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Radiological and Toxicity Impact of Uranium (^{238}U) in Ground Water to Different Age Groups at Wurno, Sokoto State, Nigeria

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One of the primary goals of the World Health Organization (WHO) is for every society to have an adequate supply of safe drinking water. This work aimed to assess the radiological and toxicity impact of ground water of Wurno Local Government Area. Uranium activity concentration from 45 water samples collected from different locations in the study area were determined using HpGe detector, the result from the analysis was used to evaluate the annual effective dose due to ingestion of groundwater from the study area by the inhabitants. Radiological and chemical toxicity risks were also calculated. High level activity was reported in Diggim while low activity level was reported in Nassarawa-Daje. The annual effective doses for adult, children and infants were estimated to be from 0.008 $mSvy^{-1}$ to 0.32 $mSvy^{-1}$. The highest risk cancer mortality value was found at Diggim with a value of 4.34×10^{-4} while the lowest value was observed at Nassarawa Daje with a value of 1.17×10^{-5}. Chemical toxicity value ranged from 0.59 – 21. 79 $\mu g.kg^{-1}.day^{-1}$ with an average dose value of 5.12 $\mu g.kg^{-1}.day^{-1}$. The lifetime average daily dose (LADD) values were reported to be higher at Diggim and lower at Nassarawa-Daje with the values 21.79 $\mu g.kg^{-1}.day^{-1}$ and 0.59 $\mu g.kg^{-1}.day^{-1}$ respectively compared with 0.6 $\mu g.kg^{-1}.day^{-1}$ WHO limit standard. Significantly, the high activity level, and chemical toxicity risk reported from this study is an indication that the area may have developed some fractures of granitic strata in the subsurface geology that contributed to the wide distribution of radiation dose.

Keywords: Boreholes; Uranium; Inhabitants; Risk; Toxicity.

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1. Introduction

Naturally occurring radionuclides materials (NORMs) found in the groundwater system varied from one location to another and exist mainly from rocks and minerals from which the water is in contact with (Maxwell and Wagiran, 2015). With emphasis on the use of groundwater, natural radioactivity has been examined widely in different parts of the world to assess the radiological risks to inhabitants (Benedik, *et al.,* 2012). Naturally occurring radioactive materials explicitly accumulate in human body primarily through the intake of food and water or as part of advanced lifestyles (El-Gamal, *et al*., 2019), they are also in the air breathed by man (Tchokossa, et al., 2011). The danger of radioactivity to human can be due to prolonged exposure of the inhabitants from natural radionuclides like ^{238}U (Adekunle, *et al.,* 2013). The contribution of drinking water as source of exposure to human is important to consider especially when the drinking-water supplies is drawn from ground water.

In Nigeria, groundwater is regarded as the most favored source of quality drinking water. Groundwater is cleaner and easy to treat when compared to the surface water. Consequently, lots of boreholes and wells have been dug everywhere especially in rural areas in order to get assess to potable drinking water (Maxwell and Wagiran, 2015). Groundwater refers to collection of water in pores and fractures of soil and rocks below the water table. Water table is the level at which the water pressure equals the atmospheric pressure. (Ndontchueng, *et al.*, 2014). However, anthropogenic activities can contaminate groundwater in addition to its natural chemical components which can results to several health issues.

Uranium occur greatly in nature as part of the composite of granites and other mineral deposits (Boekhout, *et al.*, 2015). One of the long-lived radionuclides, Uranium salt is the most soluble, and forms ions with oxidation states of +4 (UO_2

and U^{4+}) and +6 (UO_3 and UO_2^{2+}). Approximately 99.3% of natural Uranium exist as ^{238}U radionuclide with a half-life of about 4.5 billion years, its decay chain end with a stable nuclide referred to as lead-206. While the remaining isotopes consist of ^{235}U 0.72%, ^{234}U 0.0054%. (Missimer, *et al.*, 2019). All isotopes of uranium decay by alpha and gamma emissions (Khattab, *et al.*, 2017). Activity concentrations and chemical toxicity of Uranium in groundwater virtually depends on the subsurface geology, lithology, geomorphology, environmental conditions and several geological factors of the region (Jibiri, *et al.,* 2021). Uranium exist in groundwater in dissolved form due to the existence of certain minerals such as uranitie, pitchblende, and cornalite or as minor mineral in form of complexed oxide of silicate phosphate, lignite, validates, and monazite sands (Singh, *et al*., 2014).

Uranium in human body has effect to kidney, liver and other soft tissues. Many researchers (Abbasi and Mirekhtiary, 2019; Kurttio, et al., 2005, and Maxwell and Wagiran, 2015) have extensively studied these effects. Chemical concentration of uranium in groundwater based drinking water above recommended limit has been the genesis of pathological and radiological health effects in human body such as genetic damage reported in mammals (WHO, 2004). Uranium was known to be nephrotoxin as identified by WHO, (Kurttio, *et al.,* 2005), which implies that Uranium is a naturally produced chemical which can result to kidney problem. Several investigations to assess the uranium concentration and different health impact has been carried out in groundwater. (Achuka, 2017) carried out radionuclide concentration in groundwater of Ogun state. (Missimer, *et al.*, 2019). Assess the natural radiation in the rocks, soils, and groundwater of Southern Florida. Sufficient exposure to Uranium and it daughter product ^{222}Rn can results to lung cancer. Uranium concentration in groundwater system is mostly less than 50 ppb. Although, aquifers found to contain uranium mineralization bearing formation at times display uranium concentration greater than 50 ppb (Missimer, *et al.*, 2019). Many uncertainties as a result of particles recoil and chemical processes exist regarding the concentration of ^{238}U.

Considering the risk of the presence of natural radionuclides in groundwater system due to internal exposure, there is need to assess the natural radioactivity levels in groundwater of all environent in order to protect members of the public against high radiation dose due to intake (Nguelem, *et al*., 2013). Assessment of Uranium in ground water is not known to have been carried out in this study area. The present work is to study the radiological concentration and chemical toxicity risks of ^{238}U for three aged groups of the inhabitants that permanently depends on the groundwater for drinking in Wurno Local Government Area, Sokoto State.

1.1 Geography and Geology of the Study Area

The study area falls within the geographical location of Latitude 13 17' 03'' and Longitude 5 25' 39''. The study area is bounded to the north by Gwadabawa local government area, to the east by Goronyo local government area, to the south by Rabah local government area, and to the west by Kware local government area. The climate of the study area is not different from the general climate of Sokoto State, which is hot and dry for most periods, of the year. The mean temperature for most parts in the state is about 37°C. The map of the study area is shown in Figure 1. Soil in the study area are mainly sandy soil, clayed subsoil, with alluvial soils predominating along the flood plains of the river valleys (Ajayi, 2016). The study area is located within the lullumeden basin, which is surrounded by the Precambrian basement complex. The lullemmeden basin of West Africa is a sedimentary basin, which extended from Mali and western boundary of Niger republic through northern Benin Republic and northwestern Nigeria. Its southwestern sector covers northwestern Nigeria where it is called the Sokoto Basin, a multi-layered semi confined to confined groundwater basin (Adelana and Olasehinde, 2006). Minerals found around the basement complex include limestone, gold, marble, clay, kaolin, feldspar, gypsum and lignite.

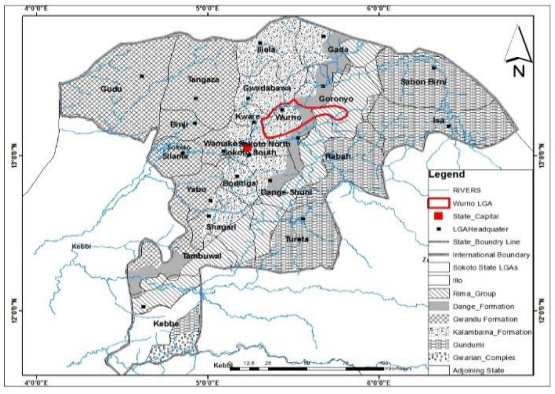

Figure 1: Map of the Sokoto State showing some geological feature

2. Methodology

2.1 Sampling Technique

The sampling technique used for this research work is the stratified random sampling. In this

research work, the study area was divided into 45 grids of 5.3km x 5.3km. Each grid according to the scale has an area of about 28.09 square kilometers. From each grid, one settlement was selected by simple random process. One sample was collected per grid, giving a total number of 45 samples.

Figure. 2: Stratified map of Wurno Local Government Area.

2.2 Sample Collection

Forty-five (45) groundwater samples from boreholes and dug wells were collected from the study area using the stratified random sampling techniques. The water samples were collected in the month of April to May 2019 towards end of dry season and the beginning of raining season. At each point of sample collection, several measures were observed to avoid contamination of the water samples. In the case of borehole water, the water was allowed to flow for at least 5min before taking the sample, to avoid collection of stagnant water from the borehole. A filter was used in collecting water sample from the hand dug wells to avoid passage of unnecessary particles into the water sample. One litre polyethylene gallon was used to collect the water sample from both boreholes and hand dug wells, about 1% of the polyethylene gallon was left unfilled to allow for expansion, and 15 ml of dilute Nitric acid was immediately added to the water samples, this was made possible to prevent adsorption of the radionuclides on the walls of the container. The water samples were thoroughly sealed and labelled accordingly. A Global Positioning System (Model) GPS was used to take the reading for the coordinate and the elevation at each sample location and were recorded immediately. Thereafter, the samples were transported to National Institute for Radiation Research and Protection (NIRRP) University of Ibadan for preparation and analysis.

2.3 Sample Preparation

Water analysis was prepared in the laboratory at the National Institute of Radiation Protection and Research (NIRPR), University of Ibadan, Nigeria. The whole samples (forty-five samples) were left for twenty-eight days (28 days) at the sample preparation lab. to enable them attain secular equilibrium before counting.

2.4 Energy Calibration

The energy calibration of standard radionuclides of known activities and well-defined energies was carried out within the energy range from 60 KeV to 2000 KeV. The standard calibration was long enough counte to produce well defined photo peaks.

2.5 Efficiency Calibration

The efficiency of the detector is the ratio of the actual events registered by the detector to the total number of events emitted the source of radiation.

In this research work, the efficiency calibrations were performed by counting radionuclides of known activities with well-defined energies in the energy range of 60 KeV to 2000 KeV. The equation below was used to determine the efficiencies.

$$\eta(\text{Eff}) = \frac{N_T - N_B}{P_E A_S T_S} \qquad (2.1)$$

Where, η(Eff) is the efficiency of the detector, N_T is the net total under a photo peak, N_B is the background count of the detector, P_E is the probability of gamma emission for energy E, A_S is the activity of the radionuclide in the calibration standard during calibration and T_A stands for the counting time.

2.6 Minimum Detectable Activity

This is an important concept in the determination of activity of a particular sample. Minimum detectable activity referred to the smallest amount of radioactivity that could be determined under certain conditions. The minimum detectable activities for the radionuclides of interest were computed using average peak areas at the gamma ray lines according to equation (3.2).

$$\text{M D A} = \frac{\sigma\sqrt{B}}{\eta P T W} \qquad (2.2)$$

Where, **σ** is the statistical coverage factor with value equal 1.645 (confidence level of 95 percent), B is the background for the region of interest of each radionuclide, P is the gamma emission probability (gamma yield) of each radionuclide, T is the counting time in second, W is the weight of the sample container and η is the detector efficiency for the measured gamma ray energy.

2.7 Activity Concentration of Radionuclides

^{238}U activity concentration was determined from 1001 keV gamma lines using equation (3.3).

$$A_C = \frac{C_N}{P_\gamma M_E} \qquad (2.3)$$

where AC is the activity concentration of the radionuclide in the sample in Bq/L Cn is the net count under the corresponding peak, Pγ is the absolute transition probability of the specific gamma ray, M is the mass of the water sample (L) and ε is the detector efficiency at the specific gamma ray energy.

2.8 Sample Analysis

The measurement of the radionuclides concentration of all the samples were done using a Camberre P-type High purity Germanium (HpGe) detector of length 69.8 mm and diameter of 78 mm with a relative efficiency of 80 %. The detector was enclosed in a lead shield of thickness 10 cm in order to reduce the interference due to background radiation from the surrounding with liquid nitrogen to serve as a cooling system. Complete electronics instrument was connected to a PC-based multichannel analyzer for gamma spectrum evaluation. The energy and efficiency calibration of the HpGe detector was performed using the 1.33 MeV gamma line of ^{60}Co resulting to energy resolution of 2.3 KeV (FWHM) with a relative yield of 1.73%. Liquid nitrogen was used to enhance the detector operation at a very low temperature. Multi-channel analyser was installed to a personal computer that acquired the data. 500 ml Marinelli beaker was used to maintained fixed geometry for both the standard source and the samples. An amplifier which was utilized by the HpGe detector signal processing was incorporated in addition to an analogue-to-digital converter (ADC). The HpGe detector was automatically connected to a multi-channel analyser that was installed in a personal computer for acquiring data. ^{238}U activity concentration was determined from 1001 keV gamma lines.

3 Result and Discussion

3.1 Activity Concentration

Table 1: Activity concentration of ^{238}U from water samples

N /So	Samples location	Elevation	Latitude	Longitude	^{238} U
1	Ruga	284	5.35358	13.26011	5.15±0.84
2	Kagar Rafi	253	5.37113	13.31319	0.53±0.15
3	Gidan Modi	264	5.48925	13.30173	1.94±0.30
4	Sisawa	301	5.34513	13.16647	2.42±0.32
5	Gyal-Gyal	276	5.3573	13.12188	0.92±0.24
6	Gidan Salihu	281	5.3533	13.24817	0.46±0.14
7	Guntun Gida	310	5.39781	13.21568	3.19±0.36
8	Achida	319	5.39636	13.16697	0.84±0.24
9	Alkammu	307	5.37324	13.13633	2.25±0.33
10	Kaurare	313	5.36822	13.12525	1.13±0.33
11	Yar Wurno Dangida	251	5.66921	13.46919	0.33±0.12
12	Dabagin Adakata	314	5.36822	13.45219	2.66±0.46
13	Sidingo	258	5.66875	13.42347	2.53±0.35
14	Saketa	286	5.40655	13.20305	2.40±0.30
15	Tudun Malami	307	5.40905	13.16269	3.01±0.42
16	Suntubawa	301	5.52336	13.21386	0.58±0.11
17	Gidan Kamba	298	5.57547	13.22852	3.41±0.51
18	Danbiso	287	5.45836	13.32836	2.72±0.44
19	Dabagin Yari	316	5.77552	13.44002	1.55±0.28
20	Gidan Koro	325	5.75184	13.3728	1.43±0.23
21	Munki	334	5.76002	13.33511	0.88±0.19
22	Dabagin Bum	327	5.80176	13.39616	7.37±0.84
23	Duhuwar Maranawa	287	5.68975	13.36113	5.76±0.98
24	Nasarawar Daje	298	5.70891	13.39505	0.26±0.07
25	Lugu	256	5.72475	13.45447	1.91±0.35

26	Dabagin Busau	328	5.76901	13.43811	2.56±0.39
27	Marnona	336	5.81882	13.35191	0.71±0.18
28	Sabon Birnin Daji	260	5.51252	13.27733	1.00±0.23
29	Sabon Garin Daji	298	5.49005	13.3278	0.69±0.16
30	Kawadata	289	5.50744	13.24263	2.59±0.36
31	Gidan Ardo	276	5.49294	13.29286	0.91±0.21
32	Chacho	286	5.45558	13.16683	1.02±0.18
33	Arba	260	5.55447	13.28641	5.75±1,19
34	Barayar Zaki	261	5.55611	13.29455	1.48±0.21
35	Gawasu	262	5.58391	13.26697	0.93±0.18
36	Ragar Gizo	284	5.59013	13.31175	1.55±0.41
37	Kwardaba	279	5.5118	13.26705	3.03±0.35
38	Doron Sule	287	5.50955	13.25933	2.79±0.52
39	Sabon Galin Liman	268	5.61477	13.28766	0.58±0.11
40	Dinawa	336	5.42594	13.23433	1.05±0.26
41	Jodo	287	5.66094	13.29472	0.63±0.16
42	Jantsara	276	5.36927	13.12877	3.01±0.31
43	Laka	260	5.80083	13.28425	2.27±0,78
44	Digim	287	5.75638	13.28694	9.66±0.97
45	Kadagiwa	269	5.77005	13.27908	4.09±0.21
		Minimum			**0.26±0.07**
		Maximum			**9.66±0.97**
		Average			**2.27±0.36**

Table 1 displayed the activity concentration from the study area in $Bq.L^{-1}$. The activity concentration ranged from 0.26 ± 0.07 to 9.66 ± 0.97 $Bq.L^{-1}$, with an average value of 2.27±0.36. The activity concentration of ^{238}U was found to be higher at Diggim with the value of 9.66 ± 0.97 $Bq.L^{-1}$, whereas, lowest value was reported at Nassarawar-Daje with 0.26 ± 0.07 $Bq.L^{-1}$. It can be observed from Table 1, and with reference to the adopted guidance level (GL) of 10.00 $Bq.L^{-1}$ for Uranium in drinking water (WHO, 2006) that activity concentration of ^{238}U in some settlements are higher than other settlements, probably due to the variations in their depth and differences in the subsurface rocks geology Difference in the geological formation is another factor responsible for the variations in the activity concentrations.

The study area exists within three geological formations, namely, Kalambaina formation, Dange formation and Rima group. Dange formation consist mainly shales separated by the calcareous. The Kalambaina formation consist of limestones and very rich in carbonate. Rima group consist of mudstones and friable sandstones separated by the fossiliferous, calcareous and shaley (Obaje, 2013). The subsurface rock containing different elements can also be responsible for the variations in the activity concentration. The reason for higher activity concentration of ^{238}U from Diggim is due to the geological features of the existing formation within the settlement (Rima group) which may contain elements responsible for the elevated radiation. Uranous state (+IV) deposit in the host aquifer-bearing rock that may also be responsible for high activity concentration. The lower activity concentration was found at Nassarawa-Daje which falls within Kalambaina formation. The activity concentration of ^{238}U found in all the locations are below the recommended set limit by WHO.

The data in Table 1 was converted to $\mu g.L^{-1}$. According to WHO proposed provisional guideline, there is 15 $\mu g\ L^{-1}$ for every 0.19 $Bq\ L^{-1}$. (WHO, 2006, Maxwell, and Wagira, 2015). The result is shown in Table 2.

Table 2: Mass concentration of ^{238}U in ($\mu g.L^{-1}$)

S/N	Samples location	^{238}U Activity Conc. ($Bq\ L^{-1}$)	^{238}U μgL^{-1}
1	Ruga	5.15±0.84	406.579
2	Kagar Rafi	0.53±0.15	41.842
3	Gidan Modi	1.94±0.30	153.158
4	Sisawa	2.42±0.32	191.053
5	Gyal-Gyal	0.92±0.24	72.632
6	Gidan Salihu	0.46±0.14	36.316
7	Guntun Gida	3.19±0.36	251.842
8	Achida	0.84±0.24	66.316
9	Alkammu	2.25±0.33	177.632
10	Kaurare	1.13±0.33	89.211
11	Yar Wurno Dangida	0.33±0.12	26.053
12	Dabagin Adakata	2.66±0.46	210.00

13	Sidingo	2.53±0.35	199.736
14	Saketa	2.40±0.30	189.474
15	Tudun Malami	3.01±0.42	237.632
16	Suntubawa	0.58±0.11	45.789
17	Gidan Kamba	3.41±0.51	269.211
18	Danbiso	2.72±0.44	214.737
19	Dabagin Yari	1.55±0.28	122.369
20	Gidan Koro	1.43±0.23	112.895
21	Munki	0.88±0.19	69.474
22	Dabagin Bum	7.37±0.84	581.842
23	Duhuwar Maranawa	5.76±0.98	454.737
24	Nasarawar Daje	0.26±0.07	20.526
25	Lugu	1.91±0.35	150.789
26	Dabagin Busau	2.56±0.39	202.105
27	Marnona	0.71±0.18	56.053
28	Sabon Birnin Daji	1.00±0.23	89.211
29	Sabon Garin Daji	0.69±0.16	54.474
30	Kawadata	2.59±0.36	204.474
31	Gidan Ardo	0.91±0.21	71.842
32	Chacho	1.02±0.18	80.526
33	Arba	5.75±1,19	453.947
34	Barayar Zaki	1.48±0.21	116.842
35	Gawasu	0.93±0.18	73.421
36	Ragar Gizo	1.55±0.41	122.368
37	Kwardaba	3.03±0.35	239.211
38	Doron Sule	2.79±0.52	220.263
39	Sabon Galin Liman	0.58±0.11	45.789
40	Dinawa	1.05±0.26	82.895
41	Jodo	0.63±0.16	49.737
42	Jantsara	3.01±0.31	237.631
43	Laka	2.27±0,78	179.211
44	Digim	9.66±0.97	762.632
45	Kadagiwa	4.09±0.21	322.894
Minimum			**20.526**
Maximum			**581.842**
Mean			**179.053**

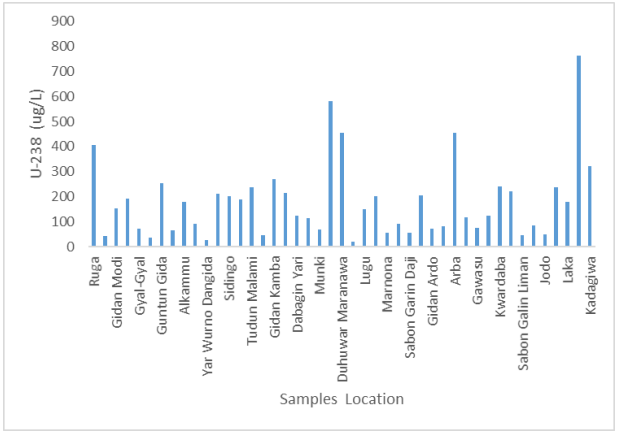

Figure 3. Activity concentration of ^{238}U in different location of Wurno Local Government Area.

3.2 Annual Effective Dose from Daily Intake of ^{238}U, from Water Samples.

The annual effective dose due to intake of ^{238}U, was calculated taking into account the activity concentration (AC) of ^{238}U in Bq L^{-1}, the dose conversion factor (DC) of the radionuclides in question given in $Sv.Bq^{-1}$ and annual water consumption (AWC) rate for an average adult in L. The activity concentration of the radionuclides was earlier displayed in Table 1, the ingested dose conversion factors was taken to be 4.5×10^{-8} for ^{238}U (ICRP, 2012).

$$AED\ (mSvy^{-1}) = AC\ (BqL^{-1}) \times DC\ (SvBq^{-1}) \times AWC\ (L\ y^{-1}) \quad 3.1$$

Where AED is the annual effective dose ($mSvy^{-1}$), AC the activity concentration of the radionuclide ($Bq.L^{-1}$) in this study, DC the dose coefficient for ^{238}U in (Sv.Bq−1) and AWC is the annual water consumption in litres per year.

Equation 4.0, was used to calculate the annual effective dose to an individual due to intake of natural radionuclide ^{238}U from all the Sampled water of the study area and was presented in Table 3. It can be observed from this table that ^{238}U shows lower values of AED. This may be due fact that ^{238}U has decayed to it daughter radionuclides and as such, little or no trace of it can be dictated. In addition, most of the areas that displayed higher value of ^{238}U are boreholes related samples with a depth much higher than the hand-dug wells probably, the ^{222}Rn content in the water may not have way to escape to the surrounding as compared to hand-dug where the ^{222}Rn content finds it easier to escape to the surrounding and consequently lower amount of ^{238}U was observed. The derived annual effective dose received by the inhabitants as a result of ingestion of ^{238}U in water is estimated to have a range of 0.008 $mSv.y^{-1}$ to 0.32 $mSv.y^{-1}$.

Diggim displayed the highest value of the annual effective dose to an individual due to Uranium

(^{238}U) contribution to the tone of 0.32 $mSv.y^{-1}$ which is higher than the recommended set limit of 0.1 $mSv.y^{-1}$ and lowest value was reported in Nassarawar-Daje with a value of 0.008 $mSv.y^{-1}$. Annual affective dose due to intake of ^{238}U and ^{226}Ra in ground water of Deidei, Kubwa, Gosa and Lugbe area of Abuja was found to be 8.9×10^{-5} $mSv.y^{-1}$, 2.8×10^{-5} $mSv.y^{-1}$, 1.5×10^{-5} $mSv.y^{-1}$ and 9.0×10^{-5} $mSv.y^{-1}$ (Maxwell and Wagiran, 2014). The values obtained by Maxwell and Wagiran, (2016) were below the recommended value. According to ICPR 69 (Duggal, *et.al* 2019), Uranium and its daughter product Radium gets to the blood through the soft tissues and excretes in urine. It can be excreted in few months but the parents could be retained for years. The variation in the annual effective dose between this present study and the study carried out by Maxwell and Wagiran, (2016) could be due to the differences in the geological formations of the two different study areas.

Table 3: Annual effective dose due to ^{238}U

		4.5×10^{-8} $Sv.Bq^{-1}$ for ^{238}U	**12.9×10^{-8} $Sv.Bq^{-1}$ for ^{238}U**	**15.5×10^{-8} $Sv.Bq^{-1}$ for ^{238}U**
N/So	**Samples location**	**Adult**	**Children**	**Infants**
1	Ruga	1.69E-04	2.33E-04	1.60E-04
2	Kagar Rafi	1.74E-05	2.39E-05	1.64E-05
3	Gidan Modi	6.37E-05	8.76E-05	6.01E-05
4	Sisawa	7.95E-05	1.09E-04	7.50E-05
5	Gyal-Gyal	3.02E-05	4.15E-05	2.85E-05
6	Gidan Salihu	1.51E-05	2.08E-05	1.43E-05
7	Guntun Gida	1.05E-04	1.44E-04	9.89E-05
8	Achida	2.76E-05	3.79E-05	2.60E-05
9	Alkammu	7.39E-05	1.02E-04	6.98E-05
10	Kaurare	3.71E-05	5.10E-05	3.50E-05
11	Yar Wurno Dangida	1.08E-05	1.49E-05	1.02E-05
12	Dabagin Adakata	8.74E-05	1.20E-04	8.25E-05
13	Sidingo	8.31E-05	1.14E-04	7.84E-05
14	Saketa	7.88E-05	1.08E-04	7.44E-05
15	Tudun Malami	9.89E-05	1.36E-04	9.33E-05
16	Suntubawa	1.91E-05	2.62E-05	1.80E-05
17	Gidan Kamba	1.12E-04	1.54E-04	1.06E-04
18	Danbiso	8.94E-05	1.23E-04	8.43E-05
19	Dabagin Yari	5.09E-05	7.00E-05	4.81E-05
20	Gidan Koro	4.70E-05	6.46E-05	4.43E-05
21	Munki	2.89E-05	3.97E-05	2.73E-05
22	Dabagin Bum	2.42E-04	3.33E-04	2.28E-04
23	Duhuwar Maranawa	1.89E-04	2.60E-04	1.79E-04
24	Nasarawar Daje	8.54E-06	1.17E-05	8.06E-06
25	Lugu	6.27E-05	8.62E-05	5.92E-05
26	Dabagin Busau	8.41E-05	1.16E-04	7.94E-05
27	Marnona	2.33E-05	3.21E-05	2.20E-05
28	Sabon Birnin Daji	3.71E-05	5.10E-05	3.50E-05
29	Sabon Garin Daji	2.27E-05	3.12E-05	2.14E-05
30	Kawadata	8.51E-05	1.17E-04	8.03E-05
31	Gidan Ardo	2.99E-05	4.11E-05	2.82E-05
32	Chacho	3.35E-05	4.61E-05	3.16E-05
33	Arba	1.89E-04	2.60E-04	1.78E-04

34	Barayar Zaki	4.86E-05	6.68E-05	4.59E-05
35	Gawasu	3.06E-05	4.20E-05	2.88E-05
36	Ragar Gizo	5.09E-05	7.00E-05	4.81E-05
37	Kwardaba	9.95E-05	1.37E-04	9.39E-05
38	Doron Sule	9.17E-05	1.26E-04	8.65E-05
39	Sabon Galin Liman	1.91E-05	2.62E-05	1.80E-05
40	Dinawa	3.45E-05	4.74E-05	3.26E-05
41	Jodo	2.07E-05	2.84E-05	1.95E-05
42	Jantsara	9.89E-05	1.36E-04	9.33E-05
43	Laka	7.46E-05	1.02E-04	7.04E-05
44	Digim	3.17E-04	4.36E-04	2.99E-04
45	Kadagiwa	1.34E-04	1.85E-04	1.27E-04
	Minimum	**8.54E-06**	**1.17E-05**	**8.06E-06**
	Maximum	**3.17E-04**	**4.36E-04**	**2.99E-04**
	Average	**7.45E-05**	**1.02E-04**	**7.03E-05**

Also the annual effective dose according to three different age groups [> 17 (adults), 2 – 17 (Children) and 0 – 2 (Infants) years] was calculated. The annual effective dose for Adult members (> 17 years) ranges from 0.008 $mSvy^{-1}$ – 0.32 $mSvy^{-1}$ with an average value of 0.074 $mSvy^{-1}$. Annual effective dose for children (2-17 years) ranged from 0.012 $mSvy^{-1}$ – 0.44 $mSvy^{-1}$ with an average value of 0.1 $mSvy^{-1}$. The annual effective dose for Infants (0-2 years) ranged from 0.0081 $mSvy^{-1}$ – 0.29 $mSvy^{-1}$ with an average value of 0.07 $mSvy^{-1}$. It can be observed from the Table 3 that children are at highest risk followed by Adult, then Infants. The highest annual effective was found in children, could be attributed to the metabolic activity and the amount of water intake for the children. The result of the annual effective dose from this study was compared with results from other studies done elsewhere. Achuka, 2017, estimated the annual effective dose for six age groups. Her result reveal high annual effective from age group 12-17 yrs. Patra, *et al.,* 2013, estimated an annual effective dose for Adult, Children and Infants. His result displayed high annual effective dose to have emanate from children.

3.3 Radiological Assessment of ^{238}U from Groundwater of the Study Area.

The aim of the radiological risk assessment in this present study is to estimate the life time cancer risk due to ingestion of ^{238}U in drinking water of the study area. The lifetime cancer risks (R), associated with the intake of a given radionuclide, was estimated from the product of the applicable risk coefficient r and the per capita activity intake I expressed as follows (Maxwell and Wagiran 2015).

$$R = r \times I \qquad 3.2$$

Where, R, is the lifetime cancer risks associated with intake of uranium and radium in ground water; r is cancer risk coefficient; and I is the per capital activity intake. The per capital activity intake (I) is the product of activity concentration in $Bq.L^{-1}$ and lifetime intake of water and was calculated for ^{238}U. The cancer mortality and morbidity risks for only the age group > 17 was considered. The average life expectancy in Nigeria was estimated to be 54.5 years according to the world health organisation (WHO), and annual consumption of water for an average adult is about 730 L $year^{-1}$, which result to a total of 39,785 L for an estimated lifetime water intake. The cancer risk coefficients (r) of ^{238}U is 1.13×10^{-9} Bq^{-1} for mortality and 1.73×10^{-8} Bq^{-1} for morbidity (USEPA 1999, UNSCEAR 2000). Equation 4.2 was used to calculate cancer mortality and morbidity risks and the results were presented in Table 4.

From Table 4, it can be observed that ^{238}U cancer mortality risk spanned from 1.17×10^{-5} – 4.34×10^{-4}, while cancer morbidity risk spanned from 1.79×10^{-5} – 6.65×10^{-4}. Their mean values were found to be 1.02×10^{-4} and 1.56×10^{-4} for mortality and morbidity respectively. The highest mortality value was found at Diggim with a value of 4.34×10^{-4} while lowest value was observed at Nassarawa Daje with a value of 1.17×10^{-5}. The highest cancer morbidity value was reported at the same Diggim town with a value of 6.65×10^{-4} and lowest cancer morbidity value was reported at Nassarawa Daje with a value 1.79×10^{-5}. In contrast with a study reported by Achuka, (Achuka, 2017) in Ogun state, Nigeria, the mean cancer mortality value of 1.02×10^{-4} which is from this study, is lower than 10.70×10^{-5} value obtained by Achuka with a factor of 5×10^{-6}. For cancer morbidity value, the value, 1.56×10^{-4} from this study was lower than 16.40×10^{-5} value obtained with a factor of 8×10^{-6}. When

compared with mean cancer risk obtained by Patra, (Patra, *et al.,* 2013) of value 4.8 × 10^{-6}. The value from this present study is higher but less than acceptable lifetime cancer risk of 10^{-3} for radiological risk (USEPA, 1999) by a factor 10^{-1}. The variation in both the cancer mortality and morbidity values from the 45 settlements of the study area and some studies mentioned earlier may be due to the differences in their geological formations, depth to sedimentary thickness and activities taking place in the areas. Theoretically, sedimentary thickness determined the types of rocks that exist within a subsurface geology and consequently the elements likely to contain high or low radiation dose (Obaje, *et al.,* 2013). In addition, activities like farming, which results to application of fertilizer, a byproduct of phosphate can contribute to high radiation values in some areas. On the other hand, mining activity taking place in study area and tectonic activity of deformed fractures that enable water to trap at the near surface since the subsurface geology allows the fast downward transfer of water sources from the source can be the major factors responsible for the high radiation dose which results to elevated cancer mortality and morbidity values.

Table 4: Lifetime cancer risks mortality and morbidity for ^{238}U

S/N	Samples location	^{238}U (Mortality)	^{238}U (Morbidity)
1	Ruga	2.32E-04	3.54E-04
2	Kagar Rafi	2.38E-05	3.65E-05
3	Gidan Modi	8.72E-05	1.34E-04
4	Sisawa	1.09E-04	1.67E-04
5	Gyal-Gyal	4.14E-05	6.33E-05
6	Gidan Salihu	2.07E-05	3.17E-05
7	Guntun Gida	1.43E-04	2.20E-04
8	Achida	3.78E-05	5.78E-05
9	Alkammu	1.01E-04	1.55E-04
10	Kaurare	5.08E-05	7.78E-05
11	Yar Wurno Dangida	1.48E-05	2.27E-05
12	Dabagin Adakata	1.20E-04	1.83E-04
13	Sidingo	1.14E-04	1.74E-04
14	Saketa	1.08E-04	1.65E-04
15	Tudun Malami	1.35E-04	2.07E-04
16	Suntubawa	2.61E-05	3.99E-05
17	Gidan Kamba	1.53E-04	2.35E-04
18	Danbiso	1.22E-04	1.87E-04
19	Dabagin Yari	6.97E-05	1.07E-04
20	Gidan Koro	6.43E-05	9.84E-05
21	Munki	3.96E-05	6.06E-05
22	Dabagin Bum	3.31E-04	5.07E-04
23	Duhuwar Maranawa	2.59E-04	3.96E-04
24	Nasarawar Daje	1.17E-05	1.79E-05
25	Lugu	8.59E-05	1.31E-04
26	Dabagin Busau	1.15E-04	1.76E-04
27	Marnona	3.19E-05	4.89E-05
28	Sabon Birnin Daji	5.08E-05	7.78E-05
29	Sabon Garin Daji	3.10E-05	4.75E-05
30	Kawadata	1.16E-04	1.78E-04
31	Gidan Ardo	4.09E-05	6.26E-05
32	Chacho	4.59E-05	7.02E-05
33	Arba	2.59E-04	3.96E-04
34	Barayar Zaki	6.65E-05	1.02E-04
35	Gawasu	4.18E-05	6.40E-05
36	Ragar Gizo	6.97E-05	1.07E-04
37	Kwardaba	1.36E-04	2.09E-04
38	Doron Sule	1.25E-04	1.92E-04
39	Sabon Galin Liman	2.61E-05	3.99E-05
40	Dinawa	4.72E-05	7.23E-05
41	Jodo	2.83E-05	4.34E-05
42	Jantsara	1.35E-04	2.07E-04
43	Laka	1.02E-04	1.56E-04
44	Digim	4.34E-04	6.65E-04
45	Kadagiwa	1.84E-04	2.82E-04
	Minimum	**1.17E-05**	**1.79E-05**
	Maximum	**4.34E-04**	**6.65E-04**
	Mean value	**1.02E-04**	**1.56E-04**

3.4 Chemical toxicity risk assessment of ^{238}U in groundwater samples of the study area

In order to determine the effects of the non-carcinogenic risks the chemical toxicity risk associated with groundwater (borehole and well) containing levels of Uranium was evaluated. The analysis was done using Hyper Pure Germanium (HPGe) detector to obtained the activity concentration of individual radionuclides and the result from gamma-ray spectrometer given in Bql^{-1} was converted to μgl^{-1} to obtained the concentration (Maxwell and Wagiran, 2015).

The chemical toxicity risk was evaluated using the lifetime average daily dose (LADD) of Uranium (^{238}U). Equation 3.3 was used.

Ingestion LADD of drinking water = $\frac{EPC \times IR \times EF \times ED}{AT \times BW}$ 3.3

Where LADD is the lifetime average daily dose ($\mu g\ kg^{-1}\ day^{-1}$), EPC is the exposure point concentration ($\mu g\ L^{-1}$), IR is the water ingestion rate ($L\ day^{-1}$), EF is the exposure frequency

(days year^{-1}). ED is the total exposure duration (years), AT is the average time (days) and BW is the body weight (kg).

Therefore, using IR = 2L day^{-1}, for an average adult, EF = 365 days, and ED = 54.5 years (WHO, 2006), AT = 19,892.5 (arrived from 54.5 × 365), and BW = 70 kg according to USEPA, weight of a standard value for man. The chemical toxicity risk for uranium over lifetime consumption of groundwater (borehole and well) from the study area was estimated and presented in Table 5.

The chemical toxicity dose ranged from 0.59 – 21. 79 µg.kg^{-1}.day^{-1} with an average dose value of 5.12 µg.kg^{-1}.day^{-1}. The LADD values was reported to be higher at Diggim and lower at Nassarawa-Daje with the values 21.79 µg.kg^{-1}.day^{-1} and 0.59 µg.kg^{-1}.day^{-1} respectively. The higher LADD dose value reported at Diggim could be due to the subsurface geochemistry which contains rocks of high density cracks and fractures that serves as source rocks to the water bearing formation caused by tectonic event of Pan-African Orogeny. Later on magmatic and metamorphic processes of granitic intrusions and it interconnectivity with geochemistry and aquifer bearing formation yield in the existence of uranium bearing rocks from the deep-seated source (Maxwell and Wagiran, 2015). The lower LADD reported from Nassarawa-Daje could be due to absence of the uranium bearing rocks. Comparing the LADD obtained in this study and the RFD (0.6 µg.kg^{-}1.day^{-1}) (WHO, 2006) the chemical toxicity risk due to ^{238}U in the water samples were all above the RFD. This shows that there may be health risks associated with ^{238}U in the water samples. Uranium in groundwater is known to have risk associated with chemical toxicity rather than radiological factor.

Table 5: Lifetime average daily dose due to ^{238}U in groundwater of the study area.

S/N	Sample location	^{238}U (LADD)
1	Ruga	11.617
2	Kagar Rafi	1.195
3	Gidan Modi	4.376
4	Sisawa	5.459
5	Gyal-Gyal	2.075
6	Gidan Salihu	1.038
7	Guntun Gida	7.195
8	Achida	1.895
9	Alkammu	5.075
10	Kaurare	2.549
11	Yar Wurno Dangida	0.744
12	Dabagin Adakata	6
13	Sidingo	5.707
14	Saketa	5.414
15	Tudun Malami	6.789
16	Suntubawa	1.308
17	Gidan Kamba	7.692
18	Danbiso	6.135
19	Dabagin Yari	3.496
20	Gidan Koro	3.226
21	Munki	1.984
22	Dabagin Bum	16.624
23	Duhuwar Maranawa	12.992
24	Nassarawar Daje	0.586
25	Lugu	4.308
26	Dabagin Busau	5.774
27	Marnona	1.602
28	Sabon Birnin Daji	2.549
29	Sabon Garin Daji	1.556
30	Kawadata	5.842
31	Gidan Ardo	2.053
32	Chacho	2.301
33	Arba	12.969
34	Barayar Zaki	3.338
35	Gawasu	2.097
36	Ragar Gizo	3.496
37	Kwardaba	6.834
38	Doron Sule	6.293
39	Sabon Garin Liman	1.308
40	Dinawa	2.368
41	Jodo	1.421
42	Jantsara	6.789
43	Laka	5.120
44	Diggim	21.789
45	Kadagiwa	9.225
	Minimum	**0.586**
	Maximum	**21.789**
	Average	**5.116**

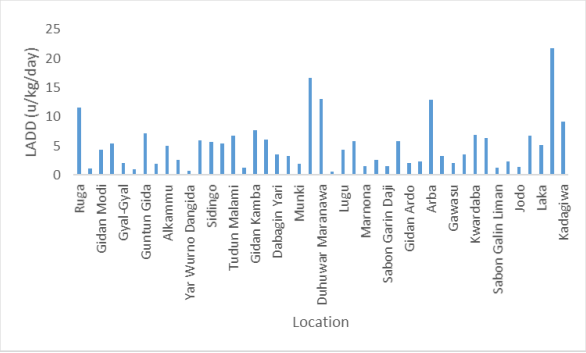

Figure 4. Lifetime average daily dose due to ^{238}U in groundwater

3.4 Estimation of hazard quotient of ^{238}U in groundwater samples of the study area

The hazard quotient due to ingestion of the radionuclides of interest from the study area was

estimated in order to ascertain the adverse health effects expected from exposure. The hazard quotient is the ratio of the lifetime average daily dose (LADD) and the set limit through which no adverse effects are expected. According to United State Environmental Protection Agency EPA, 2000, if the hazard quotient from ingestion of water containing radionuclides concentration is not above 1, then no adverse health effects is expected. The hazard quotient cannot be translated to be a probability that adverse health effects will occur, and is unlikely to be proportional to risk. Most importantly, it is wise to note that a hazard quotient more than unity does not guaranty adverse health effects. equation 4 was utilized for the calculation. (Maxwell and Wagiran, 2015) and result was presented in Table 5. From Table 5, the hazard quotient was reported to be high in almost all the 45 water samples. Only two settlements were reported to have value within the international organization standard value of <1 (UNSCEAR, 2000).

Hazard quotient = $\frac{LADD}{RFD}$ 3.4

Table 6: Hazard quotient due to ^{238}U

S/N	Sample location	^{238}U Hazard quotient
1	Ruga	19.3609
2	Kagar Rafi	1.9924
3	Gidan Modi	7.2932
4	Sisawa	9.0977
5	Gyal-Gyal	3.4586
6	Gidan Salihu	1.7293
7	Guntun Gida	11.9924
8	Achida	3.1578
9	Alkammu	8.4586
10	Kaurare	4.2481
11	Yar Wurno Dangida	1.2406
12	Dabagin Adakata	10.0000
13	Sidingo	9.5112
14	Saketa	9.0225
15	Tudun Malami	11.3157
16	Suntubawa	2.1804
17	Gidan Kamba	12.8195
18	Danbiso	10.2255
19	Dabagin Yari	5.8270
20	Gidan Koro	5.3759
21	Munki	3.3082
22	Dabagin Bum	27.7066
23	Duhuwar Maranawa	21.6541
24	Nassarawar Daje	0.9774
25	Lugu	7.1805
26	Dabagin Busau	9.6241
27	Marnona	2.6692
28	Sabon Birnin Daji	4.2481
29	Sabon Garin Daji	2.5940
30	Kawadata	9.7368
31	Gidan Ardo	3.4211
32	Chacho	3.8346
33	Arba	21.6165
34	Barayar Zaki	5.5639
35	Gawasu	3.4962
36	Ragar Gizo	5.8270
37	Kwardaba	11.3909
38	Doron Sule	10.4887
39	Sabon Garin Liman	2.1804
40	Dinawa	3.9473
41	Jodo	2.3684
42	Jantsara	11.3158
43	Laka	8.5338
44	Diggim	36.3157
45	Kadagiwa	15.3759
	Minimum	**0.977**
	Maximum	**36.315**
	Average	**8.526**

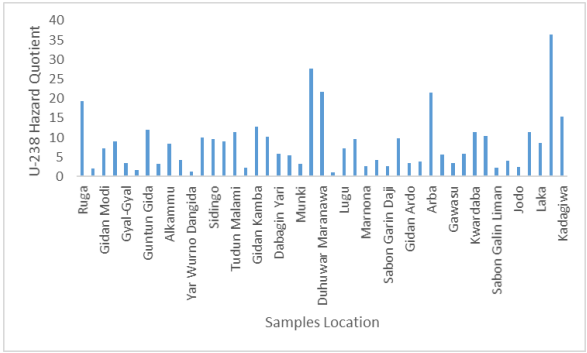

Figure 5. Showing ^{238}U hazard quotient in different location of the study area

4. Conclusion

In this present study, the variation of radioactivity content was observed from the study area. This may probably due to the variations in the depth of the boreholes and wells which allows the ^{222}Rn concentration to easily escape from wells than in boreholes. The estimated annual effective doses for the groups Adult, children and infants ranged from 0.008 $mSv.y^{-1}$ – 0.32 $mSv.y^{-1}$ with an average value of 0.074 $mSv.y^{-1}$, 0.012 – 0.44 $mSv.y^{-1}$ with an average value of 0.1 $mSv.y^{-1}$ and 0.0081 – 0.29 $mSv.y^{-1}$ with an average value of 0.07 $mSv.y^{-1}$ respectively. The highest annual effective was found in children could be attributed to the metabolic activity and the amount of water intake for the children. Radiological risks found within the study area for ^{238}U ranged 1.17×10^{-5} – 4.34×10^{-4} with an average value of 1.02×10^{-4} for mortality and 1.79×10^{-5} – 6.65×10^{-4} with an average value of

1.56×10^{-4}. The value exceeded the set limit of 10^{-3} (USEPA, 1999) in almost all the locations. Mining and tectonic activity that were taking place in the study that enable water to trap at the near surface from the source can be the major factors responsible for the high radiation dose. The chemical toxicity risk due to ^{238}U exceeded the set limit of ($0.6\ \mu g.kg^{-1}.day^{-1}$). This shows that there may be health risks associated with ^{238}U in the water samples. The hazard quotient in 43 settlements exceeded the international standard of < 1. The only two locations Yar-Wurno Dangida and Nassarawar-Daje have value within the set limit. However, this study has been created a fingerprint of the groundwater and the results can be used in determining the source of high radiation dose in Wurno Local Government. It is therefore, recommended that chemical toxicity risk (non-carcinogenic) pollution may be the major source of health risk and the groundwater in Wurno Local Government should be treated before consumption to minimized the possible health risk. Concurrently, quality protection and monitoring should be adopted.

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Conflict of Interest

The authors declare that there is no conflict of interest.

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