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Review Article

Review of Distribution of Natural Radiation in Some Parts of Nigeria

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Abstract: Activity concentrations of natural radioactivity of ^{40}K, ^{238}U, ^{226}Ra, and ^{232}Th were reviewed in connection with rock, soil, sediments, and water in the Northern and Southern parts of Nigeria to estimate the radiation dose acquire by the population. The activity concentrations of the various radionuclides from rock samples collected from different locations were generally higher than those of other environmental matrices. Comparative distribution maps of ^{40}K, ^{238}U, and ^{232}Th show the distribution of activity concentration in the Northern and Western part of Nigeria. The activity concentrations ^{40}K, ^{238}U, and ^{232}Th in rock ranges from 40 Bq kg^{-1} to 1203 Bq kg^{-1}, 34 Bq kg^{-1} to 7220 Bq kg^{-1}, and 8 Bq kg^{-1} to 1680 Bq kg^{-1} respectively. In soil it ranges from 98.7 Bq kg^{-1} to 1023.3 Bq kg^{-1}, 15.6 Bq kg^{-1} to 55.3 Bq kg^{-1}, and 5.2 Bq kg^{-1} to 195.5 Bq kg^{-1} respectively. In sediment it ranges 97 Bq kg^{-1} to 1023 Bq kg^{-1}, 12 Bq kg^{-1} to 47.9 Bq kg^{-1}, and 11.7 Bq kg^{-1} to 55.3 Bq kg^{-1}. The concentration of ^{40}K and ^{238}U in granite rocks are higher than the recommended permissible value. All the water samples were found to contain acceptable levels of radionuclides with mean activity values of 3.98±0.26, 11.00±2.58, and 17.73±5.04 Bql^{-1} for ^{40}K, ^{232}Th, and ^{238}U, respectively showing that the mean activity of ^{238}U for all the samples is the highest when compared with those of ^{40}K and ^{232}Th. The mean absorbed dose rate for all the area is 0.123mSvyr^{-1}, which is very low when compared to the recommended limit of 1mSvyr^{-1} for water.

Keywords: Activity Concentration, Radioactivity, Environmental Matrices

1. Introduction

The numerous attention expressed globally for the investigation of environmental radioactivity and naturally occurring radiation has resulted in broad surveys in many nations. Despite the small size of the natural radiation background, the interest in it is excellent and explained by the increase in the fields of application of nuclear energy, radioactive isotopes, and sources of ionizing radiation. The expansion of mineral extraction is associated with the rise to the Earth's surface of a large mass of rocks, including an increased level of radioactivity, which is accompanied by anthropogenic pollution by natural radionuclides of large areas. The estimation of natural background radiation is of particular significance because it accounts for about 80% of the combined radiation exposure of the global populace.

The main objective of the radiological protection system is to protect the people and the environment against the harmful consequences of radiation exposure without disproportionately restraining the desirable human activities that may be associated with such exposure (ICRP 2007) [1]. The human health aims of the system of radiological protection to control and manage ionizing radiation exposures to prevent deterministic effects and reduced the risks of stochastic effects to the level reasonably achievable. A central feature of the system of radiological protection is the calculation of the dose of radiation received [2]. Three dose quantities are used: the physical quantity of absorbed dose (which can relate to any mass of matter), the protection quantities of equivalent dose (which relates to specific organs and tissues), and the effective dose (which relates to the whole body). The physical quantity absorbed dose, D, is the mean energy imparted to matter by ionizing radiation divided by the mass of the matter, measured in joules per kilogram.

Naturally occurring radioactive material (NORM) have different concentrations for various geographic location; hence, the natural background radiation levels differ round the globe (UNSCEAR 2000) [3]. It is safe with no harmful effects on humans and the environment in most countries, while in some other countries, a high level of natural radionuclides concentrations are discovered in places Ramsar in Iran and Guarapari in Brazil [4]. These are the reason for the increase in the number of people (not only professionals but also the population) exposed to the impact of increasing doses of radiation, as well as interest in the background radiation is associated primarily with the solution of the question: what radiation doses are safe for humans and what is the real danger. Therefore, it is vital to be able to verify the background radiation, safe and unsafe level in Nigeria, also to investigate the causes of various forms of radiation in connection with rock, soil, sediments, and water. The study aims to provide a general review to determine the activity concentration of natural radionuclide in samples of rock, soil, sediment, and water.

2. Natural Radioactive Deposit in Nigeria

Mineral resources are essential earth resources of suitable quality and abundant quantity and to be mined for personal economic profit. Nigeria is a known country blessed with abundant mineral resources [5], with the existence of over forty different solid minerals at approximately 450 locations. Mineral naturally occurs as an inorganic element with both chemical and physical properties, and an example is uranium. Nigerian uranium minerals are discovered in sedimentary orders [6]; the valuable ores located are uraninite, pitchblende, xenotime, pyrochlore, monazite, autunite, and coffinite. The Northern part of Nigeria has a significant deposit of uranium; the states with Uranium deposits include Akan Ibom, Bayelsa, Cross River, Adamawa, Taraba, Plateau, Bauchi, and Kano state.

Radiometric geochemical analysis indicates that elements and isotopes of U, ^{234}Th, Zn, P_2O_5, Cu, ^{210}Pb, ^{226}Ra, or their fractions with Ba, Pb, Ce is used as pathfinder elements in exploration for economic ore deposits[7]. Studies confirm that a concentration of ^{226}Radon is 1000-2000bq/kg at Kanawa and uranium concentration at Kanawa, Zona, and Gubrunde (Northern part of Nigeria) is 15ppm, 6.5ppm, and >500ppm respectively [8].

Many studies had been carried out on the natural radiation background of Nigeria, and these investigations are as a result of public outcry against radiation in the environment and increase the rate of cancer. A study recorded a total of 6,915 cancer cases within the year1987-2014 comprising of 2891 males and 4024 females in Plateau state [9], giving an annual prevalence of 256 cases per annum. The most frequent cancers were those of breast, cervical, prostate, lymphoma, and liver cancers. Ref [10] also affirms the fact that there was an over 53% increase in the proportion of cancers between the years 1995-2002. The question arising is the correlation between the high uranium concentration and the increase of cancer in Plateau state. This investigation was to ascertain the level and the presence of other natural radioactivity, like Thorium, Potassium, and Rubidium present in Nigeria and the risk posed to human health and its environment. Thus it necessary to do a comprehensive review of some of the significant researches carried out in these areas.

Investigation of natural radiation in Northern Nigeria

Radiological assessment of the situation of a mining site in Plateau State investigated [11]. A portable survey meter sodium iodide NaI (Tl) detector and an Atomtex dosimeter were used for in-situ radiation measurements in the field, to identify radioactivity fluxes, and derive dose estimates to the local population and critical groups. An annual mean external effective dose of around 100 mSv y^{-1} estimated for the locations as the worst-case based on measured dose rate measurements up to 100 µGy h^{-1}, and around 10mSv y^{-1} for staying on contaminated soils based on measured dose rate measurements up to 10 µGy h^{-1}. These estimations are higher than the dose limit recommendation of the International Commission on Radiation Protection ICRP 60 (1990) [12] with a recommended value of 1 mSv y^{-1} for members of the public by ten and up to even hundred times. The geology of the State contains a large deposit of granite. Granites composition comprises of high concentrations of uranium, thorium, and potassium [13]. Thus, the presence of uranium and thorium deposits are responsible for the observed high concentration levels measured in the locations and contaminated soil samples.

Phosphate rock sample's radiological content was analyzed in Sokoto state [14], with the aid of gamma spectrometric technique sodium iodide NaI (Tl) detector. The mean activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K in the sample were 720.1±4.2 $Bqkg^{-1}$, 33.5±1.4 $Bqkg^{-1}$, and 315.3±6.7 $Bqkg^{-1,}$ respectively. The concentration of radium and potassium radionuclide activity is relatively high. The valued mean of the absorbed dose rate was at the multiple of 3.6 to the maximum value for the acceptable background radiation level, which indicates the gravity of radiation risk the people are exposed to in these areas. The calculated values for radiation hazard indices were higher than the proposed safety limits [3]. It places the research zones among high background radiation zones; thus, some preventive actions and cautionary measures are, therefore, required for the local farmers and the general public from the vantage point of radiation protection.

Background radiation of three strategic locations in the Niger State of Nigeria investigated [15]. The geology of the Niger state contains a large deposit of granite. The dose from location 1, 2 and 3 varies from 0.125 µSv/hr to 0.171µSv/hr, 0.152 µSv/hr to 0.184 µSv/hr, and 0.137 µSv/hr to 0.184 µSv/hr respectively. The mean dose rate estimation was 0.154 µSv/hr with a standard deviation value of 0.017 µSv/hr; these results can be attributed to natural sources and granite composition. The average annual effective dose obtained from the study is 0.189 mSv/annum; it is less than the International Commission on Radiation Protection [ICRP] endorsed the limit of 1mSv/annum for non-occupational population exposure. The outcome indicates that there might be a deposit of radioactive mineral around the survey areas. Thus, a broad radiological study in the areas is required to ascertain the radionuclide responsible for the elevated gamma dose rates.

The study of external background radiation was carried out in Offa industrial area of Kwara State [16]. Two Digilert radiation monitors were used at five different stations. A mean exposure rate of 0.0132mR/hr, about 20% elevation from the standard background radiation, was obtained. It suggests the possibility of the presence of radionuclide sources in the Offa environment. Further studies of an environmental ionizing radiation survey around quarry sites in Ilorin [17] were investigated using three Radalert Nuclear Radiation Monitors and Global Positioning System (GPS) in order to assess and provide up to date information on radiation levels in the environment. Measured mean radiation levels ranged from 1.11±0.05 to 1.72±0.03 mSv/yr, with an average of 1.49±0.04 mSv/yr in the study area. The radiation levels have surpassed the standard level of 1mSv/yr [18-20], but fall below the global average of 2.4 mSv/yr for the general public [21] and 20 mSv/yr for the industrial environment.

Investigation of natural radiation in Southern Nigeria

Research on the gamma radiation level due to primordial radionuclides in surface soil in some South-Western cities in Nigeria was done [22]. The annual effective dose and mean absorbed dose rate evaluated from the measurement of ^{40}K, ^{238}U, and ^{232}Th. The values of the absorbed dose rates for Lagos areas is from 18.6 to 68.4, with a mean standard deviation value of 44.2±15.9 nGy h^{-1}; While the values of the absorbed dose rates for Ibadan areas is from 26.8 to 145.6 with a mean standard deviation value of 72.9±35.6 nGy h^{-1}, and the value for Akure ranges from 30.9 to 98.9, with a mean standard deviation value of 64.2±26.5 nGy h^{-1}. The mean effective dose for Lagos, Ibadan, and Akure are 56.5, 93.3, and 82.2 μSv yr^{-1}, respectively. The estimation for the mean value for the province is 0.8 mSv year^{-1}, less than the recommended [UNSCEAR 2000] 1mSv yr^{1} for a healthy environment [3]. Ibadan has a high activity concentration than Lagos because of their different geological zones. The city is Ibadan is surrounded by granite rocks while Lagos is within in sedimentary areas. The geology of the town suggests that the soil in Ibadan town has a large deposit of granite. It is well known that granites contain high concentrations of uranium, thorium, and potassium [23].

Radionuclide concentration levels in soil samples analyzed with the aid of gamma-ray spectrometry in three different cement companies in Port Harcourt [24]. The soil sample's average absorbed dose rates values for the three companies were 49.27 nGy/h, 45.21 nGy/h, and 42.33 nGy/h. Mean dose rate equivalents of 0.39mS/y obtained for the soil samples. These results are below the (ICRP) maximum permitted limit and, therefore, have no significant radiological health effect on the people and the environment. Ref [25] investigated the activity concentrations of ^{40}K, ^{226}Ra, and ^{232}Th in an elevated radiation area of Oyo south-west Nigeria. In order to estimate the radiation dose acquire by the people, In situ gamma dose rates were likewise analyzed at each collection point. The average activity concentrations of ^{40}K, ^{226}Ra, and ^{232}Th in rock samples were 935.1 ± 702.1, 3.0 ± 5.4, and 271.7 ± 301.0 Bq kg^{-1}, respectively. Table one the comparison of activity concentrations of primordial radionuclides in rocks, soil, and sediments carried out by various researchers obtained from some Northern and Southern part of Nigeria.

Table 1. *Comparison of activity concentrations of primordial radionuclides in Nigeria.*

Sample type	Location	Region	Activity concentration (Bq kg^{-1})			References
			^{40}K	^{238}U	^{232}Th	
Rock	Kubwa	North Central	573	34	61	[32]
	Gosa	North Central	573	26	63	[32]
	Obajana	North Central	89.6	11.3	8.0	[33]
	Jos Plateau	North Central	–	7220	1680	[34]
	Sokoto	North-west	40	557.9	16.1	[35]
	Ikogosi	South-west	1203	58	82	[36]
	Oyo	South-west	931.5	3.0	271.7	[25]
	Nassarawa	Northcentral	8504.88	26.71	8.79	[44]
	Enugu	Southeast	217	57	83	[41]
	Bauchi	North east	491.89	38.78	105.77	[43]
Soil	Zamfara	Northwest	527	44.22	43.96	[39]
	Kano	Northwest	775.21	89.9	109.84	[40]
	Itagumodi	South-west	505.1	55.3	26.4	[45]
	Ekiti (Farmland)	South-west	1023.3	14.6	19.6	[46]
	Abak	South-South	98.709	24.826	5.172	[47]
	Nasarawa)	North Central	403.963	32.52	56.23	[37]
	Lagos	South-west	173	17	44	[22]
	Ibadan	South-west	419	26	66	[22]
	Akure	South-west	300	28	59	[22]
	Kebbi	North-west	425.96	23.85	18.80	[48]
	Oyo	South-west	304.2	15.6	195.3	[25]
	Ilorin	North central	1492.3	54.14	12.87	[38]
	Kaduna	Northwest	553	5.67	73.09	[42]
	Niger	North- Central	482.16	55.39	82.41	[15]

Sample type	Location	Region	Activity concentration (Bq kg^{-1})			References
			^{40}K	^{238}U	^{232}Th	
Sediment	Niger Delta	South-South	97	12	12	[49]
	Ogun River	South-west	499.48	12.65	11.78	[50]
	Oguta Lake	South-east	1023	47.89	55.37	[51]
	Oyo	South-west	426.0	28.5	30.3	[25]
	Kogi	North central	1608.1	63.4	27.4	[33]
	Portharcourt	South-south	772.19	82.02	8.22	[25]

The mean activity concentration of ^{40}K is higher in rock samples in the North-Central region of the country in Nassarawa with a value of 8504.88 $Bqkg^{-1}$ and Ikogosi in South-West with a value of 1203$Bqkg^{-1}$ than other locations. The mean activity concentration of ^{228}U is higher in rock samples in the Northern region with a mean value of 7220 $Bqkg^{-1}$ in Jos, this value is higher than IAEA 1000 $Bqkg^{-1}$ and a mean value of 557.9 $Bqkg^{-1}$ in Sokoto; while it is relatively low in other locations. The mean activity concentration of ^{232}Th is higher in rock samples is higher in Jos and Oyo with a mean value of 1680 $Bqkg^{-1}$ and 271.7 $Bqkg^{-1,}$ respectively, while compared with values of other locations. According to different researches, Jos Plateau, had been identified as a high background radiation area in Nigeria. For soil samples, the mean activity of ^{40}K is higher in the South-West region in Itagumodi with a mean value of 1023.3 $Bqkg^{-1}$, while the mean value for other locations was distributed uniformly; also, the mean activity concentration of ^{238}U was evenly distributed across all-region. The mean activity concentration of ^{232}Th in the soil is higher in Oyo with a mean value of 195.3 $Bqkg^{-1}$ than values from all other regions in Nigeria. In sediment samples, the mean activity concentration of ^{40}K is high in all Sothern regions, while the mean activity concentration of ^{238}U and ^{232}Th is entirely at the acceptable recommended level. Comparative distribution maps are given for the concentration of ^{40}K, ^{238}U, and ^{232}Th in figure 1, figure 2, and figure 3.

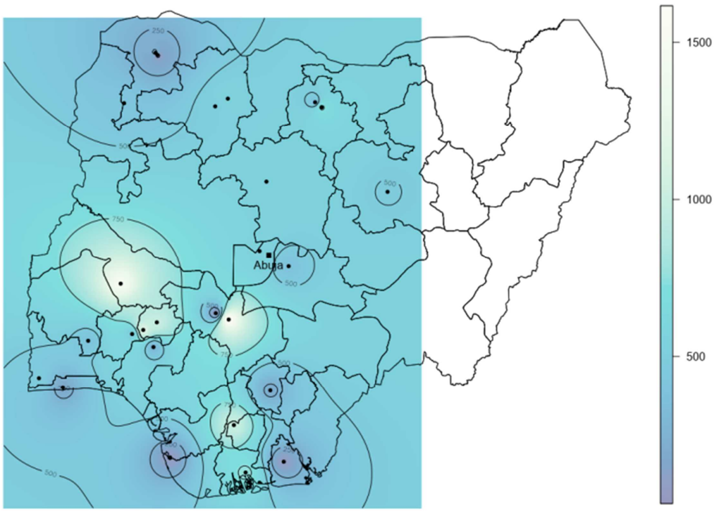

Figure 1. *Distribution of ^{40}K concentration in the Northern and Western part of Nigeria.*

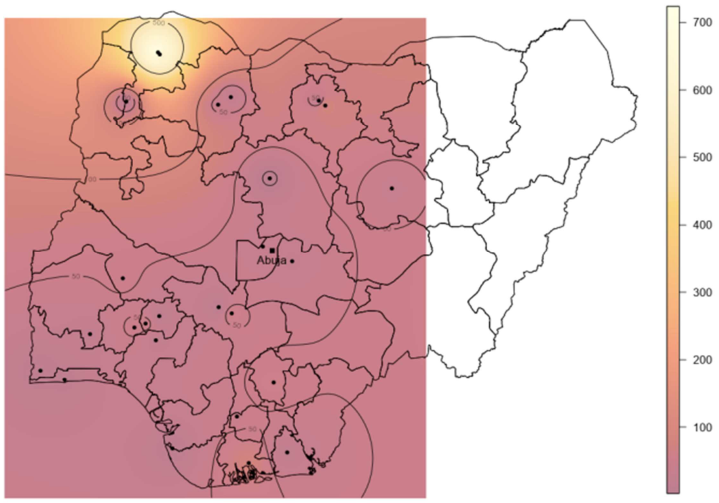

Figure 2. *Distribution of ^{238}U concentration in the Northern and Western part of Nigeria (10 * $Bqkg^{-1}$).*

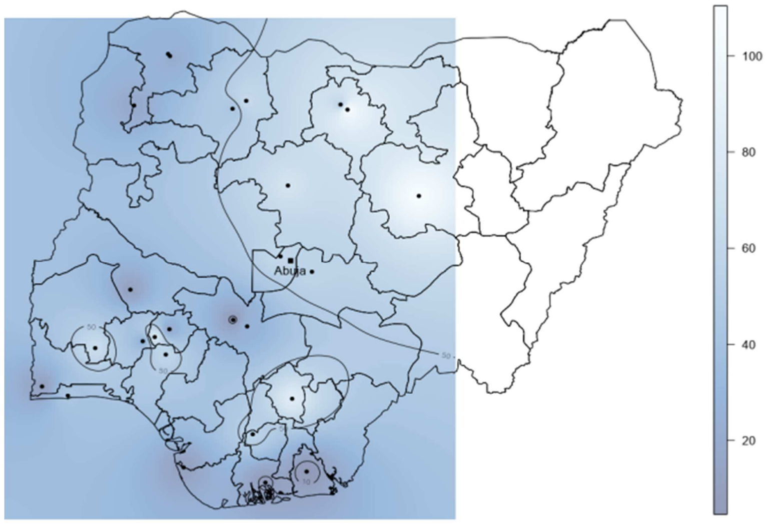

***Figure 3.** Distribution of ^{232}Th concentration in the Northern and Western part of Nigeria (10 * Bqkg^{-1}).*

Figure 1, 2 and 3 shows the distribution of ^{40}K, ^{238}U, and ^{232}Th concentration in the Northern and Western part of Nigeria. Figure 1 showed that the activity of ^{40}K is above 1500 Bq kg^{-1} in the North-Central. However, it is relatively low in the South-South and North-West of Nigeria. The concentration of ^{238}U in figure 2 is above 7000 Bq kg^{-1} in the North-Central; this is a result of a large deposit of Uranium in the Northern zone of Nigeria. While it has low concentration activity in the South-West. The highest concentration of ^{232}Th in figure 3 found in the North-Central with a value above 1000 Bqkg^{-1} and North-West of the country, this value is higher than the recommended permissible level. While the concentration is relatively low in South-West. However, some areas were not captured in this review; it is due to insurgency unrest in those localities, which makes the collection of data difficult to get.

Investigation of Natural Radiation in water in various part of Nigeria.

Studies are ongoing on natural radionuclides in water in various parts of Nigeria. The average concentrations of radionuclides different types of water were investigated in Ife local government areas [26]. ^{40}K, ^{226}Ra, and ^{228}Ra were observed in water samples from the dam, streams, boreholes, wells, and tap, as shown in Table 2.

***Table 2.** Mean specific activity contents (Bql^{-1}) in various water supplies [26] in Ife-Central and Ife-East local government areas.*

Types of water	Number of samples	^{226}Ra		^{228}Ra		^{40}K	Mean
		Range	Mean	Range	Mean	Range	
Well	12	2.90-13.55	8.67±4.28	0.34-3.89	2.31±1.48	92.00-108.88	98.99±6.23
Tap	9	10.50-13.65	12.41±1.37	2.35-2.58	2.47±0.09	71.33-109.39	85.06±17.27
Dam	9	10.30-10.61	10.40±1.70	2.34-2.72	2.70±1.30	69.07-73.20	72.60±9.10
Borehole	12	6.92-15.84	12.45±3.39	2.28-3.83	3.02±0.64	92.00-106.36	97.46±6.35
Stream	6	6.38-7.70	7.04±0.66	3.43-3.68	3.55±0.13	48.39-89.98	69.18±20.80

Table 2 shows the mean specific activity contents (Bq l^{-1}) in various water supplies in Ife local government areas. The result shows that the most significant contribution to the overall activity in all the various types of water samples came mainly from ^{40}K with the lowest value of 48.39±5.45 Bql^{-1}, the highest being 109.39±2.41 Bq l^{-1} compared to the activity ranges of 2.90-15.84 Bql^{-1} and 0.3-3.89 Bql^{-1} for ^{226}Ra and ^{228}Ra, respectively. It is because most of the various water samples in the study were collected from soils that are mostly granite rocks, which contains high levels of ^{40}K [27]. Hence, ^{40}K contributes to humans the highest radiation dose from ingestion. ^{40}K is a naturally occurring radionuclide which abounds in the earth's crust and the human body [28, 29]. The specific activity due to natural thorium is relatively low in all the water samples investigated. It is because ^{238}U is very mobile than ^{232}Th.

Ref [30] investigate Radionuclide concentrations in water supply from Bore-holes in Ogbomosoland, Western Nigeria. The concentration of ^{238}U, ^{232}Th, and ^{40}K was determined for the water samples from eight bore-holes around Ogbomosoland by gamma-ray spectrometry with a high purity germanium (HPGe) detector connected to a multichannel analyzer. The Beck et al. [31] was used to calculate the absorbed dose rates D, at 1.0m above the ground, using the following relationship:

$$D\ (nGyh^{-1}) = 0.042C_U + 0.662C_{Th} + 0.043C_K$$

Where C_U, C_{Th}, and C_K are the activity concentrations of ^{238}U, ^{232}Th, and ^{40}K, respectively, in the water samples.

All the water samples from these bore-holes were found to contain acceptable levels of radionuclides with mean activity values of 3.98±0.26, 11.00±2.58, and 17.73±5.04 Bql^{-1} for ^{40}K, ^{232}Th, and ^{238}U, respectively showing that the mean activity of ^{238}U for all the samples is the highest when compared with those of ^{40}K and ^{232}Th. The mean absorbed dose rate for all the area is 0.123mSvyr$^{-1,}$ which is very low when compared to the recommended limit of 1mSvyr^{-1} for bore-hole water. Overall, the radionuclide concentration of the bore-hole water supply in Ogbomosoland is negligible and poses no radiological hazards to the public.

3. Conclusion

The natural radioactivity levels of ^{40}K, ^{228}U, and ^{232}Th in rock, soil, sediment, and water were reviewed across the Northern and Sothern regions of Nigeria. The presence of ^{238}U and ^{232}Th concentration was high in the Northern region with value higher than the IAEA 1000 Bqkg^{-1}, while it was relatively low in the southern region. The concentration of ^{40}K was high in the Southern region of the country. The concentrations of ^{40}K, ^{238}U, and ^{232}Th in Nigeria were compared with values gotten in other countries. The activity concentration is higher than values obtained from other countries with normal background radiation levels and similar to outcome found in well-known elevated radiation zones such as Brazil, Bangladesh, Iran, Italy, Egypt, and Pakistan.

Furthermore, the study of natural radionuclides in water shows that the most significant contribution to the overall activity in all the various types of water samples came mainly from ^{40}K. The mean concentrations of the radionuclides ^{232}Th, ^{238}U, ^{226}Ra ^{228}Ra, and ^{40}K in water samples from the Bore-holes, Well, Stream, and Tap around Nigeria is low when compared with known literature values. So also does the absorbed dose rate, which is low when compared with the ICPR value of 1 mSvyr^{-1}. Thus, the concentration of these radionuclides in the bore-hole water supply in this Nigeria poses no radiological threat to people. Further study is necessary to assess radiological risk on the people due to external and internal irradiation of ^{40}K, ^{238}U and ^{232}Th decay chains.

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