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COMPARATIVE ASSESSMENT OF NATURAL RADIONUCLIDE CONTENTS IN SOIL AND HOUSEHOLD WELL WATER COLLECTED FROM BIRNIN-GWARI LOCAL GOVERNMENT AREA OF KADUNA STATE NIGERIA

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ABSTRACT
The assessment of natural radioactivity in soil and water sample from different point in Birnin-Gwari local Government area of Kaduna state, Nigeria was measured by means of gamma-ray spectrometer with NaI(Tl) detector to establish a baseline data for activity concentration of 40K, 226Ra and 232Th. It was found that, the mean activity concentration of 40K, 226Ra and 232Th in soil collected from different location (SI, S_2, S_3, S_4, S_5, S_6 and S_7) is (272.41±5.31, 25.61±1.89 and 77.53±2.08)Bg/kg, respectively is above the world average of 50 Bq/kg (UNSCEAR, 2000). While that in water was 0.4303±0.0219Bg/kg for α and 2.322x10^-3±0.0595Bg/kg for β. The maximum cancer risk was found in soil with a value of 13945.04msv/yrs having a highest percentage assessment of 34.78% than that of water with a value of 9.313msv/yr with lower percentage of 29.8%. Results from the fourteen field samples analysed also indicated that the activity concentration in percentage due to 40K in the soil samples ranked highest against the lowest value obtained for sediments in the water samples.

Keywords: Natural Radionuclide; water; soil; hazard indices; Birnin- Gwari; percentage.

Introduction

Radionuclide is naturally found throughout all environments. They are present in varying amounts in air, water, plants, animals, soil and rocks. Naturally occurring radionuclide are mainly derived from three separate decay chains (235U, 238U and 232Th. The longest-lived member is 232Th, which has half-life of 1.405 x 1010 years. The immediate parent of 232Th was 236U, which had a life of 2.342 x 107 years and is no longer found in the environment. The second longest series is the 238U–series. Naturally occurring uranium contains 99.2745% by weight 238U, 0.7200% 235U, and 0.0055% 234U Omale *et al*. (2014). In addition, water contains cosmogenic radionuclide (e.g. 3H, 7Be, 10Be and 14C), which are formed in the upper atmosphere, and radioactive potassium (40K), whose activity concentration is a constant proportion of stable potassium. Groundwater is formed from precipitation, which infiltrated soil and bedrock. The activity concentrations of natural radionuclide in groundwater are connected to the activity concentrations of uranium (238U and 235U) and thorium (232Th) and their decay products in soil and bedrock. This is because groundwater reacts with soil and bedrock and releases quantities of dissolved components, depending on the mineralogical and geochemical composition of the soil and rock, chemical composition of the water, degree of weathering of the rock, redox conditions and the residence time of groundwater in the soil and bedrock. In addition, naturally occurring radionuclide and particularly their decay products are transported in groundwater and surface water. As a result, this radionuclide may enter the food chain through irrigation waters, and the water supply through groundwater wells and surface water streams and rivers. The health risks to humans are real, due to high mortality rate and health related cases reported specifically in Birnin gwari area of Kaduna state. (National Research Council 1999) asserted that, Inhaled daughters of 222Rn cause a dose to the lungs. Long-lived radionuclide's, 234U, 238U, 226Ra, 210Pb and 210Po, causes a dose to the kidneys, liver, bladder and other similar health hazards cases. Naturally occurring radioactive materials (NORMs), under certain conditions, can reach radio logically hazardous levels. The natural radioactivity in soil comes mainly from the radionuclides in the U-238 and Th-232 series, and K-40. The radiological implication of these radionuclides is external radiation exposure by gamma rays and internal exposure due to inhalation of radon and

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its daughters. UNSCEAR, (2014). High level of such natural occurring radionuclide's in both soil and water is a major public health problem in Africa with over 100 million clinical episodes and nearly five hundred thousand faces with a deleterious radiological health effects and approximately 200 thousand deaths annually. However, the risks of morbidity and mortality associated with radiation exposure particularly in semi-arid and highland regions vary with the human activity and the consumable rate. Health risks related to natural radioactivity are of great concern and require assessment in order to estimate the risks exist especially in the study area where there are series of ill cases as a result of such existing unstable elements. Thus, the aim of this study is to measure the activity concentrations and estimate the percentage of radiological hazard indices in soil and in water samples collected from seven different locations in Birnin-Gwari local government areas in Kaduna State, Nigeria. The results obtained in this study will provide information on natural occurring radionuclides in soil and water in Kaduna State, Nigeria and add to the existing data on radioactivity in soils in UNSCEAR data bank.

Study Area

The study area is Birnin - Gwari town, located in the northern part of Kaduna State. It is among the oldest Local Government Area out of twenty-three (23) Local government areas in the State. Birnin-Gwari is situated at 11.02° North latitude, 6.78° East longitude and 599 meters elevation above the sea level. It is bounded in the north by funtua local government area of katsina state. In the south by Rafi local government area of Niger state. The major area surrounding the Local Government include Randagi, kakangi, dogon Dawa, dawaki, dogon hawa ungwan Nakiya, Bagoma, Kuriga, Ungwan fari. Geology of Birnin-Gwari Local Government area of Kaduna State is predominantly metamorphic rocks. And in general, 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 USEPA, (2016). The area has a population of about 22,380 thousands, National Population Commission NPC, (2006) with major ethnic groups as Gbagy, Kamuku, Hausa, Adara, igbo,Yoruba Gwandara, and Bassa. Crop cultivation, fishing, rearing of animals, hunting and commercial activities form the thrust of the economy of the study area, which engage well over 75% of the working population of the area. Their basic and regular source of water is from Wells, Boreholes and lakes.

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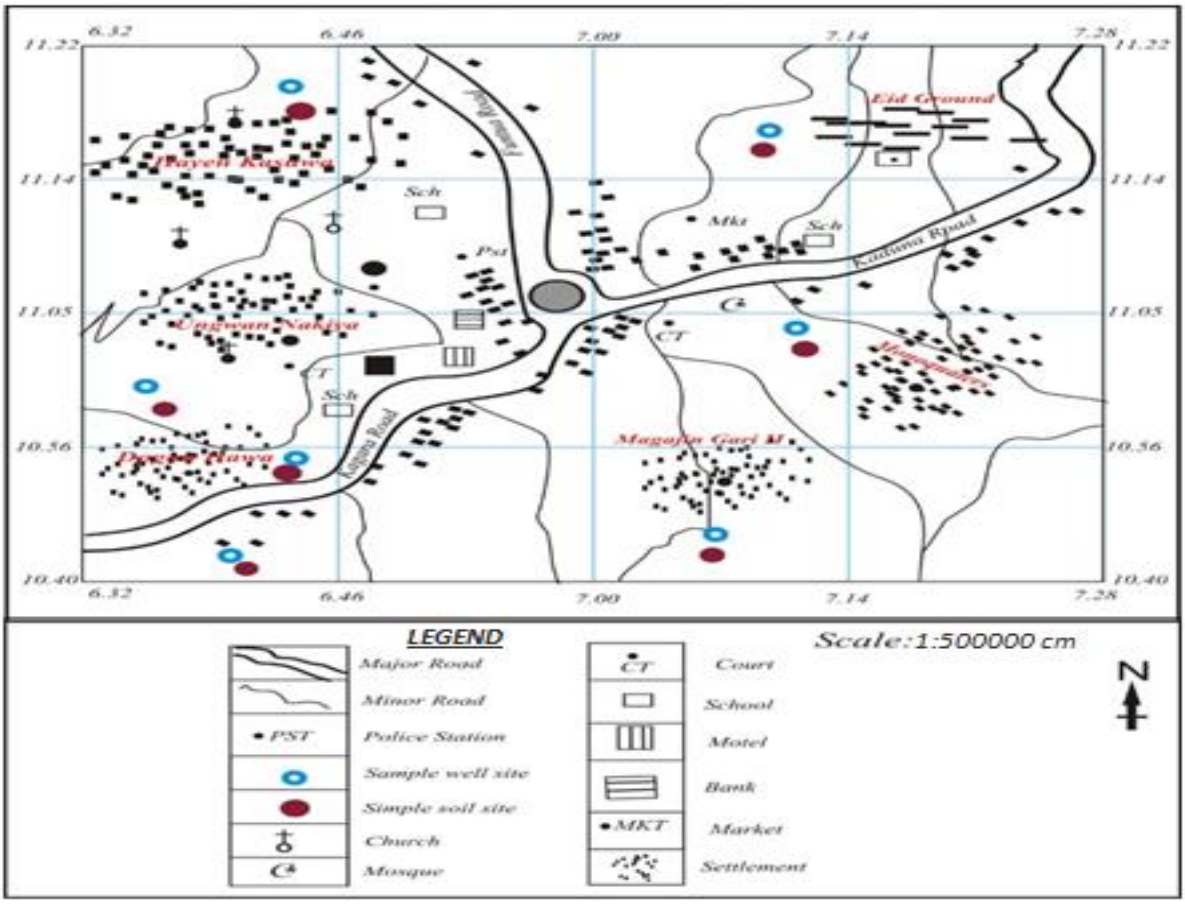

Map of Birnin-Gwari Local Government showing sample points with grids (KSMLS, 2019)

Materials and Method.

Sample Collection and Preparation

Seven (7) soil samples from the site mention above were collected using grid system. The samples were collected into a very clean polythene bag and well labeled to avoid mixed up of samples. The soil samples along with the extraneous materials were dried at ambient temperature until there was no detectable change in the mass of the sample. The dried samples were thoroughly crushed, grounded and pulverized to powder. Due to the limited space of the detector shield, only 200g - 300g of the soil samples (dry– weight) were used for analysis. The samples after weighing were transferred to radon-impermeable cylindrical plastic containers of uniform size (60mm height by 65mm diameter) and were sealed for a period of about 30 days. This was done in order to allow for Radon and its short-lived progenies to reach secular radioactive equilibrium prior to gamma spectroscopy. A lead-shielded 76 × 76 mm NaI(TI) detector crystal (Model No. 727 series, Canberra Inc.) that is coupled to a Canberra Series 10 plus Multichannel Analyzer (MCA) (Model No.1104) through a preamplifier was used for the radioactivity measurements. It has a resolution (FWHM) of about 8% at energy of 662.0KeV (^{137}Cs) ensured for a period of 29000 seconds (8 hours). The net area under the corresponding peaks in the energy spectrum was computed by

subtracting counts due to Compton scattering of higher peaks and other background sources from the total area of the peaks.

Gross Alpha and Beta:

Samples of water were collected directly into seven litre plastic kegs (polyethylene containers) after washing the containers properly and rinsed with the water sample to be collected. About 10ml of concentrated hydrochloric acid ($HN0_3$) was added at the point of collection. The addition of concentrated $HN0_3$ help preserve the radionuclides present in the water samples and it also prevent the absorption of the water with the inner wall of the containers among others. The addition of $HN0_3$ assists in reducing the pH of the water samples below 2 EPA, (1980). well water sample from different location within the area were collected and treated with the reagent. Care was taken to avoid fetching from the stagnant wells' areas.

Experimental Set Up

For gross alpha counting, the high voltage was set at 1600v and samples were counted for 3 cycles of 2700s (45mins) per cycle. The results were displayed as raw counts; count rate (count/min). The data were acquired for alpha mode only and the specific activity for alpha in the samples was calculated using the formula below. Activity

$$(\alpha)\ (Bq/L) = \frac{\text{Net count (CPM) } (\alpha)}{\text{DE x 60 x } Sample\ Size\ (Volume)\ X\ Sample\ Efficiency}$$

Where D.E is the detector's efficiency and net counts is given by:

Net counts = Raw counts (CPM) – Background (CPM).

Gross Beta Counting

The high voltage for gross beta counting was set at 1700V and samples were counted for 3 cycles over a preset period of 2700s in beta mode only. The specific activities were calculated using the formula below.

$$\text{Activity } (\beta)\ (Bq/L) = \frac{\text{Net count (CPM) } (\beta)}{\text{DE x 60 x } Sample\ Size\ (Volume)\ X\ Sample\ Efficiency} \qquad (1)$$

The proportional counter is a gas filled detector and a single-channel equipment which is automated. The counting procedure involves entering the pre-set time, number of cycles and counting mode. The results when the preset time elapsed were displayed as raw counts and count rate, i.e. count per minute (CPM). The raw counts (CPM) were repeated three times each for all the samples, either alpha or beta and the average value were obtained respectively.

Estimation of Radiological Hazard Indices

The radium equivalent activity is an index that has been used to represent the specific activities of Uranium, thorium and potassium by one quantity that takes into account the radiation hazards associated with them. Radium equivalent activity is a weighted sum of activities of the studied natural radio nuclides and is based on the assumption that 370 BqL^{-1} of ^{238}U, 259 BqL^{-1} of ^{232}Th and 4810 of ^{40}K generate the same gamma radiation dose rate Farrai *et al*., (2004). Radium equivalent was calculated by the equation described by Beretka and Mathew (1985) and Yang *et al* (2005).

$$Raeq = {}^{238}U + 1.43\,{}^{232}Th + 0.077\,{}^{40}K \qquad (2)$$

Where ^{238}U, ^{232}Th and ^{40}K are the activity concentrations in $BqL-1$ of Uranium-238, Thorium-232 and Potassium-40 respectively. The maximum value for Raeq must be less than $370Bq/L$ for safe use. The hazard index is a quotient of some measure of exposure of man to a given environmental pollutant over a corresponding accepted or selected limit. The hazard index can be defined as $HI = Q/QL$ where Q is the measure of exposure of man to a pollutant, QL is the selected or established limit that should not be exceeded Philip (1998). (Hex) Generally, is used to determine the indoor radiation dose rate due to external exposure to gamma radiation from natural radio nuclides as reported by Tiwary *et al* (201).

$$Hex = {}^{238}U/370 + {}^{232}Th/259 + {}^{40}K/4810 \quad (3)$$

Where ^{238}U, ^{232}Th and ^{40}K are the activity concentrations in BqL^{-1} of Uranium, Thorium and Potassium respectively. The internal hazard index (Hin) is a parameter for determining the negative effect of radioactive materials on lungs and other respiratory organs. The risk internal exposure due to the natural radio nuclides ^{232}U, ^{232}Th and ^{40}K could be assessed from the value of Hin using this equation

$$Hin = {}^{238}U/185 + {}^{232}Th/259 + {}^{40}K/4810 \quad (4)$$

Where ^{238}U, ^{232}Th, ^{40}K maintain the same meaning. The Excess Lifetime Cancer Risk $(ELCR)$ can be defined as the excess probability of developing cancer at a time due to the level of radiation exposure to human (Taskin *et al*., 2009). $ELCR$ Was evaluated using the equation

$$ELCR = AEDE \times DL \times RF \quad (5)$$

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*., (2000).

Results and Discussion

The activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in soil samples are shown in Table 1.0 The highest concentration of ^{226}Ra was found to be $39.07780 \pm 4.914692\ Bq/kg$ at sample point S_5, while the lowest concentration was found to be $6.992448 \pm 1.638231 Bq/kg$ at sample point S_4 with a mean value of $25.612 \pm 1.8787\ Bq/kg$. The highest activity concentration of ^{232}Th was found to be $97.43265 \pm 2.0446 Bq/kg$ at point S_7 while the lowest concentration was found to be $67.7466 \pm 2.1625 Bq/kg$ at a point S_1 with a mean value of $77.537 \pm 2.08388\ Bq/kg$ and the highest activity concentration of ^{40}K was found to be $488.3896 \pm 7.7760 Bq/kg$ in sample station four (3) while the lowest concentration was found to be $125.9720 \pm 4.2366\ Bq/L$ in station four (4) with a mean value of $272.406 \pm 5.309\ Bq/kg$ this is illustrated in Fig.1.0

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Table 1.0 Activity Concentration of ^{40}k, ^{226}ra and ^{232}th in Soil Samples

S/N	SAMPLE ID	^{40}K Bq/Kg	^{226}Ra Bq/Kg	^{232}Th Bq/Kg
1	S1	127.74±5.47	36.48±2.077	67.35±2.16
2	S2	135.67±4.18	27.05±0.39	68.69±3.07
3	S3	488.38±7.77	31.01±1.96	71.71±3.81
4	S4	125.97±4.24	6.99±1.63	58.66±1.10
5	S5	226.95±6.11	39.08±4.92	85.24±0.78
6	S6	223.04±3.70	14.58±2.08	93.26±1.61
7	S7	579.07±5.68	1.12±0.09	97.43±2.44
Mean		**272.41±5.31**	**25.61±1.89**	**77.53±2.08**
WHO		**10**	1	**10**

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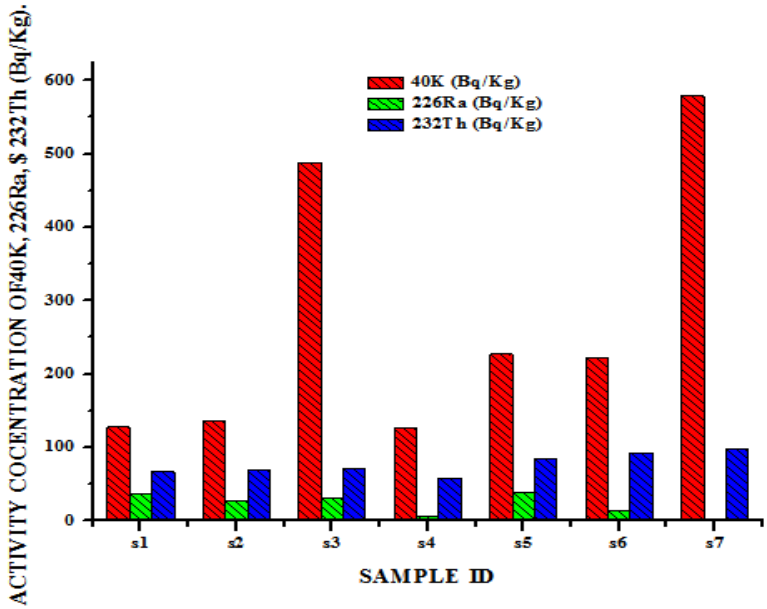

Figure 1.0 Plot of activity concentration of the ^{40}K, ^{226}Ra, and ^{232}Th versus sample stations in soil sample

Figure 1.0 is a bar plot interpretation of specific activity concentrations of ^{40}K, ^{226}Ra and ^{232}Th in soil samples against the various sample stations. The plot revealed that (S_7) Dogon hawa (1) indiate the highest concentration of potassium having a value of $519.07 \pm 5.68\ Bq/kg$, followed by (S_3) Ungwan Nakiya (1) with an approximate value of $127.74 \pm 5.47\ Bq/Kg$, (S_5) Magajin-Gari (1) with a value of $226.95 \pm 6.11 Bq/kg$, (S_6) Magajin-Gari (II) with avalue of $223.04 \pm 3.70\ Bq/kg$, (S_2) Dogon hawa (II) with a value of $135.67 \pm 4.18\ Bq/Kg$, (S_4) U/Nakiya (II) carrying a value of $135.97 \pm 4.24 Bq/Kg$. Finally the lowest concentration of potassium was found in sample (S_1) Dogon hawa (I) with a value of about 127..74±5.68.The activity concentration of ^{226}Ra is also analysed following the same trend. It was found that the highest activity was found in station (S_7) Magajin Gari (I) having a value of 39.04±4.92 Bq/Kg, followed by (S_1) Dogon Hawa station(I) having a value of $36.48 \pm 2.07 Bq/$,Kg (S_2) Dogon Hawa station (II) with a value of $27.05 \pm 0.09 Bq/Kg$, (S_3) U/Nakiya station (I) with a value of $31.01 \pm 1.96 Bq/Kg$, (S_6) Magajin Gari station (II) having a value of $14.58 \pm 2.68 Bq/Kg$ also (S_4) U/Nakiya station (II) Kagoma borehole having a value of $6.99 \pm 1.63 Bq/Kg$. Finally a negligible amount of radium concentration was found in station (S_7) as indicated from the bar plot with a value of $1.12 \pm 0.09\ Bq/Kg$. Furthermore, the activity concentration of thorium was also observed in different station, it was found generally that the thorium concentration is significant at various stations levels. Hence in station (S_7) Science school Birnin-Gwari has the highest concentration with the maximum value of $97.43 \pm 2.44 Bq/Kg$, followed by station (S_6) Magajin Gari (II) with the concentration value $93.26 \pm 1.61 Bq/Kg$, All other station shows a pronounce concentration values, hence the lowest concentration was found in station (s_4) U/Nakiya having a value of $3.92 \pm 0.74 Bq/l$, This occur as a result of human activities such as mining, milling and processing of uranium ores and mineral sands, smelting of metal liferous ores, manufacture of fertilizers, drilling, transportation, processing and burning of fossil fuels which has lead to an increase in naturally occurring radioactive materials in the study area, which is in accordance with the research carried out by Bala et al (2014). In addition, the dumping of large amount

of waste materials in sites without adequate soil protection measures result in soil as well as, surface and ground water pollution, which is similar with Karraham (2017).

Table 2.0: Gross Alpha and Beta Radioactivity Concentration in Well Water

S/N	SAMPLE ID	α (Bq/kg)	β (Bg/kg)
1	WI	9.060X10^-^{2}±3.346X10^-^{2}	5.29X10^-^{3}±2.0112X10^-^{1}
2	W2	9.750X10^-^{2}±3.1IX10^-^{2}	4.93X10^-^{3}±1.710X10^-^{2}
3	W3	3.707X10^-^{1}±1.534X10^-^{3}	1.23X10^-^{2}±1.710X10^-^{2}
4	W4	4.620X10^-^{1}±1.764X10^-^{2}	1.142X10^-^{3}±4.289X10^-^{2}
5	W5	1.250X10^^{0}±7.78X10^-^{3}	4.43X10^-^{4}±1.399X10^-^{2}
6	W6	2.650X10^-1±4.99X10^-^{2}	2.152X10^-^{3}±9.403X10^-^{2}
7	W7	4.767X10^1±1.193X10^-^{2}	1.060X10^-^{3}±2.993X10^-^{2}
8	**Mean**	**0.4303±0.0219**	**2.322x10^-^{3}±0.0595**

The gross Alpha and Beta concentration in water sample at different station were analysed as shown in the above table, it was found that, the concentration of α(Bq/kg) at different station is more significance than β (Bq/kg) concentration. Generally it was discovered in station (W_5) Magajin Gari well (I) and Dogon Hawa well(I) has the highest concentration value of gross Alpha and Beter as 1.250X10^^{0}±7.78X10^-^{3} Bg/kg 5.29X10^-^{3}±2.0112X10^-^{1} Bg/kg and the lowest concentration of gross Alpha was found in station (w_6) Magajin Gari well(II) with a value of 2.650X10^-1±4.99X10^-^{2} Bk/kg while that of Alpha was found in station (w_5) Magajin Gari well (I) having a value 4.43X10^-^{4}±1.399X10^-^{2}·Bg/kg Which is closely in accordance with the result of Najib M.U.(2014). Hence in station (w_3) U/Nakiya and station (w_2) Dogon Hawa emitting almost the same α and β radiation with a value of 3.707X10^-^{1}±1.534X10^-^{3} Bg/kg and 4.93X10^-^{3}±1.710X10^-^{2}·Bg/kg Similarly in station (w_5) and (w_6) emitting the same β and α radiation a minimum value of 4.43X10^-^{4}±1.399X10^-^{2} Bg/kg And 2.650X10^-1±4.99X10^-^{2}.Bg/kg The high concentration of such α and β in some selected area of study is due to the activity concentration of natural radionuclide in ground water, which are connected to the activity concentration of (^{238}U and ^{235}U) and (^{232}Th). And their decay product in soil and bedrocks, hence, releases quantities of dissolved components depending on the water, weathering of the rock, redox conditions, and residence time of ground water in the soil and bedrock. This is in accordance with the research done by Botenzatu et al (2015). The graphical representation of the above table is shown below in figure 2.0

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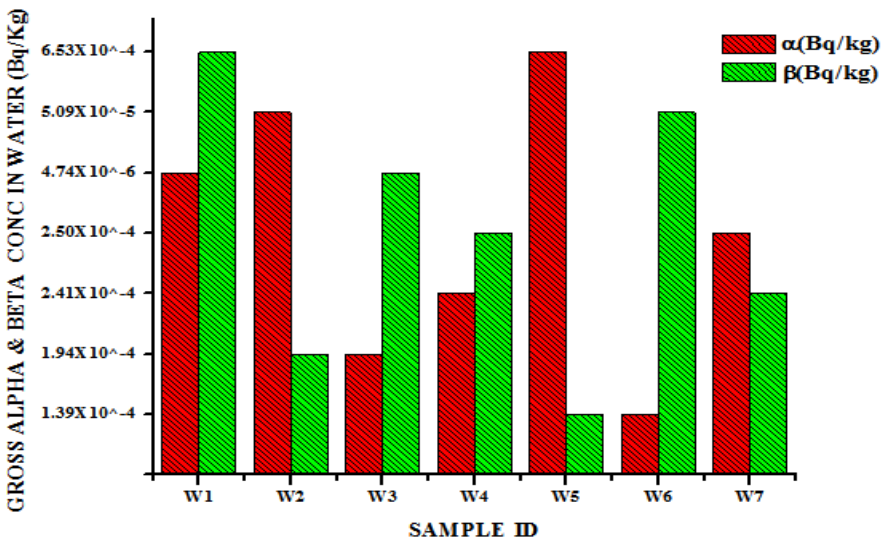

Figure 2.0 Gross Alpha and Beta Radioactivity Concentration in Water.

Excess Lifetime Cancer Risk in Soil.

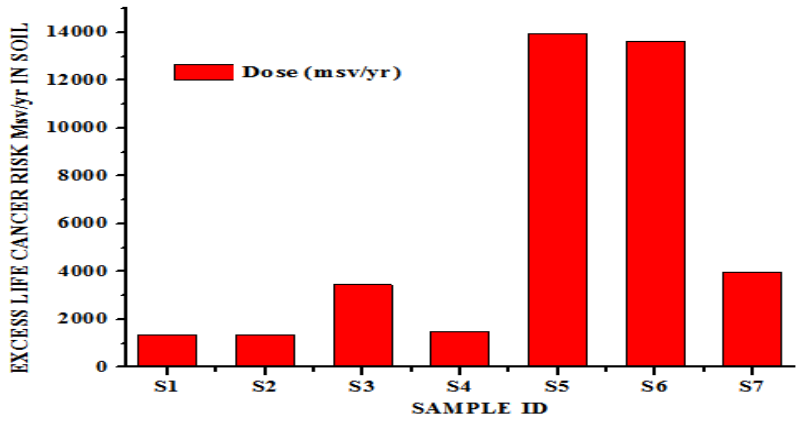

Figure 3.0: Plot of Excess Lifetime Cancer Risk Concentration Soil Versus Sample ID.

Figure 3.0 is the bar-graph of excess lifetime cancer risk in soil sample against the various sample ID stations under investigation. It was found that, Station three (S_5) Magajin Gari (I) indicated the highest value as 13,945.04 followed by (S_6) Magajin Gari station (I) with a value of 13,945.04, (S_7) Science school Birnin-Gwari of 3982.64, (S_3) U/Nakiya station (I) 3443.42 and (S_4) U/Nakiya station (II) with a value of 1482.88 respectively, (S_1) Dogon hawa station (I) and (S_2) Dogon Hawa station (II) have a similar values of 1353.5msv/yr and 1348.13msv/yr simultaneously. From the above analysis, it was found that, the highest value of cancer risk was observed in station (S_5) and the lowest value was found in station (SI) and (II) respectively. All these values obtained in soil were incomparable with the world safe recommended limit of 1×10^{-3} by (WHO, 2016). And the highest value obtained could be as a result of high concentration of radionuclides in the study area due to nature of rocks, human activity, road construction, using of contaminated building materials and testing of Nuclear weapons. And is in accordance with a research done by Avwiri *et al.* (2007), Oluyide *et al.* (2019) and Ononugbo *et al.* (2016). This suggests that

the chances of having cancer by community involved in farming activities from these areas are significant (Otton, 1994).

Excess Lifetime Cancer Risk in Water.

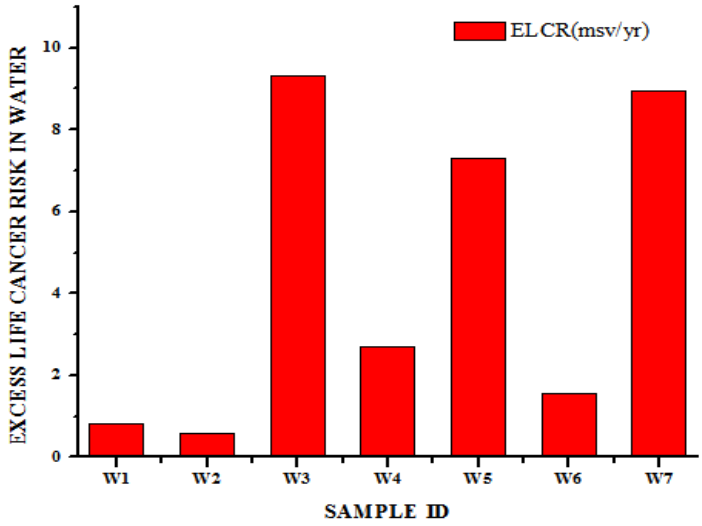

Figure 4.0: Plot of Excess Lifetime Cancer Risk Concentration Versus Sample ID.

Figure 4.0 is the bar-graph of excess lifetime cancer risk in well water against the various sample stations ID. It was found that Station three (w_3) U/Nakiya well (I) has the highest excessive cancer risk with a maximum value of 9.313msv/yr followed by Science school B/Gwari well (w_7) with a value of 8.951msv/yr then Magajin Gari station (w_5) with an excessive value of 7.285msv/yr Station (w_4) U/Nakiya with a (II) with a value of 2.697msv/yr Magajin gari (II) (W_6) having a value of 1.558msv/yr. Finally, the two station Dogon hawa well (w_1) and Dogon hawa well (w_2) with a least values of excessive cancer risk as low as 0.828msv/yr and 0.5887msv/yr correspondingly. From the analysis above, the high and the lowest value of cancer risk from various station is as a result of the nature of soil found there, this occur as a result of 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). And is in accordance with the research conducted by Avwiri *et al.* (2007), Oluyide *et al.* (2019) and Ononugbo *et al.* (2016). This shows a significance cancer risk for the entire community benefitting from the source of water (Otton, 1994). Hence the entire values obtained are far from the world safe recommended limit of 1×10^{-3} by (WHO, 2016).

Percentage Assessment of Excess Cancer Risk in Soil and in Water.

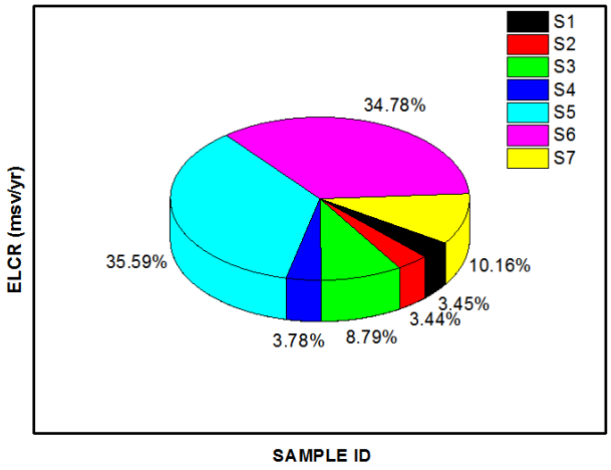

Figure 5.0 Percentage Concentration of Excess Cancer Risk in Soil

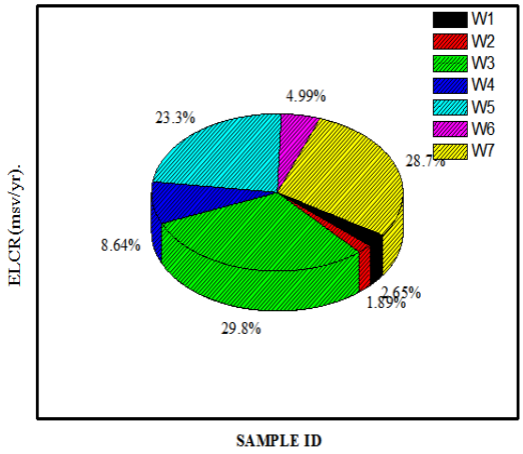

Figure 6.0 Percentage Concentration of Excess Cancer Risk in Well Water.

From the above figures, it was found that, figure 6.0 is the percentage composition of the excess cancer risk found in well water at different station while figure 4.10 is the percentage composition of the excess cancer risk found in soil. Based on the analysis, in station (S_1) and (w_1) the highest percentage of cancer risk was found in soil than in well water with a percentage of about 3.45% in soil and 2.65% in water. Likewise the percentage at station (S_2) in soil is high than the percentage at station (W_2) in water, this may be attributed due to the high concentration of such unstable radionuclide in the soil due to human activities, an less of leaching process in that particular stations, which is in accordance with a report, reported by Jibiri et al (2010). In Station (S_3) and (w_3) reverse is the case, percentage concentration of cancer risk in water is far greater than that in soil. Having a value of 8.79% in (S1) and 29.8%. In (W_1). The same apply to (S_4) and (W_4) with a value of 3.78% and 8.64%. The highest percentage in water can be attributed due to the nature of rocks that exist beneath the earth which has a high amount of unstable radioactive elements, the least amount in soil in that station may be due to less human activities such as farming activities, testing of nuclear weapons etc in the area, which is in line with research done by Usikalu et al (2015). Which is in line with research done by Usikalu et al (2015)? Furthermore, in station (S_5), (S_6) in soil and

station (W_5), (W_6) water. The percentage concentration is more pronounce in soil than in water having a value of 35.59%, 34.78% in soil and 23.3% , 4.99% in water , the high percentage in soil could be attributed to the nature of the soil and the vegetation that exist in that area, consequently leading to a reasonable control of leaching in the soil resulting to a low percentage of cancer risk in soil at that particular station, this is in accordance with the work done by Adekoya, et al (2010). Finally, station (S_7) and (W_7), the higher percentage in (W_7) having a value 28.7% is as result of the bedrock nature found and the metamorphic nature of surface rocks found in the study area which exhibit some level of radionuclide's, while least found in soil with a value of 10.16% it could be as a result of a virgin nature of the land, which is in line with the research on the Measurement of Natural Radioactivity in Soil, Vegetation and Water in the Industrial District of the Federal Capital Territory (FCT) Abuja, Nigeria Umar et al (2012).

Conclusion

The wide variation in the activity concentration was as a result of the varying amounts of Radium, 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. Based on the present study, it was concluded that concentrations of ^{226}Ra, ^{232}Th and ^{40}K in all samples collected from soil and household Well water were high and excess life time cancer risk evaluated for all samples were greater than the recommended limits of $370Bqkg^{-1}$ therefore, the human activities in the soil, such as applications of fertilizers, spraying of chemicals, mining activities, domestic sewage, waste dump and the used of contaminated building materials in the soil should be control, also the groundwater from these areas should have a proper treatment against the unstable nuclide before ingestion so as to reduce the radiation health risk.

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