Bq/kg, respectively. Furthermore, the average values of ^{226}Ra, ^{232}Th, and ^{40}K were calculated as 106.3379Bq/kg, 110.1520Bq/kg, and 354.9511Bq/kg, respectively. According to UNSCEAR, the activity concentration and average values of 226Ra and 232Th were higher than the world average values of 35Bq/kg and 30Bq/kg for both samples (2000). The average value of 40k was estimated to be 354.9511Bq/kg, which is less than the 400Bq/kg stipulated by the world's average value. The activity concentration of 40K in Dene (Gravel), Kor (Mud Block), and Katam Biri (Cement Block) was, however, higher than the world average of 400Bq/kg, as recommended by the World Health Organization (IAEA1999). Radium equivalent (Raeq), absorbed Dose rate (Dr), Annual Effective Dose (AED), Annual Gonadal Dose Equivalent (AGDE), Hazard indices (Hex and Hin), Activity Concentration index (I), and Excess Lifetime Cancer Risk (ELCR) were all measured and shown in Table 2 with mean values of 291.1865Bq/kg, 130.4614 nGyh-1, 900.4614 Svyr-1, 0.064045mSv/yr, 0.786492, 1.073891,1.023537, and 0.2910-3. The mean values of the radiological hazards showed that the annual effective dose and external hazards for radium equivalent were less than or equal to the permissible limits of 370Bq/kg,0.48mSv/yr, and less than or equal to unity, as recommended by the EPA (UNSCEAR 2000). The Katambiri Cement Block and Tiles, on the other hand, exceed the allowable limits. Meanwhile, all of the absorbed dose (Dr nGyh-1) and ELCR samples, as well as their mean values, surpass the UNSCEAR world average limits of 57 nGyh-1 and 0.29 10^{-3}, respectively. In addition, the internal hazard index has a mean value of 1.073891, which is significantly higher than the ≤ 1 and the mean value of the activity concentration index is within the permissible range of 1. Though some study areas had values greater than unity, as seen in Table 2, all of the values were above the recommended AGDE safety limits of 0.05 mSv/yr (ICRP, 1999). As a result, the general population is at risk of developing cancer problems as a result of the use of such construction materials.

Table: 1 Activity Concentration of Ra-226, Th-232 and K-40 in some selected building materials in Pankshin, Plateau State North Central Nigeria.

Activity concentration in (Bq/Kg)							
SAMPLE CODE	Sample ID	Ra-226	Error ±	Th-232	Error ±	K-40	Error ±
A	GRAVEL(DRNE 1)	86.8089	7.3506	110.1717	4.6396	412.4839	1.1422
B	MUD BLOCK (KOR)	100.4714	6.7913	102.1113	5.2687	424.5495	1.0779
C	GRAVEL (GRA)	93.4404	6.4318	102.8976	4.0499	277.0270	1.1047
D	SAW-DUST (MONDAY MKT)	100.5513	6.5516	123.1469	4.3251	346.1497	0.8634
E	BRAZILIAN CEILING	101.8297	6.7114	71.6784	5.0721	347.1686	0.9760
F	CEMENT (DANGOTE)	111.6970	5.5928	53.7883	5.3867	309.5238	40.4440
G	CEMENT (BAU)	107.8619	5.7127	57.6809	4.9149	262.8164	0.7186
H	CEMENT BLOCK (KATANG BIRI)	100.7111	6.8313	178.0754	6.2910	475.3861	1.2012
I	CEMENT BLOCK(GER-DUK)	101.3705	1.7981	72.4649	4.3251	290.0198	2.6278
J	TILES	158.6369	5.9923	229.5046	7.0774	404.3865	1.0457
	AVE	106.3379	5.97639	110.152	5.13505	354.9511	5.12015
	MIN	86.8089	1.7981	53.7883	4.0499	262.8164	0.7186
	MAX	158.6369	7.3506	229.5046	7.0774	475.3861	40.4440
	WORLD AVERAGE	35		30		400	

Table 2: Radiation dose and Radiation hazard index in some selected building materials in Pankshin, Plateau State North Central Nigeria

		Radiation dose				Radiation hazard indices (≤)			
SAMPLE CODE	SAMPLE ID	Raeq Bq/kg	DR nGyh^{-1}	AGDE µSv yr^{-1}	AED mSv/yr	H_{EX} Bq/kg	H_{IN} Bq/kg	I_γ	ELCR 0.29 ×10^{-3}
A	**GRAVEL(DRNE 1)**	276.1157	123.85	858.2772	0.060799	0.745747	0.980366	0.977716	0.212797
B	**MUD BLOCK (KOR)**	279.1809	125.7967	870.5904	0.061755	0.75406	1.025605	0.986978	0.216142
C	**GRAVEL (GRA)**	261.915	116.8716	805.8293	0.057373	0.707424	0.959965	0.918298	0.200807
D	**SAW-DUST (MONDAY MKT)**	303.3049	135.2699	934.1486	0.066405	0.819196	1.090956	1.066289	0.232419
E	**BRAZILIAN CEILING**	231.0618	104.816	723.2804	0.051455	0.624142	0.899358	0.813547	0.180093
F	**CEMENT (DANGOTE)**	212.4476	96.99929	667.1693	0.047618	0.573911	0.875794	0.744439	0.166663
G	**CEMENT (BAU)**	210.5824	95.63091	656.9238	0.046946	0.568864	0.860383	0.73555	0.164312
H	**CEMENT BLOCK (KATANG BIRI)**	391.9637	173.9097	1204.824	0.085374	1.058575	1.330767	1.384543	0.298809
I	**CEMENT BLOCK(GER-DUK)**	227.3268	102.6958	707.2043	0.050414	0.614057	0.888031	0.796899	0.17645
J	**TILES**	517.9662	228.7739	1576.495	0.112307	1. 39893	1.827687	1.811108	0.393076
	MIN	210.5824	95.63091	656.9238	0.046946	0.568864	0.860383	0.73555	0.164312
	MAX	517.9662	228.7739	1576.495	0.112307	1. 39893	1.827687	1.811108	0.393076
	mean	291.1865	130.4614	900.4742	0.064045	0.786492	1.073891	1.023537	0.224157
	World average	370	57	0.05	0.48	1	1	1	0.29 ×10^{-3}

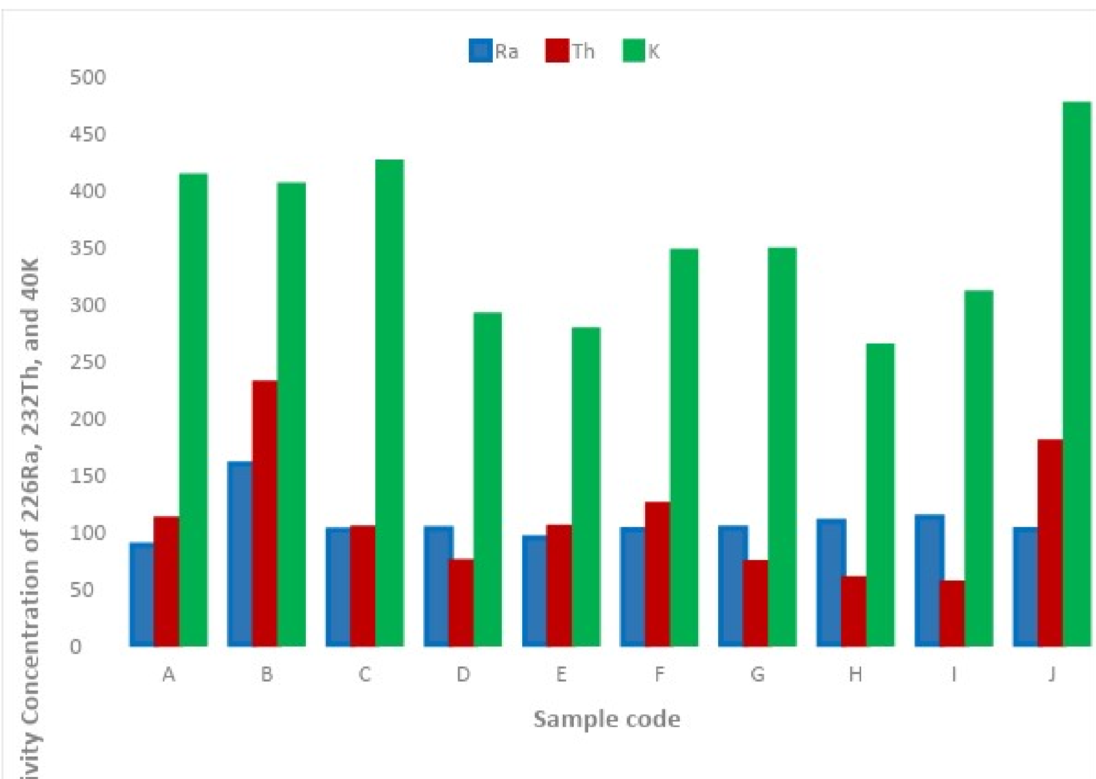

Figure 2: Activity concentration of ^{226}Ra, ^{232}Th, and ^{40}K against sample code

V. CONCLUSION

In Pankshin, plateau state North Central Nigeria, activity concentrations, radiation doses, and radiation hazard indices of 226Ra, 232Th, and 40K were calculated for some building materials. The findings indicate that some products surpass global precautionary values while others fall short, posing a substantial radiological danger to the local population.

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