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Assessment of Radiological Hazards Accompanied with Naturally Occurring Radioactive Materials (NORM) at Selected Boreholes in the FCT, Abuja

Nimat Omowumi Abdulazeez, Emmanuel Osiewundo Ojo*, Hammed Olanrewaju Shittu

Department of Science Infrastructure, National Agency for Science and Engineering Infrastructure (NASENI), Idu Industrial Area, Abuja, Nigeria

Abstracts

Water, irrespective of its sources is extensively used by man, animal and for our environment. The presence of natural radionuclides in it results in internal and external exposure to the public. Therefore, it is needful to determine the concentration of naturally occurring radioactive materials (NORMs), namely: ^{238}U, ^{232}Th and ^{40}K in water samples collected at different locations in Abuja, FCT. 14water (boreholes) samples were collected from seven different locations in FCT Abuja. In order to measure the specific activities in these samples, Gamma-ray spectrometer was used for the analysis of the samples. The result of ^{238}U, ^{232}Th and ^{40}K showed that the activity concentration values of various samples analyzed varies from (1.06±1.07 to 5.44±0.05, 2.04±0.30 to 8.04±0.87, and 4.41±4.40 to 26.39±2.37) respectively. From the result it is clear that the mean concentration of ^{238}U, ^{232}Th and ^{40}K are below the safety limit of 35, 30 and 400Bq/l respectively as recommended. The mean Absorbed Gamma Dose Rate (AGDR), Annual Effective Dose Equivalent (AEDEq) and Annual Gonnadial Dose Equivalent (AGDEq) in the study fell below the standard set safe limits recommended, in all the samples. The Excess Life time Cancer Risk (ELCR) was higher than the safe limit. The findings of the study show that the radiation exposure level of the areas is significantly high and could be harmful to human health.

Keywords

Natural Radioactivity, Radiological Hazards, NaI (Tl) Detector, Gamma-Ray Spectrometry

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1. Introduction

There are numerous sources of radiation in the environment. Gamma radiation emitted from naturally occurring radionuclides, also called terrestrial background radiation, represents the main external source of exposure to human body. Human beings are exposed to radiation primarily from cosmic rays and from the gamma ray emitters in soils, building materials, water, food, and air. Investigation concerning the level of radionuclide distribution in the environment provides vital radiological information [1]. Radionuclides have been essentially present in the environment since the creation of the earth. Human beings have always been exposed to ionizing radiation from the earth [2]. Assessment of this radionuclide in soil, water and rocks in many parts of the world has also been on the increase in the past two decades and even more because of their hazard on the health of the populace according to [12] and [9]. The soil is the major source and pathway of radionuclides to living beings. The distribution of radionuclides in nature, their concentration and movements can seriously be affected by the activities of population [3]. Therefore, the assessment of the concentrations of the

* Corresponding author
E-mail address: wuminimat@yahoo.com, (N. O. Abdulazeez), emmacyosy13@gmail.com (E. O. Ojo), hammedshittu4luv@yahoo.com (H. O. Shittu)

radionuclides (uranium U, thorium Th and potassium K), the radiological hazard indices and the biological imparts on the human being from borehole water collected at selected locations in FCT Abuja are the objectives of this present study.

2. Materials and Methods

Gamma spectrometry was used to determine and measured the radionuclide concentration in the water samples collected at selected locations in FCT Abuja. Gamma ray spectrometer is a powerful technique which identifies and quantifies specific energy photons (gamma rays), in environmental and geological samples thereby quantifying specific radionuclides. Gamma rays from a sample enter the sensitive volume of the detector and interact with the detector atoms. The interactions are converted into voltage pulses proportional to the photon energy. Pulses are stored in sequence infinite energy equivalent increments, over the desired spectrum range. After sample counting, the accumulated pulses over a certain area may result in a peak that can be identified and quantified as specific radionuclide by its peak area.

2.1. Study Area Geology

The underlying rocks of the FCT consist basically of Basement Complex and sedimentary rocks. The Basement Complex rocks made up of igneous and metamorphic rocks cover about 48% of the total area and in some places the land is occupied by hills and dissected terrain [16]. The rocks consist mainly of schists, gneiss sand older granite. The mountain ranges together with some isolated inselbergs are believed to have been poured out of volcanoes within the tertiary period. The areas underlain by the sedimentary rocks cover about 52% of the total area of the Federal Capital Territory (FCT) and largely constitute the undulating plains. These plains form present day remnants of erosion processes of the Quaternary period. Towards the southwest of the FCT there exist sand ridges with outliers of sandstone capings. Sandstone and clay also occur in significant proportions of parts of Abaji and Kwali Area Councils. These areas are easily dissected and indeed exhibit very glaring evidences of severe gully erosion [13]. [14] and [15] also described the geology of the Federal Capital Territory as almost predominantly underlain by high grade metamorphic and igneous rocks of Precambrianage. These rocks consist of gneiss, migmatites and granites and schist belt outcrops along the eastern margin of the area. The belt broadens southwards and attains a maximum development to the south-eastern sector of the area where the topography is rugged and the relief is high. In general, the rocks in the FCT are highly sheared as shown in Figure 1 below.

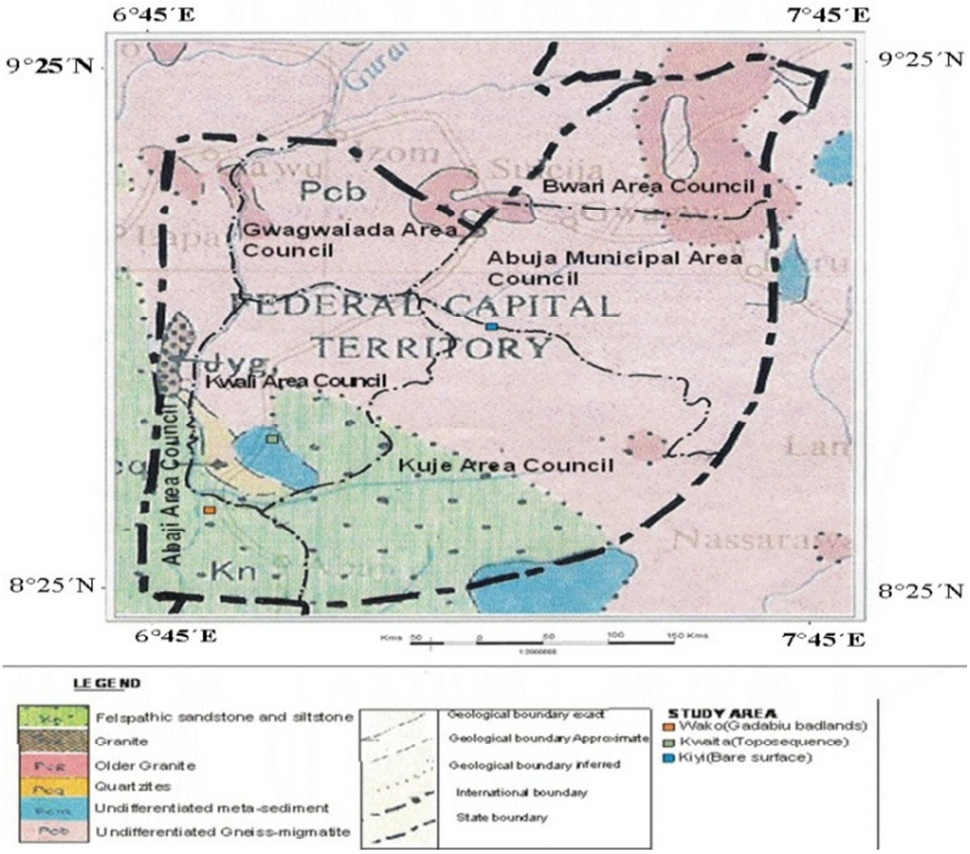

Figure 1. Geology Map of Abuja, Federal Capital Territory of Nigeria. As cited in [3].

2.2. Data Collections

The water samples were collected at seven different sites (figure 2), as shown below;

Kuje: Dantata and Sawoe Quarry (KJ), Gbaupe: Jinjia Quarry (GB), Mpape: Julius Berger (MP), Mpape: Setraco Quarry (MPO), Dutse Bopkumo: Istanbul Quarry, Dutse Mbuko: Venus Quarry (V), Kubwa: Zeberced Quarry (ZB).

Two samples each were collected from borehole at selected locations in FCT Abuja, the water samples were collected during the month of April (Dry Season).

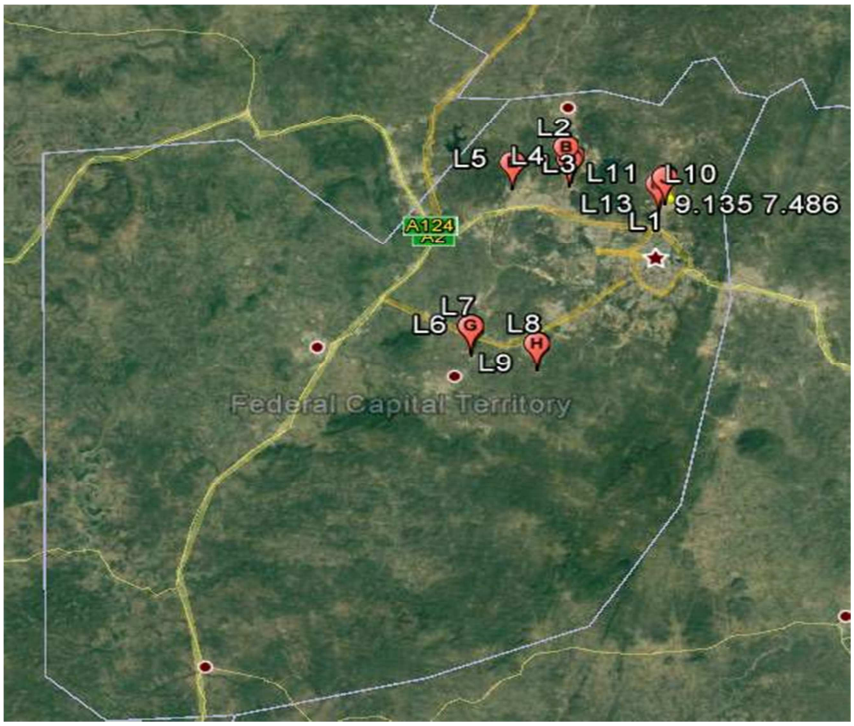

Figure 2. Sketch of the Sample Sites/ location (L in the figure represents location).

The samples were collected at seven (7) different quarry sites, 1000ml samples of water was collected from each quarry site in clean white plastic bottles according to standard procedures described in the sampling guide [5].

Table 1. Activity Concentration (Bq/Kg) of ^{40}K, ^{232}Th and ^{238}U and Hazard Indices Studied in Borehole Water.

Name	^{40}K (Bq/L)	^{238}U (Bq/L)	^{232}Th (Bq/L)	Hazard Indices			
				AGDR (nGy/h)	AEDEq (mSv/y)	AGDEq (μSv/y)	ELCR
DB01	12.46±2.50	2.54±1.42	3.34±1.55	3.7	0.01	25.72	0.02
DB02	4.41±4.40	2.67±0.97	8.04±0.87	6.27	0.01	43.24	0.03
KJB1	14.63±5.18	1.87±1.46	3.96±0.19	3.85	0.01	26.92	0.02
KJB2	17.21±2.58	1.06±1.07	2.46±1.42	2.68	0.01	18.96	0.02
GBB12	16.07±3.78	2.12±1.43	5.48±0.51	4.94	0.01	34.5	0.02
GBB2	20.83±2.57	2.36±1.17	6.41±0.12	5.81	0.01	40.62	0.03
MPB1	13.51±3.57	1.78±1.28	6.17±1.93	5.1	0.01	35.53	0.02
MPB2	11.71±2.53	1.92±0.69	2.04±.30	2.59	0.01	18.13	0.01
MPBO1	26.39±2.37	1.74±1.26	5.33±0.26	5.1	0.01	35.94	0.02
MPBO2	21.07±4.24	3.46±1.64	4.37±0.07	5.1	0.01	35.57	0.02
VB1	15.89±4.29	3.56±0.83	4.56±0.59	5.05	0.01	35.05	0.02
VB2	15.74±4.73	2.52±1.06	4.60±0.23	4.58	0.01	31.95	0.02
ZBB1	23.09±3.60	3.40±0.44	4.52±1.32	5.24	0.01	36.64	0.02
ZBB2	22.03±4.01	5.44±0.05	3.17±0.93	5.33	0.01	36.97	0.02
Mean	16.78	2.6	4.61	4.67	0.01	32.57	0.02

2.3. Data Preparation and Analysis

Part of the samples collected for the study was poured into clean containers. A 1000ml quantity of each of the water samples was preserved with 10ml of concentrated HCl with the use of a syringe, this was shaken gently. The samples were then poured into a beaker of about 1000ml and left for incubation to achieve secular equilibrium.

Concentration of radionuclide in the water samples were determined with a 7.62cm×7.62cm NaI (Tl) detector, this is adequately protected with a thick lead shield.

A counting time of 25200, was used and the activity concentration determined in Bq/Kg from the count spectra obtained from each of the samples using the gamma ray photo peaks corresponding to energy of 1120.3keV(214Bi), 911.21keV(228Ac) and 1460.82keV(^{40}K) for ^{238}U, ^{232}Th and ^{40}K respectively as presented in table 1.

2.4. Assessment of Radiological Hazard Indices

One of the major objectives of the radioactivity measurement in environmental sample is not simply to determine the activity concentrations of ^{238}U, ^{232}Th and ^{40}K but also to estimate the radiation exposure dose and to assess the biological effects on humans. The assessment of radiological risk can be considered in various terms. In the current study four related quantities were study (table 1), these being: (i) Absorbed Dose Rate, (ii) Annual Effective Dose Equivalent, (iii) Annual Gonnadial Dose Equivalent and (iv) Excess Lifetime Cancer Risk.

2.4.1. Absorbed Gamma Dose Rate – AGDR (nGyh^{-1})

This is the amount of radiation energy absorbed or deposited per unit mass of substance. The Absorbed Gamma Dose Equivalent due to gamma radiations in air at 1m above the ground surface for the uniform distribution of the naturally occurring radionuclides (^{238}U, ^{232}Th and ^{40}K) were calculated according to guidelines in [4]:

$$D\ (nGy/h) = 0.462A_u + 0.604A_{Th} + 0.041A_k$$

Where ^{A}K, ^{A}U and ^{A}Th are the activity concentrations of ^{40}K, ^{238}U and ^{232}Th in Bqkg^{-1} respectively (table 1).

2.4.2. Annual Effective Dose Equivalent – AEDEq (mSvy^{-1})

This is the effective dose equivalent received outdoor by a member of the public. The Annual Effective Dose Equivalent (AEDEq) in mSvy^{-1} resulting from the Absorbed Gamma Dose Equivalent values (AGDR) was calculated using the following formula (table 1).

$$AEDEq\ (mSvy^{-1}) = AGDR\ (nGy/h) \times 8760h \times 0.7Sv/Gy \times 0.2$$

$$AEDEq\ (mSvy^{-1}) = AGDR\ (nGy/h) \times 0.00123$$

2.4.3. Annual Gonnadial Dose Equivalent – AGDEq (uSvy^{-1})

The gonads, the bone marrow and the bone surface cells are considered as organs of interest by [4] because of their sensitivity to radiation. AGDEq is a measure of the genetic significance of the dose received annually by the public reproductive organs [9]. A high AGDEq (uSvy^{-1}) is known to affect the bone marrow, causing destruction of the red blood cells that are then replaced by white blood cells. This situation results in a blood cancer called leukemia which is fatal.

AGDEq is determined by the following equation [4].

$$AGDEq\ (\mu Svy^{-1}) = 3.09\ (U) + 4.18\ (Th) + 0.314\ (K)$$

Where (U), (Th) and (K) are the radioactivity concentration of ^{228}U, ^{232}Th and ^{40}K in the sample (table 1).

2.4.4. Excess Life Cancer Risk (ELCR)

This is the probability of developing cancer over a lifetime at a given exposure level. A higher value of ELCR implies higher probability of the individual exposed can be induced to cancer. This is calculated as:

$$ELCER = AEDE \times DL \times RF$$

Where AEDE, DL and RF are annual effective dose equivalent, duration of life (54.5yrs) and risk factor (0.05Sv^{-1}) i.e. fatal cancer risk per Sievert (table 1).

3. Result and Discussion

3.1. Activity Concentration

Results obtained for the Gamma spectroscopic analysis of borehole water samples collected from the study area is shown in Tables 1. The activity concentration of ^{40}K, ^{232}Th and ^{238}U are shown in Bq/L. In all, concentration of ^{40}K is highest while that of ^{238}U is lowest. In borehole water samples, Activity concentration of ^{40}K ranges from 4.41±4.40 Bq/L (DB02) to 26.39±2.37 Bq/L (MPB1) with mean value of 16.78Bq/L, ^{232}Th ranges from 2.04±0.30 Bq/L (MPB2) to 8.04±0.87 Bq/L (DBO2) with mean value of 4.61Bq/L and ^{238}U ranges from 1.06±1.07 Bq/L (KJB2) to 5.44±0.05 Bq/L (VB1) with mean value 2.6 Bq/L. The mean activity concentrations of the radionuclides are much lower than the standard limit of ^{40}K (400Bq/L), ^{232}Th (45Bq/L) and ^{238}U (32Bq/L) set by the United Nations scientific Committee on the Effects of Atomic Radiation [7]. The mean concentrations for the two radioelements are 4.61±1.10Bq/L and 2.6±0.88 Bq/L. The highest concentration of ^{238}Th was recorded in Dutse (DB02) with 8.04±0.87 Bq/L while the lowest was recorded in Mpape borehole water (MPB2) with 2.04±.30 Bq/L.

3.2. Assessment of Radiological Hazard

Parameters of measuring radiological hazards in water samples were calculated (Table 1). The Absorbed Gamma Dose Rate (AGDR nGyh^{-1}) is the amount of radiation energy absorbed or

deposited per unit mass of substance. The amount of gamma dose absorbed per unit mass measured in $nGyh^{-1}$ clearly falls below the 30-70nGy/h safe limit stipulated by the United Nations Scientific Committee on the Effect of Atomic Radiation [8] in the water samples. [11] and [8] have recommended 0.48 mSv/y and 70 uSv/y limit for the Annual Effective Dose Equivalent (AEDEq) and Annual Gonnadial Dose Equivalent (AGDEq). AEDEq is the effective dose equivalent received outdoor by a member of the public while AGDEq is a measure of the genetic significance of the dose received annually by the public reproductive organs [6]. The mean AGDEq is 32.57 µSv/y (table 1). High AGDEq value is undesirable in water sample as it may destroy the red blood cells of people in the area [4] [11]. The United Nations Scientific Committee on the effect of atomic radiation [7] has recommended a safe limit of $0.29x10^{-3}$ as the Excess Lifetime Cancer Risk (ELCR) for people living and working in mining areas just as case of the studied locations, this value is also clearly exceeded in the borehole water samples studied, indicating the risk posed to people in the area. ELCR is the probability of developing cancer over a lifetime at a given exposure level. A higher value of ELCR implies higher probability of the individual exposed can be induced to cancer.

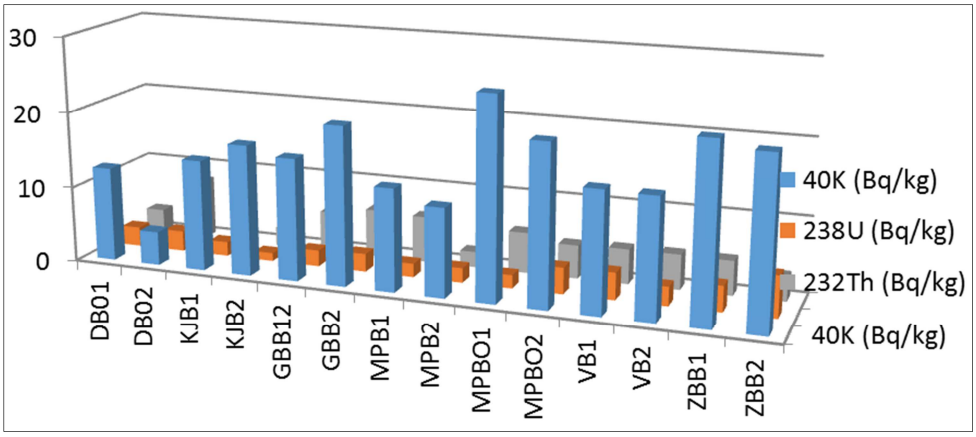

Figure 3. Activity Concentration of ^{238}U, ^{232}Th and ^{40}K in Borehole water Samples.

4. Conclusion

Radionuclide materials of water sample collected from selected sites in Abuja Municipal, Bwari and Kuje Area Councils of FCT, Nigeria was carried out by using the Gamma spectroscopy (NaI/TI) technique for the radionuclide materials, The result of ^{238}U, ^{232}Th and ^{40}K showed that the activity concentration values of various samples analyzed varies from (1.06±1.07 to 5.44±0.05, 2.04±0.30 to 8.04±0.87, and 4.41±4.40 to 26.39±2.37) respectively as seen in figure 3. Other factors that affect the variation of the activities concentration are geological and geographical formation of the study areas. From the result it is clear that the mean concentration of ^{238}U, ^{232}Th and ^{40}K are below the safety limit (45, 32 and 400) Bq/l as recommended by [7].

The mean AGDR (4.67nGy/h), AEDEq (0.01mSv/y) and AGDEq (32.57µSv/y) in the study fell below the standard set safe limits recommended by [5] in all the samples (table 1). The ELCR (0.02) is higher than the safe limit as seen in table 1.

The findings of the study show that the radiation exposure level of the areas is notably high and could be harmful to human health.

Recommendations

The evaluation of radiation dose indices in water samples from selected quarry sites in Abuja suggest that the inhabitants in the studied areas could be exposed to radiation. Thus, they have the possibility of developing radiation induced clinical symptoms.

It is recommended that:

i Inhabitant should be educated about threat posed by consuming such water.

ii Health screening should be carried out periodically on the inhabitant to check.

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