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Comparative Studies of Radiological Hazards Indices Resulting from Boreholes and Local Wells H_2O at Selected Locations in FCT Abuja, Nigeria

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Abstracts

H_2O, regardless of its sources is extensively used by man, animal and for our environment. The presence of natural radio nuclides in H_2O results in internal and external exposure to man and its environment. Therefore, it is necessary to determine the concentration of naturally occurring radioactive materials (NORMs): namely ^{238}U, ^{232}Th and ^{40}K and the radiological hazards parameters in the water samples collected from different sources (boreholes and local wells) at selected locations in the Abuja, FCT. Twenty four H_2O (boreholes and local wells) samples were collected from seven different locations in the studied areas. In order to measure the specific activity 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 varied 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) for borehole and (2.06 ± 1.23 to 8.91 ± 1.13, 5.89 ± 0.98 to 9.47 ± 0.89 and 30.37 ± 4.96 to 61.78 ± 5.58) for the local well respectively. From the results it is clear that the mean concentration of ^{238}U, ^{232}Th and ^{40}K are well below the safety limit of 35, 30 and 400Bq/l respectively as recommended by United Nation Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). The Absorbed Gamma Dose Rate (AGDR), the mean Annual Effective Dose Equivalent (AEDEq), Annual Gonnadial Dose Equivalent (AGDEq) in the studied areas fell below the standard set safe limits recommended but Excess Lifetime Cancer Risk (ELCR) was higher than the safe limit in both borehole and local well H_2O. The hazard indices studied and compared revealed that local well contained double the amount observed in borehole. The findings of the study showed that the radiation exposure level (ELCR) originating from both boreholes and well H_2O of the mining sites were significantly high and could be harmful to human consumption and health.

Keywords

Comparatives, Radiological Hazards, Borehole, Local Well, NaI (Tl) Detector, Gamma-Ray Spectrometry

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1. Introduction

There are several sources of radiation in the atmosphere. Gamma radiation emitted from naturally occurring radionuclides, also called terrestrial background radiation, represents the core external source of exposure to human body systems. Human beings are exposed to radiation primarily from cosmic rays and from the gamma ray emitters in soils, building materials, water, food, and air. An

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investigation concerning the level of radionuclide distribution in the environment provides vital radiological information [1]. Radio nuclides have been essentially present in the environment from the beginning of the earth. Human beings have always been exposed to ionizing radiation emanating from the earth [2]. Assessment of this radionuclide in soil, *water* and rocks in many parts of the world has been on the increase in the past two decades and even more because of their hazard on the health of the populace according to available literatures [12, 9]. The soil is the major source and pathway of radio nuclides to living beings. The distribution of radio nuclides in nature, their concentration and movements can seriously be affected by the activities of population [3]. Groundwater has been identified as a carrier of these nuclides. Hence, the comparatives studies of the concentrations of the radio nuclides (uranium U, thorium Th and potassium K) and the radiological hazard indices originating from boreholes and local wells are considered very necessary so as to ascertain the best among the two sources of groundwater for onward information to the populace.

2. Materials and Methods

Gamma spectrometry is used to determine and measure the radionuclide concentration in the water samples. Gamma ray spectrometer is a powerful analytical 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 in finite 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 mainly of Basement Complex and sedimentary rocks. The Basement Complex rocks which are 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 and 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 and largely constitute the undulating plains. These plains form present day remnants of erosional processes of the Quaternary period. Towards the south west of the Federal Capital Territory there exist sand ridges with outliers of sandstone capping's. 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 evidence 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 Precambrian age. These rocks consist of gnesis, 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.

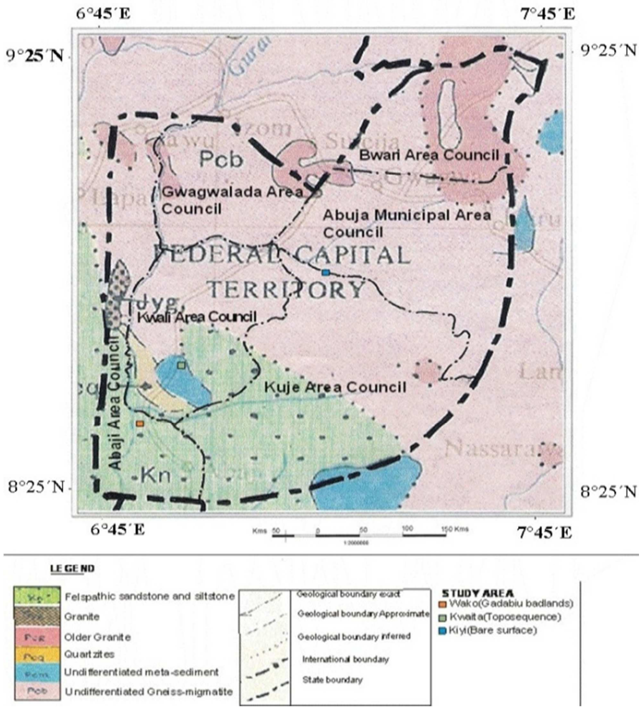

Figure 1. Geology Map of Abuja, Federal Capital Territory of Nigeria. As cited in [2].

2.2. Data Collections

The samples were collected from seven different sites (table 1), listed below;

Table 1. Quarry Company, Towns and their Coordinates.

S/N	Mining Company/ Towns	Locational Cordinates
1	Jinjia (Gbaupe)	N 8^0 9.05' E 7^0 34.42¹
2	Setraco (Mpape)	N 9^0 8.31' E 7^0 30.42¹
3	Dantata & Sawoe (Kuje)	N 8^0 9.38' E 7^0 26.19'

S/N	Mining Company/ Towns	Locational Cordinates
4	Julius Berger (Mpape)	N 9^0 14.39^1 E 7^0 47.31^1
5	Istanbul (Dutse)	N 9^0 13.47$'$, E 7^0 24.13$'$
6	Venus (Mbuko)	N 8^0 9.08$'$ E 7^0 22.66$'$
7	Zeberced (Kubwa)	N 9^0.96.21^1 E 7^0 18.66$'$

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

The samples were collected from 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 2. 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	AEDEq	AGDEq	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

Table 3. Activity Concentration (Bq/Kg) of ^{40}K, ^{232}Th and ^{238}U and Hazard Indices Studied in Local Well Water.

Name	^{40}K (Bq/L)	^{238}U (Bq/L)	^{232}Th (Bq/L)	Hazard Indices			
				AGDR	AEDEq	AGDEq	ELCR
DBW1	61.78±5.58	2.09±1.65	8.17±1.93	8.43	0.01	60.01	0.04
DBW2	57.56±6.37	3.71±1.86	9.41±1.89	9.75	0.02	68.87	0.04
KJW1	36.89±4.32	4.07±1.56	6.43±1.08	7.27	0.01	51.03	0.04
KJW2	43.77±4.14	5.30±1.53	7.31±1.27	8.65	0.02	60.67	0.04
GBW1	40.50±5.27	3.62±1.05	9.47±0.89	9.05	0.02	63.48	0.04
GBW2	44.99±3.16	2.06±1.23	6.39±0.65	6.65	0.01	47.2	0.04
MPW1	30.37±4.96	8.91±1.13	6.69±1.28	9.4	0.02	65.03	0.05
MPW2	42.10±3.06	5.92±1.43	7.89±1.09	9.22	0.02	64.26	0.04
MPWO1	45.30±4.21	4.41±1.64	5.89±0.98	7.45	0.01	52.47	0.04
MPWO2	31.37±3.57	5.02±1.70	6.89±1.75	7.76	0.01	54.16	0.04
Mean	43.46	4.51	7.54	8.41	0.02	59.09	0.04

2.3. Data Preparation and Analysis

Part of the samples collected for the study was poured into clean containers. 10ml of concentrate HCL was added with a syringe to 1litreof the water samples, this was shaken gently and preserved. The samples were then poured into a beaker of about 1littre and left for incubation to achieve secular equilibrium.

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

A counting time of 25200s, was used and the activity concentration determined in Bq/Kgfrom the count spectra obtained from each of the samples using the gamma ray photo peaks corresponding to energy of 1120.3 keV (214Bi), 911.21 keV (228Ac) and 1460.82 keV (40K) for 238U, 232Th and 40K respectively (table 2 and 3).

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 studied (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 1 m 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 (mSv y^{-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) × 8760 h × 0.7 Sv/Gy × 0.2

AEDEq (mSvy-1) = AGDR (nGy/h) × 0.00123

2.4.3. Annual Gonnadial Dose Equivalent - AGDEq (uSv y^{-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 (uSv y^{-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 can lead to a fatal condition of blood cancer called leukemia.

AGDEq is determined by the following equation [4]

AGDEq (μSvy-1) = 3.09 (U) + 4.18 (Th) + 0.314 (K)

Where (U), (Th) and (K) are the radioactivity concentration of ^{228}U, ^{232Th} 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 × DL × 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 from the Gamma spectroscopic analysis of borehole and well water samples collected from the study area are shown in Tables 2 and 3. The activity concentration of ^{40}K, ^{232}Th and ^{238}U are shown in Bq/L. In all, concentration of ^{40}K was the highest while that of ^{238}U was the lowest. In borehole water samples, Activity concentration of ^{40}K ranges from 4.41±4.40Bq/L (DB02) to 26.39±2.37Bq/L (MPB1) with mean value of 16.78Bq/L, ^{232}Th ranging from 2.04±0.30Bq/L (MPB2) to 8.04±0.87Bq/L (DBO2) with mean value of 4.61 Bq/L and ^{238}U ranging from 1.06±1.07 Bq/L (KJB2) to 5.44±0.05Bq/L (VB1) with mean value 2.6 Bq/L, and (2.06 ± 1.23 to 8.91 ± 1.13, 5.89 ± 0.98 to 9.41 ± 1.89 and 30.37 ± 4.96 to 61.78 ± 5.58) for well water. The mean activity concentrations of the radionuclides were much lower than the standard limit of ^{40}K (400 Bq/L), ^{232}Th (45 Bq/L) and ^{238}U (32 Bq/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±0.87Bq/L while the lowest was recorded in Mpape borehole water (MPB2) with 2.04±.30Bq/L (figure 2 and 3).

3.2. Assessment of Radiological Hazard

Parameters of measuring radiological hazards in water samples were calculated (Table 2 and 3). The Absorbed Gamma Dose Rate (AGDR nGyh-1) is the amount of radiation energy absorbed or deposited per unit mass of substance. The values of AGDR in well water and borehole are 4.67 and 8.41 respectively. 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 both well water and borehole samples. [11, 8] have recommended 0.48mSv/y and 70uSv/y limit for the Annual Effective Dose Equivalent (AEDEq) and Annual Gonnadial Dose Equivalent (AGDEq). AEDEq has mean values of 0.01 and 0.02 for borehole and well water respectively. 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 are 32.57 and 59.09 Sv/y for boreholes and well water respectively (table 1 and 2). High AGDEq value is undesirable in water sample as it may destroy the red blood cells of people in the area [4, 11]. ELCR has mean values of 0.02 and 0.04 for boreholes and well water respectively (table 4). The United Nations Scientific Committee on the effect of atomic radiation [7] has recommended a safe limit of 0.29 x 10^{-3} as the Excess Lifetime Cancer Risk (ELCR) for people living and working in mining areas, this value is also clearly exceeded by 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.

3.3. Comparatives Analysis of the Two Water Sources

Table 4 shows the comparative studies of water sample emanating from borehole and well water; it shows that there are significant differences even though AGDR, AEDEq, and AGDEq fell below the standard limit [7], as seen in table 4. ELCR has mean values that was considered high and above the standard limit [7], from the studies local well water has double values of borehole. These shows that the hazards risk available in boreholes by the above indices are double in all ramification in local well water (table 4).

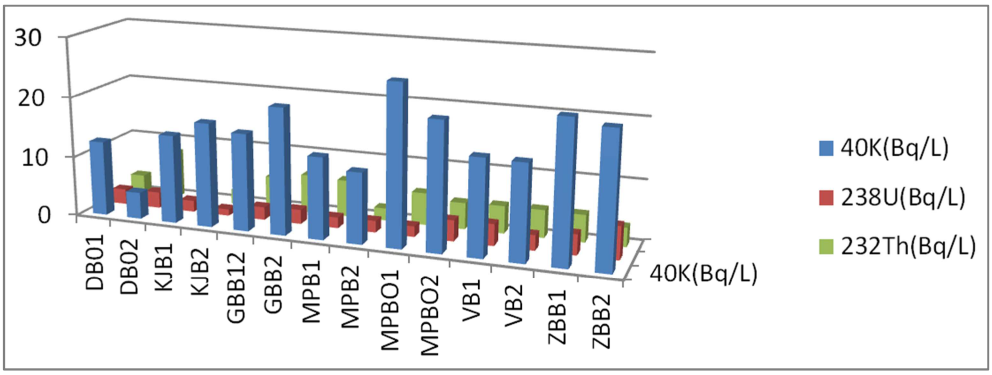

Figure 2. Activity Concentration of ^{238}U, ^{232}Th and ^{40}K in Borehole water Samples.

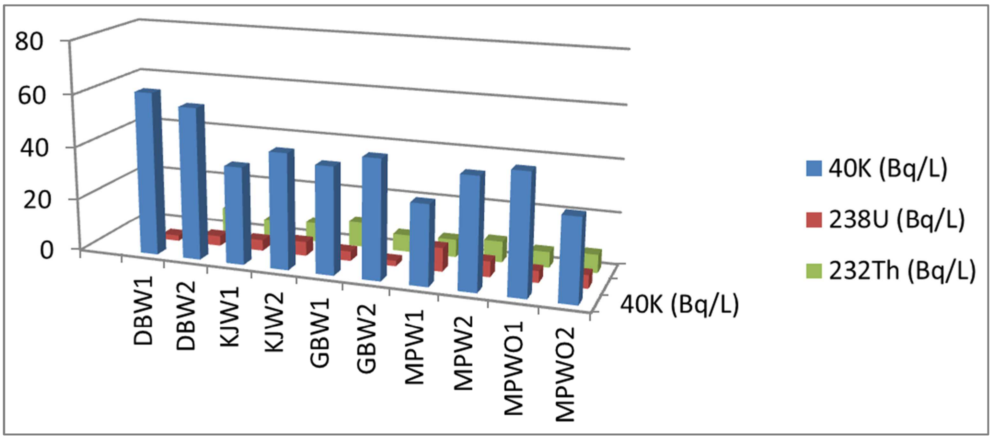

Figure 3. Activity Concentration of ^{238}U, ^{232}Th and ^{40}K in Well Water Samples.

Table 4. Comparative table of hazard values as calculated with standard values.

Hazard Indices	Standard/Acceptable values [5, 7, 8]	Boreholes	Local Wells
AGDR (nGy/l)	30 – 70	4.67	8.41
AEDEq (mSv/y)	0.48	0.01	0.02
AGDEq (uSv/y)	70	32.57	59.09
ELCR	$0.29 * 10^{-3}$	0.02	0.04

4. Conclusion

The result of ^{238}U, ^{232}Th and ^{40}K showed that the activity concentration values of various samples analyzed and studied varied 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) for borehole water and (2.06 ± 1.23 to 8.91 ± 1.13, 5.89 ± 0.98 to 9.41 ± 1.89 and 30.37 ± 4.96 to 61.78 ± 5.58) for well water. Other factors that affect the variation of the activities concentration are the 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 (35, 30 and 400) Bq/l as recommended by [7].

Table 4 clearly shows that the hazard indices originating from borehole water sources has a good safety limit as compared with the calculated values originating from the local well water sources, although they both fell below the standard/ acceptable level except the ELCR that exceeded significantly the standard limit which portrait greater danger to the environment and life. The hazard indices values from the local wells are twice those from the boreholes, the difference observed may be as a result of the borehole casement as seen in table 4 (this is open for further studies and investigation).

The findings of the comparative studies show that the radiation exposure levels of local wells are notably high and could be harmful to human health especially the ELCR exposure level (table 4).

Recommendations

The evaluations of radiation dose and hazard indices in boreholes and well water samples from selected quarry sites in FCT, Abuja suggested that the inhabitants in the study areas could be exposed to radiation hazards (ELCR). Thus, they may have the possibility of developing radiation induced clinical symptoms with time [2].

It is recommended that

i. Inhabitant should be educated about the threat posed by consuming water from these sources.

ii. Health screening should be carried out periodically on the inhabitant to check their health status and level exposure.

iii. Purification means be engaged before consumption.

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