International Journal of Research (IJR)

e-ISSN: 2348-6848
p-ISSN: 2348-795X
Vol. 9 Issue 04
April 2022

ASSESSMENT OF NATURAL RADIONUCLIDE CONTENTS IN RESIDENTIAL BOREHOLE WATER COLLECTED FROM A SELECTED AREA OF JEMA'A LOCAL GOVERNMENT OF KADUNA STATE NIGERIA

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Abstract

The analysis of radioactivity level in groundwater in Jema'a Local Government area of Kaduna State, Nigeria was determined using inductively coupled plasma mass spectroscopy. The result revealed the concentration levels of radioactive materials in each of the water samples which include uranium, thorium and potassium. The mean activity concentration of ^{238}U, ^{232}Th and ^{40}K in borehole water samples were 33.21±1.10 BqL^{-1}, 3.39±1.18 BqL^{-1} and 61.88±0.90 BqL^{-1} respectively which were found to be higher than the permissible values, and the percentage cancer risk is found directly proportional to the absorbed dose. Therefore, the final results were not favorable because all the radioactive materials detected and their concentration levels exceeded the international maximum contaminant levels set by UNSCEAR, 2000 and WHO, 2008 standards. The lifetime cancer risk evaluated for all the water samples were found to be greater than the recommended limit. The result revealed that the environment has been polluted with un-segregated wastes which may contain some radio elements. Therefore, continual radiation exposure of the populace will pose significant health threat. It recommends the need for the people of Jema'a Local Government Area of Kaduna communities to treat their water before consumption and an awareness programs should also be implemented to inform the people of Jema'a Local Government Area of Kaduna communities of the status of the water quality and methods that can be used to avoid getting ill as a result of water contamination.

Key words: Radioactivity, Concentration, Hazard, Cancer, Risk.

Introduction

Radioactive materials (NORMS) occur naturally in the environment (e.g. uranium, thorium and potassium). Some of these radioactive materials arise from human activities (e.g. from medical or industrial uses of radioactivity). In essence, natural sources of radiation are concentrated by mining and other industrial activities (Al-Masri & Siman, 2003). The activities going on in the study area include agricultural activities such as the excessive application of organic and chemical fertilizers by farmers, uncontrolled use of pesticides, herbicides, water softener discharge, uncontrolled domestic and sewage dump. A large extent of human exposure to radiation comes from natural sources from external sources of radiation, which includes cosmic radiation, or from consumption or breathing in of radioactive materials (Cadieux, Clark, Fjeld, Reboul & Sowder, 1994). Naturally occurring element such as uranium is widespread in nature. It is mostly found in low levels within all rocks, soils and water. The element which is the heaviest is usually found in significant quantities on earth. As opined by the United Nations Scientific Committee on the Effects of Atomic Radiation the normal concentration of uranium in soil is 300µg/kg (micro gram per kg) to 11.7 mg/kg (milligram per kg) (UNSCEAR, 1993). Greater levels of uranium are found in some types of soils and rocks, mostly granite, and the ocean.

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The rise in the concentration of radioactivity is due to viable movement of radio nuclides to groundwater, drainage of contaminants into the ground water bodies, unrestrained use of fertilizers on farm lands, relinquish industrial locations, nuclear power plants, post-quarry sites, waste dump areas, can also attribute to the radioactivity concentration. There is the possibility for groundwater to ordinarily produce anew but, at times, takes longer period as it progresses very slowly steadily. Significance of water quality evaluation and control in the context of radioactivity cannot be overstressed (Nwankwo, 2013).

Uranium concentration in ground water depends on the lithology, geomorphology and other geological factors of the region. In ground water, both uranium and toxic elements are presenting particulate and dissolved form due to certain minerals such as urinates, pitchblende and cornalite or as secondary mineral in form of complex oxide of silicate, phosphate, validates, lignite and monazite sands (Mahesh Avadhani, Someshekarappa, Karunakara, Narayana & Siddappa, 2001). To guide the groundwater quality in an environment, some areas that have been contaminated by high concentration of uranium and toxic elements need to be identified, the degree of damage assessed and the causes resulting to imbalances determined. Some toxic metals potentially resulting from anthropogenic activities cause severe disturbances to the ecosystems (Abderahaman & Abu-Rukah, 2006). However, it is essential to protect the quality of the environment all over, such that the human activities of negative effect will be drastically reduced. The toxic effect of some radioactive elements like uranium compound has been extensively studied in kidney (Kurttio, Auvinen, Salonen, Saha, Pekkanen, Mäkeläinen & Komulainen (2002). Larivière, Packer, Marro, Li, Chen & Cornett, 2007).
The toxicity of the human kidney by chronic ingestion of uranium through drinking water in the range of 0.004 to 9 mgL^{-1} per body weight per day, may produce interference with kidney functions (Zamora *et al*., 1998). In more recent studies on human nephrotoxic effects of uranium in drinking water were found even for low concentrations without clear threshold (Kurttio *et al*., 2002). Most results from uranium studies in drinking water suggest that the safe concentration of uranium in drinking water may be within the range guide line values of 2–30 mgL^{-1} (Kurttio *et al*., 2002; WHO,2008). Because uranium is predominantly alpha-emitting radionuclide, the raised concern is about the potential DNA damage if the emitted alpha-particles reach the cell nuclei of the body, for instance through water ingestion. Attempt by cells to repair this damage if occurs, may result in repair errors, producing gene mutations or chromosomal aberrations. These effects, when sufficiently severe, may be manifested as cancer and possibly as developmental malformations in children and developing fetus. Hence, this work seeks to evaluate the NORM content of water and to estimate the radiological health implication to the general public.

Study Area

Jema'a Local Government is located in Kaduna South Senatorial District of Kaduna State, about 70km away from the State capital. The town is located on $longitude$ 9º 11' – 9º 31' $North$ and $latitude$ 8º00' – 8º 33' $East$ and it has a population of 278,735 at the 2006 census. (Fig. 1.1**)** The major towns in the Local Government include Kafanchan A & B, Gidan-Waya, Ugwan Mailafiya, Jagindi, Godogodo, Ungwan Pataki, Nisama ,Kagoma and Barde.

International Journal of Research
(IJR)

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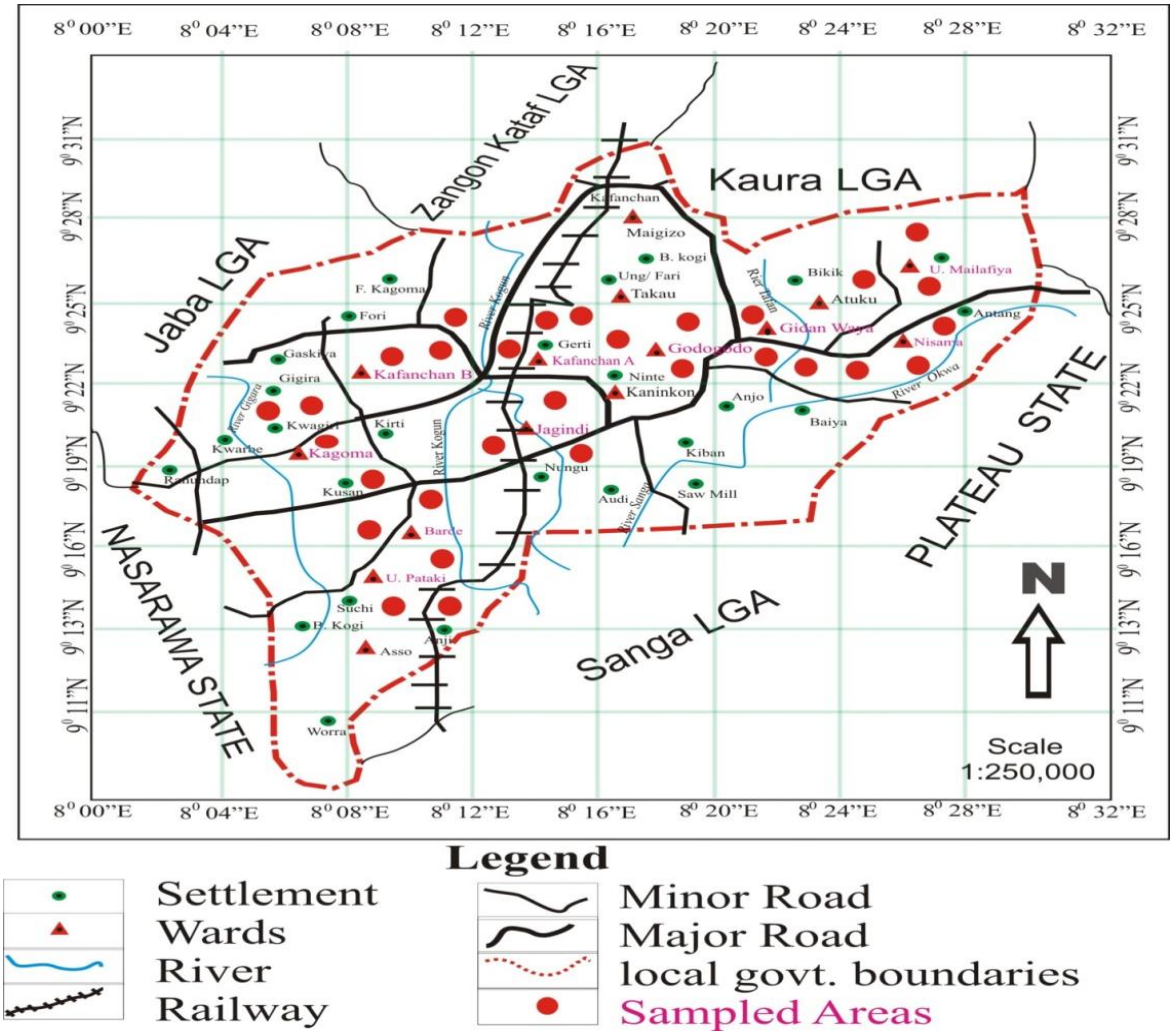

Fig. 1.1: Map of Jema a Local Government showing sample points with grids (KSMLS, 2016).

The bedrock geology of Jema'a Local Government area Kaduna State, Nigeria is predominantly metamorphic rocks of the Nigerian basement complex consisting of biotic gneisses and older granites; younger plutonic igneous rocks and batholiths are also obvious. Extensive chemical and fluvial erosion controlled by the bio-climatic nature of the environment have developed characteristic high undulating plains with subdivided interflow (JEPR, 2016). The major occupation of the people includes farming and business amongst others. Their basic and regular source of water is from Boreholes. The borehole water sample locations and their coordinates are shown in Table 1.0 also, the geographical map of Jema'a Local Government Area can be shown in Figure 1.0

Table 1.0. Borehole water sample locations and coordinates

S/N	SAMPLE LOCATION	SAMPLE ID	LONG.	LAT.	ELEVATION
1	GODOGODO BOREHOLE	S1	8.3	9.1	538
2	GIDANWAYA BOREHOLE	S6	8.3	9.3	536
3	JAGINDI BOREHOLE	S8	8.3	9.0	506
4	KAFANCHAN A BOREHOLE	S11	8.3	9.3	719
5	KAFANCHAN B BOREHOLE	S13	8.3	9.3	781
6	KAGOMA BOREHOLE	S16	8.1	9.1	763
7	U/PATAKI BOREHOLE	S20	8.3	9.3	552
8	NISAMA BOREHOLE	S23	8.1	9.0	554
9	BARDE BOREHOLE	S27	8.3	9.3	547
10	U/MAILAFIYA BOREHOLE	S28	8.1	9.1	533

Method of Sample Analysis

Experimental set up

Measurement using ICP-MS was performed at Center for Energy Research and Development Obafemi Awolowo University, Ile Ife Osun State, Nigeria; the instrument performs analyses at parts-per-trillion. The reason for the measurements was to determine the concentrations of ^{238}U, ^{232}Th and ^{40}K in groundwater, the concentrations of ^{238}U, ^{232}Th and ^{40}K of few selected samples were measured using High Purity Germanium (HPGe). The counting equipment was a Canberra vertical High-purity coaxial germanium crystal (HPGe) detector model Gc2018-7500, serial number b 87063 enclosed in a 100-mm lead shield that is computed to a Canberra multichannel Analyzing (MCA) computer system. The measure of radionuclide present in water samples was obtained through energy and efficiency calibration using a well calibrated standard water sources supplied by the International Atomic energy Agency (IAEA). The MCA was calibrated so as to display gamma photo peaks. The counting time was 36000s. An empty sample container is also counted for the same counting time using the same geometry to determine the background distribution spectrum. The photo peaks observed with reliable regularity belong to the naturally occurring series-decay radionuclide headed by ^{238}U and ^{232}Th, as well as the non-series decay type ^{40}K. The activities of radionuclide were calculated from the difference between net peak and net peak background areas, accumulation time, absolute peak efficiency, absolute gamma-ray emission probability and the volume. Measurement of radionuclide concentrations in the water sample were carried out at least twice to check on the reproducibility of results and the stability of the counting system.

Measurement of Radium Equivalent in Borehole Water

The radium equivalent in Borehole water was calculated using equation 1.0

$$Raeq = {}^{238}U + 1.43\,{}^{232}Th + 0.077\,{}^{40}K$$

Where ^{238}U, ^{232}Th and ^{40}K are the activity concentrations in BqL^{-1} of Uranium, Thorium and Potassium respectively.

Measurement of External and Internal Hazard Indexes in Borehole Water

The external and internal hazard indexes in Borehole water were calculated using equations 1.2 and 1.3 respectively.

$$Hex = {}^{238}U/370 + {}^{232}Th/259 + {}^{40}K/4810 \quad (1.2)$$

and

$$Hin = {}^{238}U/185 + {}^{232}Th/259 + {}^{40}K/4810 \quad (1.3)$$

Where ^{238}U, ^{232}Th and ^{40}K are the activity concentrations in BqL^{-1} of Uranium, Thorium and Potassium respectively.

Measurement of Absorbed Dose in Borehole Water

The absorbed dose in Borehole water was calculated using equation 1.4

$$D(nGy/hr) = 0.429\,{}^{238}U + 0.666\,{}^{232}Th + 0.42\,{}^{40}K \quad (1.4)$$

Where ^{238}U, ^{232}Th and ^{40}K are the activity concentrations in BqL^{-1} of Uranium, Thorium and Potassium respectively.

Measurement of Excess Lifetime Cancer Risk in Borehole Water

The excess life time cancer risk in Borehole water was calculated using equation 1.5

$$ELCR = AEDE \times DL \times RF \quad (1.5)$$

Where $AEDE$ is the annual effective dose, $AEDE$ (mSv/yr) = $I \times A \times C \times 365$

DL is the duration of lifetime (30-70)

RF is the risk factor in Sievert which is the fatal cancer risk per Sievert. For stochastic effect, ICPR assumed value of 0.05 for RF factor for the public (Taskin *et al*., 200).

RESULTS AND DISCUSSION.

The activity concentration of uranium, thorium and potassium in borehole water sampled from Jema'a Local Government Area. The data comprises of stations such as Godogodo borehole, GIdan-waya borehole, Kafanchan A borehole, Kafanchan B borehole, Kagoma borehole, Nisama borehole, U/Mailafiya borehole, Barde borehole, U/Pataki borehole and Jagindi borehole. This is presented in Table 1.2

TABLE 1.2: ACTIVITY CONCENTRATION OF ^{238}U, ^{232}Th AND ^{40}K IN BOREHOLE WATER SAMPLES

S/N	SAMPLE ID	^{238}U Bq/l	^{232}Th Bq/l	^{40}K Bq/l
1	S1	31.90±0.91	3.32±0.22	59.68±1.08
2	S2	38.49±2.39	3.92±0.74	69.20±2.89
3	S3	32.02±0.85	3.35±0.14	62.71±1.36
4	S4	31.68±1.03	3.32±0.23	61.16±0.55
5	S5	33.12±0.62	3.32±0.21	59.44±1.19
6	S6	32.79±0.21	3.19±0.42	61.57±0.85
7	S7	32.12±0.78	3.52±0.39	59.94±0.95

8	S8	33.18±0.48	3.25±0.45	63.16±0.35
9	S9	33.70±0.98	3.35±0.13	60.13±0.84
10	S10	33.10±0.60	3.44±0.27	61.89±0.99
Mean			**3.39±1.18**	**61.88±0.90**
	33.21±1.10			
WHO		**10**	**1**	**10**

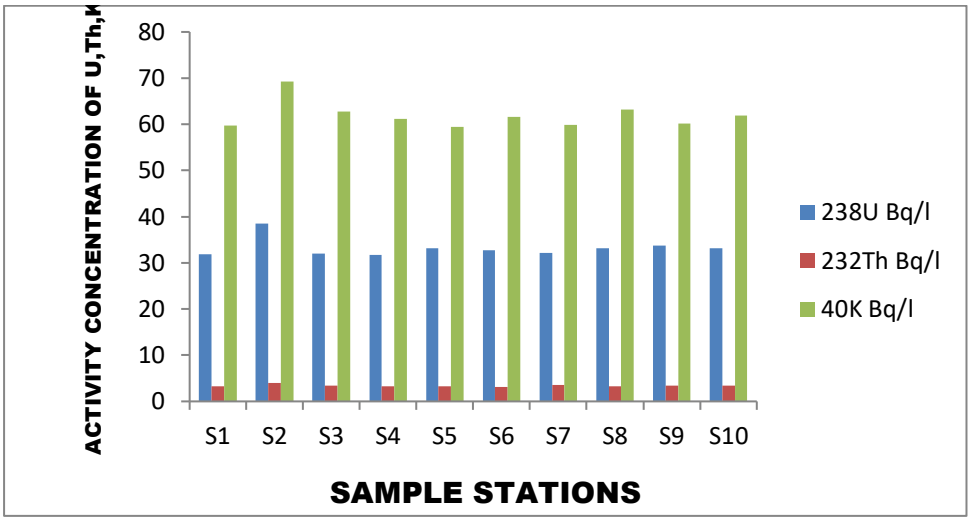

Figure 1.2 Plot of activity concentration of the ^{238}U, ^{232}Th and ^{40}K versus sample stations in borehole water S1-S10

Figure 1.2 is a bar plot of the specific activity concentrations of uranium, thorium and potassium in borehole water samples against the various sample stations.

Radium Equivalent in Borehole Water.

Radium equivalent in borehole water samples is obtained using the activity concentrations of ^{238}U, ^{232}Th and ^{40}K in Table 1.2. The radium equivalent was calculated using equation 1.0 This is illustrated in Fig. 1.3

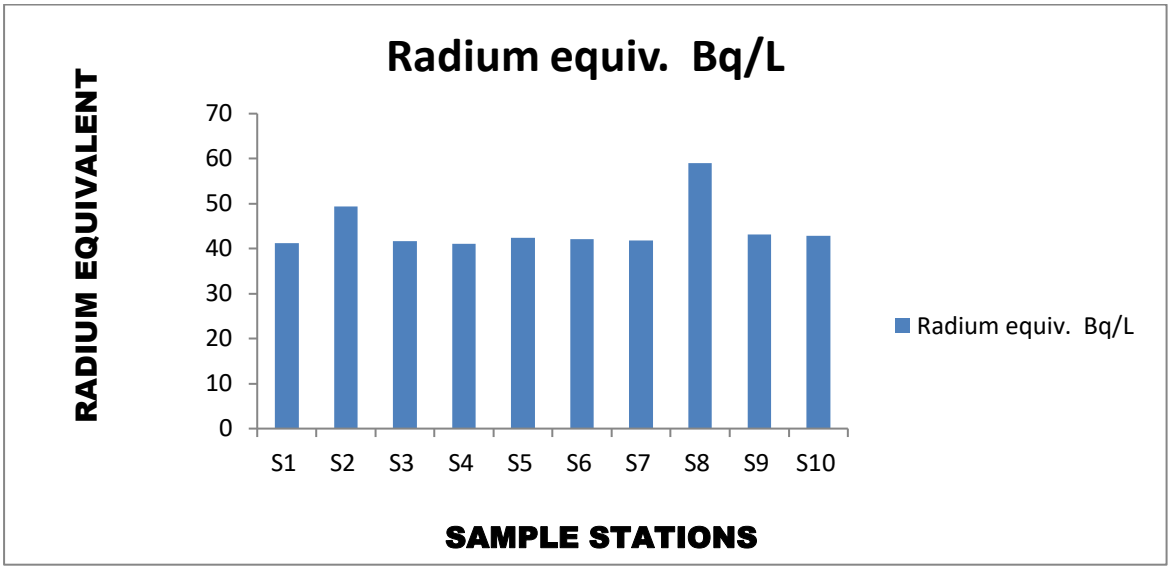

Figure 1.3: Plot of Radium equivalent concentration versus sample stations in borehole water S1-S10

Internal and External Hazard Indexes in Borehole Water

The internal and external hazard indexes in borehole water samples obtained using the activity concentrations of ^{238}U, ^{232}Th and ^{40}K in Table 1.2 The internal hazard index was calculated using equation 1.2 while the external hazard index was calculated using equation 1.3. This is illustrated in Fig. 1.20

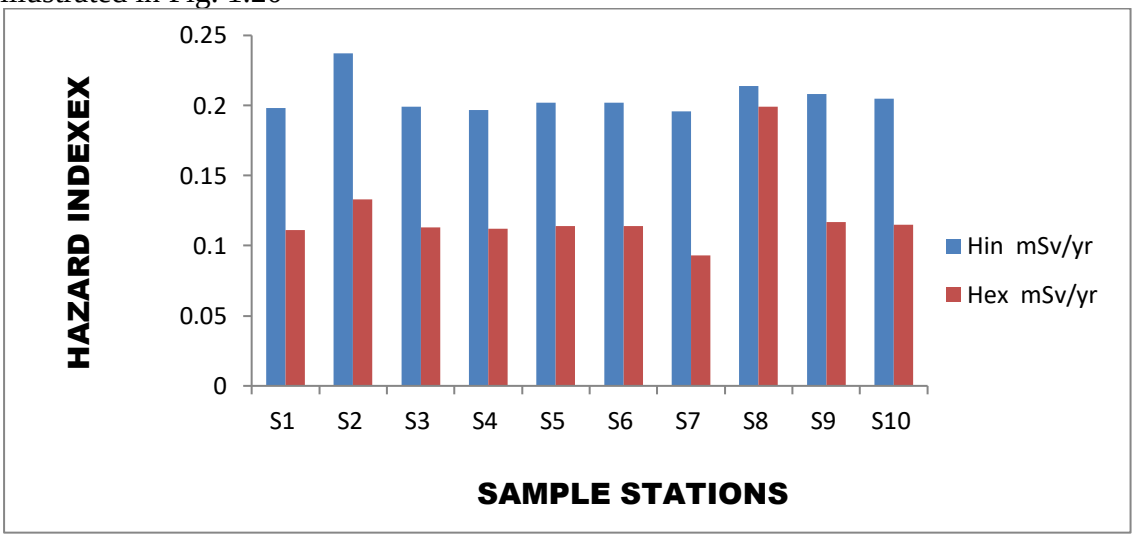

Figure 1.4: Plot of External and Internal Index concentration versus sample stations in borehole water S1-S10

Absorbed Dose Rate in Borehole Water

This present the absorbed dose rate in borehole water samples, obtained using the activity concentrations of ^{238}U, ^{232}Th and ^{40}K in Table 1.2. The absorbed dose was calculated using equation 1.4. This is illustrated in Fig. 1.4

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p-ISSN: 2348-795X
Vol. 9 Issue 04
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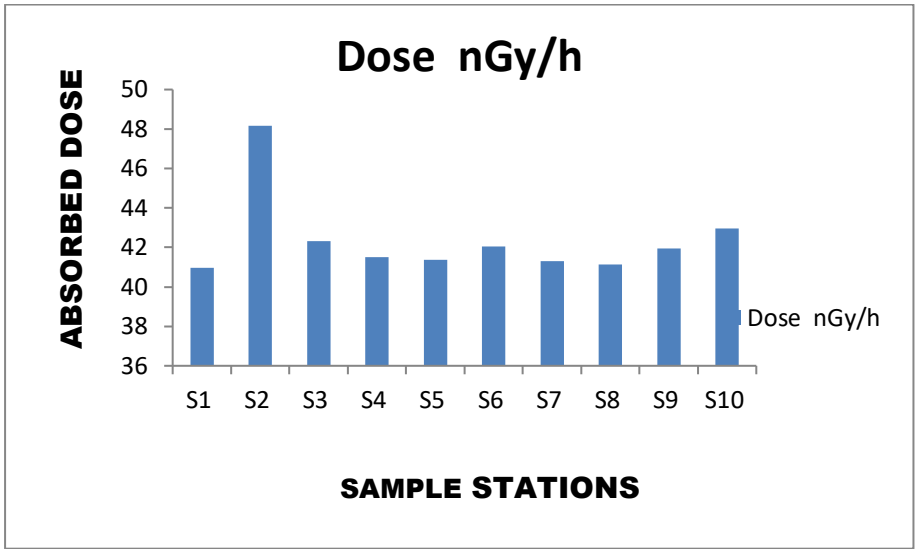

Figure 1.5: Plot of Absorbed dose rate concentration versus sample stations in borehole water S1-S10

Excess Lifetime Cancer Risk in Borehole Water.

The excess lifetime cancer risk in borehole water samples obtained using the activity concentrations of ^{238}U, ^{232}Th and ^{40}K in Table 1.2. The excess lifetime cancer risk was calculated using equation 1.4. This is illustrated in Fig. 1.6

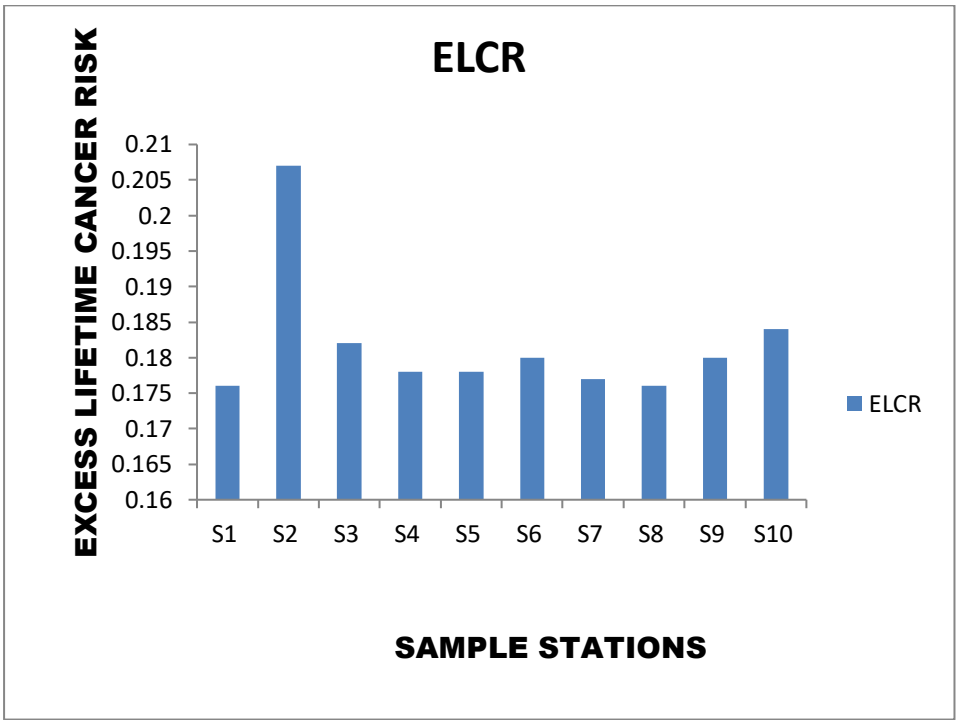

Figure 1.6 Plot of Excess Lifetime Cancer Risk concentrations versus sample stations in borehole water S1-S10

The highest and the lowest percentage absorbed dose and excess cancer risk in each sample station is analyzed below in Fig 1.5 and Fig 1.6 corresponding angle. Hence, it shows clearly that, the percentage absorbed dose is proportional to the excess cancer risk in each sample stations.

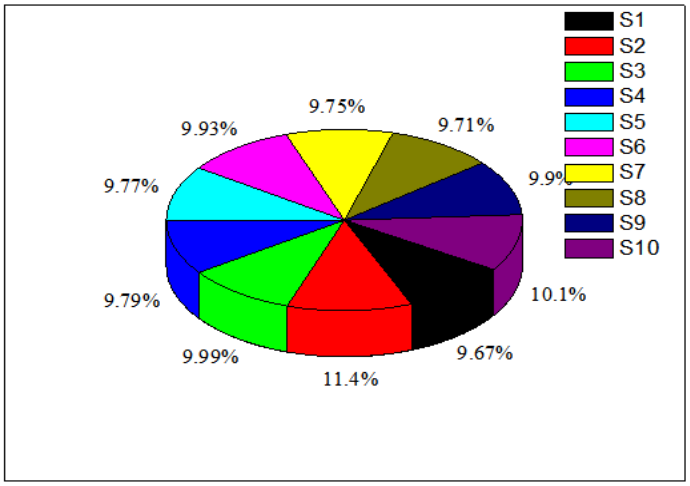

Fig 1.7 Percentage absorbed dose in borehole water

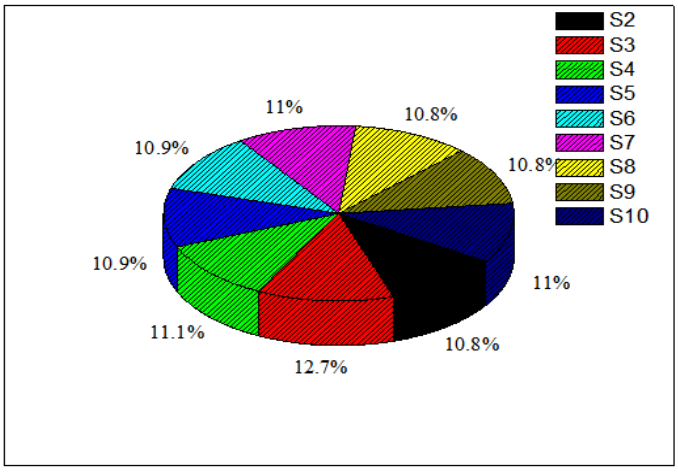

Fig 1.8 Percentage excess cancer risk in borehole water

From Table 1.2 it shows that, the highest value of ^{238}U in borehole water is 38.49±2.39 BqL^{-1} was detected in (S_2) Gidan-waya borehole while the lowest concentration of ^{238}U in borehole water which is 31.68±1.03 BqL^{-1} was detected in S_4 Kafanchan A borehole. All these values obtained for uranium in borehole water samples were not comparable to 10BqL^{-1}. High values of 38.49±2.39 BqL^{-1} observed in borehole water samples in the study area can be attributed to the hydro geological situation of aquifer bearing formation, chemical complexion and oxidation potential of the environmental rock formation; the type of rocks found in the study area includes igneous and metamorphic rocks where the lower complex rocks are specifically granites, gneisses, migmatites and quartzite which contains high amount of radioactive materials which could contaminate the groundwater. It could also be as a result of the mining activity going on within the area as well Maxwell *et al.* (2014). In this regard it was found that, the findings for ^{238}U in this study is not in line with the findings of Avwiri *et al.* (2007), who

found the activity concentration of ^{238}U to be 3.51±1.22 BqL^{-1}, Ononugbo *et al.* (2017) who found the activity concentration of ^{238}U to be 3.98±0.26 BqL^{-1} and Tchokosa *et al.* (1999) whose activity concentration of ^{238}U was found to be 10.81±3.67 BqL^{-1} , where the activity concentration of ^{238}U in the study area were higher than those of the control area and the world average values poses a serious health risk to the environment and its inhabitants. The variation in the level of ^{238}U concentrations may be as a result of the geology, lithology and geomorphology of each environment and the type of activities going on in each study area (Okezie, 1970).

Furthermore, considering the activity concentration of ^{232}Th in borehole water samples, revealed that the highest concentration of ^{232}Th in h in borehole water was detected in (S2) Gidan-waya borehole with a value of 3.92±0.74 BqL^{-1} and the lowest concentration of thorium in borehole water was detected in (S6) Kagoma borehole with a value of 3.19±0.42 BqL^{-1}. All these values obtained for thorium were not comparable to the world recommended safe limit of 1 BqL^{-1}. The activity concentrations of 3.92±0.74 BqL^{-1} for ^{232}Th can be attributed to the abundance of metamorphic rocks like shale and quartz of pathic gneisis in the current study area (Gondar, 2011). The findings for ^{232}Th in this study is in line with the findings of Avwiri *et al.* (2007), but not in accordance with Ononugbo *et al.* (2017) who found the activity concentration of ^{232}Th to be 13.49±04.60 BqL^{-1} and Tchokosa *et al.* (1999) who found the activity concentration of ^{232}Th to be 11.00±0.58 BqL^{-1}. This variation can be attributed to the types of rocks found in the study area.

In addition, the activity concentrations of ^{40}K in borehole water samples revealed that the highest concentration of ^{40}K in borehole water was detected in (S_2) Gidan-waya borehole which has a value of 69.20±2.89 BqL^{-1} while the lowest concentrations of ^{40}K in borehole water was detected in (S_5) Kafanchan B borehole 59.44±1.19 BqL^{-1}. High activity concentrations in the study area can be attributed to the abundance of phosphorus in the soil due to excessive application of fertilizers by farmers on the farm which might have eventually leached into the water ways Ononugbo *et al.* (2017). The findings for ^{40}K in this study is not in line with the findings of Avwiri *et al.* (2007) who found the activity concentration of ^{40}K to be 23.03±4.73 BqL^{-1}, Tchokosa *et al.* (1999) who found the activity concentration of ^{40}K to be 17.73±5.04 BqL^{-1} and Ononugbo *et al.* (2017) whose activity concentration for ^{40}K was 170.19±55.28 BqL^{-1}. These values obtained for potassium from boreholes were not comparable to the recommended safe limit of 10 BqL^{-1}. This wide range of variation could be attributed to several factors that governed their occurrence in groundwater such as the geology, mineralogy and the geochemistry of rocks or solids aquifer and soil in the different states Avwiri *et al.* (2007).

(U, Th, K) radionuclides in groundwater depends on the litholodgy, geomorphology and geological factors of the region. All these values obtained were found to be above the recommended safe limit of 10BqL^{-1}, 1BqL^{-1}, 10BqL^{-1} for ^{238}U, ^{232}Th and ^{40}K respectively set by (UNSCEAR, 2000; WHO, 2008) standards. This however suggest that boreholes under investigation is potential for causing health hazard if not well treated as excess potassium in water may lead to nervous and digestive disorders and even heart failure (Tiwary, 2001).

In this regard, the radiological hazards indices shown in Figures 1.2 revealed that, the the highest level of radium equivalent calculated in borehole water was observed in (S_8) Nisama a value of 59.02 BqL^{-1} while the lowest level was observed in (S_4) Kafanchan A borehole with a value of 41.14 BqL^{-1}. All these values were found to be comparable to the world safe recommended limit of 370 BqL^{-1} by (IAEA 1990). High values of the radium equivalent of 59.02 BqL^{-1} this can be attributed to the high concentrations of radionuclides in such stations detected during the study. When people are exposed to very high levels of radium for a long

period of time, cancer of the bones and nasal cavity may result. This is in accordance with a study conducted by Ononugbo *et al.* (2016), but not in line with the findings of Avwiri *et al.* (2007) who found the radium equivalent to be 2.499 BqL^{-1} and Oluyide *et al.* (2019) whose mean radium equivalent was 27.31 BqL^{-1}. This variation in the values of radium equivalent can be attributed to the high level of radionuclide found in the study area this is because higher levels of radionuclide may result to high level of radium equivalent.

Furthermore, in the analysis of internal hazard index, findings revealed that, the analyzed results presented in 1.2 shows that the highest mean value of the internal hazard index in borehole water was observed in (S_2) Gidan-waya borehole with a value of 0.237 mSv/yr. while the lowest level was observed in (S_7) U/Pataki borehole with a value of 0.196 mSv/yr. All these values were found to be comparable to the world safe recommended limit of 1mSv/yr by (WHO, 2016). The main contributor of the internal hazard index is the result of high rates of radionuclide being ingested into the human bodies through drinking water this is because of high concentration of this radionuclide in the study area WHO (2016). This finding is in line with that of Ononugbo *et al.* (2017), Avwiri *et al.* (2007) and Oluyide *et al.* (2019). This is also in line with the WHO (2016) standard for drinking water which will not cause any threat to the populace living in such area.
In addition, the analyzed results in Figure 1.2 shows that the highest mean value of the external hazard index in (S_2) Gidan-waya borehole with a value of 0.133 mSv/yr. while the lowest concentration was observed in (S_7) U/Pataki with a value of 0.093 mSv/yr. All these values were found to be comparable to the world safe recommended limit of 1mSv/yr by (WHO, 2016). The main contributor of the external hazard index is as a result of high rates of radionuclides being inhaled into the human bodies through the air as a result of high concentrations of radionuclide in the study area WHO (2016). The findings of the external hazard index obtained in this study is in accordance with Ononugbo *et al.* (2017), Avwiri *et al.* (2007), Oluyide *et al*. (2019) and Tchokosa *et al.* (1999). This is also in line with the WHO (2016) standard for drinking water which may not cause any threat to the populace living in such area.

Figure 1.3 shows the highest calculated mean value of the absorbed dose was observed in (S_2) Gidan-waya borehole with a value of 48.18 nGy/h. while the lowest level was observed in (S_1) Godogodo with a value of 40.96 nGy/h. All these values were found to be comparable to the world safe recommended limit of 51 nGy/h by (WHO, 2016). High concentration of the absorbed dose rate noted could be attributed to the endless chemical weathering and fluvial erosion influenced by the bio-climatic nature of the environment. It can also be attributed to the high concentrations of radionuclide that was detected in the study area. Although, excessive consumption of this water by the people can cause serious threat. This therefore could cause potential health risk for humans in the near future (Sparks, 2005). The findings of the absorbed dose obtained in this study is in line with the findings of Ononugbo *et al.* (2016), Tchokosa *et al.* (1999), but not in accordance with Avwiri *et al.* (2007) who found the absorbed dose to be 1.64 nGy/h and Oluyide *et al.* (2019) whose mean absorbed dose was 12.47 nGy/h. This wide variation can be attributed to the high concentrations of radionuclide that was detected in the study area. It can also be as a result of geochemistry of the aquifer of rocks found in each area.
In considering the life cancer risk analysis, it was revealed in Figure 1.4 that, the highest mean value of excess lifetime cancer risk observed in Gidan-waya borehole with a value of 0.207 while the lowest value was observed in Godogodo borehole Nisama borehole with same value of 0.176. All these values obtained were found not to be comparable to the world safe

recommended limit of 1×10^{-3} by (WHO, 2016). Higher values detected could be due to the high concentration of radio nuclides in the study area due to the nature of rocks found there. Reasons being that the water level could be affected due to higher distortion of breakage which enabled water to trap at the near surface since the subsurface geology permits the downward movement of water sources from the source (Otton, 1994). The findings of the excess lifetime cancer risk in this study is in line with Avwiri *et al.* (2007), Oluyide *et al.* (2019) and Ononugbo *et al.* (2016). This suggests that the chances of having cancer by the populace that use the water from these areas are significant (Otton, 1994).

Conclusion

The radiological significance of different water samples has been determined using plasma spectroscopy technique and mathematical models. Concentrations of ^{238}U, ^{232}Th, and ^{40}K, radiological parameters such as the radium equivalent, external and internal hazard indexes, the absorbed dose rate and excess life time cancer risk were determined to assess the radiological hazards in the water samples. The wide variation in the activity concentration was as a result of the varying amounts of uranium, thorium and potassium contents due to the different geological formation of each area and also based on the type of human activities going on in each area as well. It was concluded that concentrations of ^{238}U, ^{232}Th and ^{40}K in all samples collected from Boreholes were high and excess life time cancer risk evaluated for all samples were greater than the recommended limits, therefore, groundwater from these areas should be treated for radio nuclides before ingestion so as to reduce the radiation health risk. This research concludes that if all hands are on deck and the government has the political will to control human activities such as the excessive application of fertilizers by farmers, herbicides, pesticides, domestic sewage and waste dump and other activities will go a long way in reducing the level of these radio nuclides detected from the water samples in the study area.

RECOMMENDATIONS

Based on the findings of this research, it is recommended that; there is also the need for enlightenment campaign and changes in human behaviour through education and capacity building to better improve quality and preserve water resources in the study area and the need for political cooperation in the development and application of management schemes of water in Jema'a Local Government Area of Kaduna.

There is the need for the people Jema'a Local Government Area of Kaduna communities to treat their water before consumption and an awareness programs should also be implemented to inform the people Jema'a Local Government Area of Kaduna communities of the status of the water quality and methods that can be used to avoid getting ill as a result of water contamination.

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