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Natural Radioactivity and Radiation Dose Estimation in Various Water Samples in Abua/Odua Area, Rivers State, Nigeria

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Authors' contributions

This work was carried out in collaboration between both authors. Author CPO designed the study, wrote the protocol, and wrote the first draft of the manuscript. Author GT managed the literature searches, performed the spectroscopy analysis and author CPO performed analyses of the data. Both authors read and approved the final manuscript.

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ABSTRACT

Gamma spectroscopy was used to determine the activity concentration of ^{238}U, ^{232}Th and ^{40}K and radiation dose estimates in water resources of Abua/Odual Local Government Area in Rivers State of Nigeria. A total of 19 water samples (7 borehole water, 6 river water and 6 hand dug well) were collected from 7 districts of Abua/Odua area. The concentration of ^{238}U, ^{232}Th and ^{40}K were measured by direct counting using sodium iodide [NaI(Ti)] detector interphased with a multi channel analyzer (MCA). The maximum activity concentration of ^{238}U in borehole water, river and hand dug well were 11.58, 2.12 and 26.27 Bql^{-1} respectively. The mean activity concentration of ^{232}Th in borehole water, river and hand dug well water were 46.21, 8.44 and 66.27 Bql^{-1} respectively while the activity concentration of ^{40}K in borehole water, river and hand dug well water were 39.22, 47.47 and 609.8 Bql^{-1} respectively. The mean activity concentration of ^{40}K is higher than ^{238}U and ^{232}Th in all the water samples. The committed effective dose was calculated for infants and adults population of the area. The mean committed effective dose for infants and adults

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that utilize borehole water were 3.21 and 10.25 $mSvy^{-1}$ respectively. For infant and adult that use river water, the committed effective doses were 1.13 and 2.14 $mSvy^{-1}$ respectively while those that consume hand dug well water were 3.11 and 7.36 $mSvy^{-1}$ respectively. The doses estimated from the activity concentrations of radionuclide showed values within safe limits. Therefore, utilization of the water resources studied would not endanger the lives of the final users.

Keywords: Natural radioactivity; committed effective dose; nai (Tl) detector; gamma-ray spectrometry.

1. INTRODUCTION

Radionuclides of natural origin are normally present in different amounts in drinking water [1]. Their activity concentrations vary widely since they depend on the nature of the aquifer. The processes of erosion and dissolution bring radioactive elements from the rocks into the ground water [2]. In environmental studies, water is considered very important because of its daily use for domestic use, human consumption and its ability to transport contaminants [3]. Radioactive elements in drinking water cause human internal exposure due to radioactive decay of the radio isotopes taken into the body through ingestion and inhalation indirectly when they are incorporated into the food chain [4].

The main sources of drinking water in the area of study include tap (borehole) water, well water and river water. These sources are constantly subjected to contamination from radiation sources especially the natural radioactivity from radionuclide such as ^{40}K, ^{238}U and ^{232}Th [5]. Access to safe drinking water is essential to health, a basic human right and a component of effective policy for health protection [6]. For this reason its quality must be strictly controlled. Drinking water may contain radionuclide that could present a risk to human health. The radioactivity in ground water comes mainly from radionuclide of natural decay chains of ^{238}U and ^{232}Th and ^{40}K in soil and bedrock. Some radionuclide can easily dissolve in water depending on the mineralogical and geochemical composition of the soil and rock, redox condition and the residence time of ground water in the soil and bedrock as a result of their interaction [7]. Consequently these radionuclide transported by the ground water can enter the food chain through irrigation water and the water source through ground water wells. The radionuclides are naturally present in the earth and can get into these water bodies through the process of seepage and surface run-off [8]. Ingestion of radionuclide can result to cancer of the skin, kidney, lung, bones and other diseases such ssterility, leukaemia [9] or lead to death [10].

Several radionuclides in the radioactive decay chain starting from ^{238}U and ^{235}U are highly radiotoxic [11]. Radium is the most radiotoxic and a known carcinogen and exists in several isotopic forms. Considering the high radio toxicity of ^{226}Ra and ^{228}Ra, their presence in ground water and the associated health risks require particular attention. When radium is ingested into the body, an appreciable proportion is deposited in the bone, and the remaining fraction is distributed to soft tissues [12]. Exposure to high levels of radium for a long period of time, could lead to cancer of the bone and nasal cavity [13].

The largest proportion of human exposure to radiation comes from natural sources which includes cosmic and terrestrial radiations. The United Nations Scientific Committee on Effect of Atomic Radiation (UNSCEAR) [14] has estimated that exposure to natural sources contributed about 70% of the population radiation exposure dose and the global average human exposure from natural source is 2.4 $mSvy^{-1}$. Many studies have been carried out on radioactivity concentration in various water samples (tap, river and well) collected from cities in Nigeria and other countries [15-19]. However, systematic data on the radioactivity of public water supplies in Abua/Odua local Government area of Rivers State is not available in the literature. Hence the need for this study which aims at evaluating the natural radioactivity of surface and ground water and estimation of radiation doses received by infants and adults in order to access the radiological risk associated with internal exposure due to ingestion of water.

2. MATERIALS AND METHODS

2.1 Study Area

Abua/Odual Local Government Area in Rivers State of Nigeria lies between longitudes 6°24' and 6°50' latitudes 4°40' and 4°55' (Fig. 1). This area is located at the central part of the Niger Delta. Abua/Odual Local Government Area has an area of 704 Km^2 and a population of 282,988

(NPC 2006). The area is divided into two major parts Abua and Odual by the Orashi River (fresh water) flowing in the north – south direction. The Odual axis is full of Saka-Creek distributaries forming streams and fresh water swamps. The salty Sombrero river influences the Abua creeks and streams. The area falls within the coastal belt dominated by low lying coastal plains which structurally belong to the sedimentary formations of the Niger Delta [20]. The region is criss-crossed by numerous south flowing rivers and creeks with the River Orashi being the largest. Its hydro-geologic profile is characterised by alluvial sedimentary strata composed chiefly by poorly leached loosed porous sandy to loamy soils. The area had experienced several oil spills, gas flare and other land pollution from industrial wastes.

2.2 Sample Collection and Preparation

Various water samples were collected from nineteen different sampling stations in Abua/ Odua Local Government Areas of Rivers State, Nigeria as shown in Fig. 1. All the water samples were collected into carefully washed 2L linear polypropylene bottles. The collected water samples were acidified with 1M of concentrated hydrochloric acid (HCl) to avoid adsorption of radionuclide unto the walls of the containers [8]. Each water sample was sealed and stored for 28 days to reach secular equilibrium between ^{238}U and ^{232}Th and their respective progeny before analysis [15].

2.3 Gamma Spectrometry

The gamma spectrometric measurement was carried out using Gamma ray spectrometric system coupled with a NaI (Tl) model 802 detector at the National Institute of Radiation Protection and Research, University of Ibadan, Ibadan. The detector is mounted vertically coupled with 8 KPC based Multi-channel Analyzer (MCA) and the detector is enclosed in a massive lead shield to reduce background of the system. The detector was calibrated with point sources Co-60, Cs-137, Am-241 and Na-22 for energy calibration and the efficiency calibration of the detector was done with volume source, IAEA-385. The detector which was well calibrated used Menager et al. [21] as its operating software in the analyses of various energies of ^{40}K, ^{238}U and ^{232}Th. Each sample was counted for 36,000 seconds to reduce the statistical uncertainty. An already washed empty Marinelli beaker was also placed in the detector for the same counting time (36,000 seconds) under identical geometry to determine the background radiation level of the laboratory

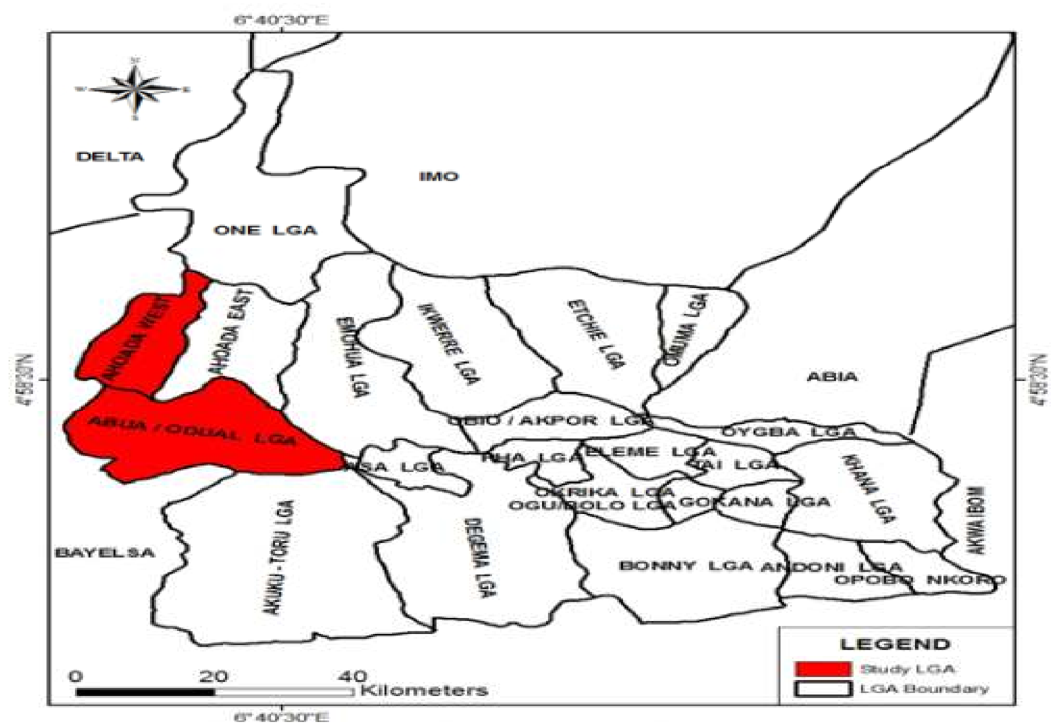

Fig. 1. Rivers state showing study LGAs

environment. It was later subtracted from the measured γ−ray spectra of each sample. At the end of the measurement, the various region of interest which was deducted from the background reading was computed with a specialized template involving the energy, percentage error, count, uncertainty, Activity concentration, and uncertainty in activity, Gamma probability, and uncertainty in gamma probability, Efficiency and uncertainty in efficiency were used to determine the radionuclide concentration in each sample.

According to published reports, the activity concentration, A, in unit of $Bqkg^{-1}$, for a radionuclide with a detected photopeak at energy E, is obtained from the following equation given by [22,23].

$$A_s\,(Bq/l) = \frac{N}{\varepsilon \times t \times \gamma \times M} \quad (1)$$

Where A_s is sample activity concentration, N is the net peak- area of the radionuclide, ε is the detector energy dependent efficiency, t is the counting live time in seconds, γ is the gamma-ray yield per disintegration of the nuclides and M is the mass of the samples measured in litres.

3. RESULTS AND DISCUSSION

3.1 Radioactivity Concentration Levels

The activity concentrations of natural radionuclide ^{238}U, ^{232}Th and ^{40}K of the collected water samples indicated the variability of the geological formation and the type of activities in the area studied. Table 1 shows the activity concentrations of ^{238}U, ^{232}Th and ^{40}K in borehole, river and hand dug well water samples and their radium equivalent. Table 2 gives the committed effective dose and excess lifetime cancer risk estimated from the activity concentrations of the radionuclide.

The activity concentrations of ^{232}Th in borehole water samples, river and hand dug well water are distinctively higher than that of ^{238}U and it ranges from BDL (below detectable level) to 69.02 Bql^{-1} with an arithmetic mean activity of

Table 1. Specific activity of ^{40}K, ^{238}U and ^{232}Th in all the water samples and their radium equivalent values

S/N	District	Sampling point	^{238}U Bql^{-1}	^{232}Th Bql^{-1}	^{40}K Bql^{-1}	Ra_{eq} Bql^{-1}
			Borehole water (Tap)			
1	Kugbo	Emago	12.20±3.35	69.02±6.86	BDL	110.90
2	Adibom	Emelego	11.55±3.04	51.85±4.96	BDL	85.70
3	Arughunya	Anyu	26.37±6.10	36.61±3.63	137.2±10.51	89.30
4	Abua cent	Ogbema	24.62±6.18	26.90±2.75	BDL	63.10
5	Okpeden	Egbolom	14.16±3.58	BDL	66.52±4.99	19.30
6	Otapha	Agada 2	10.57±2.81	BDL	32.22±237	13.10
7	Emughan	Aminigboko	4.58±1.20	39.21±3.98	BDL	60.70
	Mean		14.86±1.31	31.94±2.0	33.71±3.12	63.16
			River water samples			
8	Kugbo	Emago	0.65±0.18	11.67±1.18	261.93±19.5	37.50
9	Adibom	Emelego	2.07±0.55	2.92±0.74	BDL	6.20
10	Arughunya	Anyu	BDL	13.29±1.31	BDL	1.00
11	Abua centr	Ogbema	BDL	7.13±0.74	BDL	0.50
12	Okpeden	Egbolom	10.02±2.67	BDL	BDL	10.02
13	Otapha	Agada 2	BDL	16.53±1.68	22.87±1.65	25.40
	Mean		2.12±0.21	8.44±1.02	47.47±3.22	13.44
			Well water samples			
14	Kugbo	Emago	1.85±0.51	43.42±4.36	136.16±9.97	74.43
15	Arughunya	Anyu	9.37±2.46	BDL	603.8±48.21	55.90
16	Abua cent	Ogbema	6.32±1.74	23.01±2.41	BDL	39.20
17	Okpeden	Egbolom	15.15±3.99	14.58±1.49	BDL	36.00
18	Otapha	Agada 2	9.15±2.33	BDL	BDL	9.20
19	Emughan	Aminigboko	20.27±5.29	60.27±6.18	BDL	106.5
	Mean		10.35±2.1	23.55±1.23	123.32±5.21	53.54
	Standard		10.0	1.0	10.0	

BDL = Below detectable limit

28.10±1.02 Bql^{-1} for borehole water, BDL to 16.53 Bql^{-1} with an arithmetic mean of 8.59±0.21 Bql^{-1} for river water and BDL to 60.27 Bql^{-1} with an arithmetic mean activity of 23.55±0.31 Bql^{-1} in hand dug well. ^{238}U activity concentration in borehole, river and hand dug well water samples ranges from 4.58 to 26.37 Bql^{-1} with an arithmetic mean activity of 14.86±1.12 Bql^{-1} in borehole water samples, BDL to 10.02 Bql^{-1} with an arithmetic mean of 2.12±0.03 Bql^{-1} in river water samples and 1.85 to 20.27 Bql^{-1} with an arithmetic mean activity of 10.35±1.20 Bql^{-1} for hand dug well water and these are found to be lower than that of both ^{232}Th and ^{40}K. The activity of ^{40}K is observed comparatively higher than that of both ^{232}Th and ^{238}U in all the water samples in some locations and it ranges from BDL to 137.2 Bql^{-1} with an arithmetic mean activity of 33.76 Bql^{-1} in borehole water samples. BDL to 261.93 Bql^{-1} with an arithmetic mean activity of 47.47±1.02 Bql^{-1} in river water and it ranges from BDL to 603.8 Bql^{-1} with an arithmetic mean activity of 123.33±3.21 Bql^{-1}.

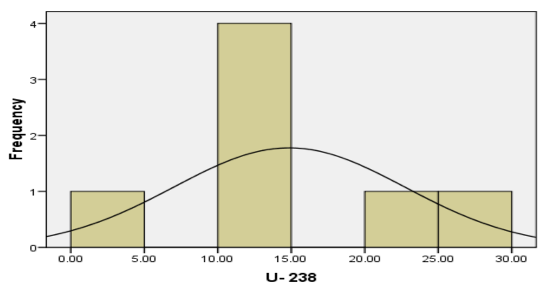

Fig. 2. Frequency distribution of ^{238}U in borehole water samples

The results obtained in this study are comparable to worldwide average concentrations of these radionuclide in water reported by UNSCEAR [14] which are 10.0, 1.0 and 10.0 Bql^{-1} for ^{238}U, ^{232}Th and ^{40}K respectively. The highest concentration of ^{232}Th was observed at Kugbo district in borehole water, Otapha district in river water and Emughan district in hand dug well. This may be due to oil and gas drilling activities in the area. Also, the geological constituent (presence of metamorphic rocks like shale and quartz of elds pathic gnesis) in the area could account for the high level of ^{232}Th. The high activity concentration of ^{40}K in all the samples which was observed to be sparsely distributed within the farm lands in Arughunya, Kugbo, Otapha, Abua central and Emughan districts could be due to the use of potassium fertilizer in farming practices while other areas recorded low values below detectable limit of the detector.

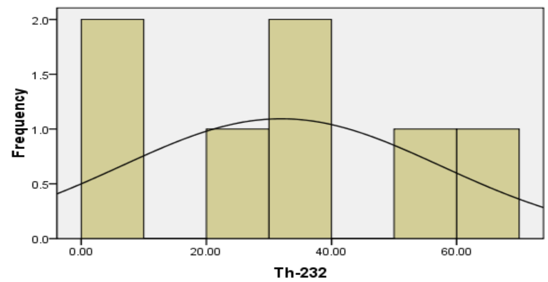

Fig. 3. Frequency distribution of ^{232}Th in borehole water samples

The activity concentration of ^{238}U, ^{232}Th and ^{40}K in borehole and hand dug well water is higher than that of the river water. This may be due to radionuclide transport system in surface water. The relatively low permeability of the sandy clay separating the topsoil from the aquifer would reduce the rate of vertical infiltration of radionuclide from the soil surface [24]. The mean activity concentrations of ^{238}U, ^{232}Th and ^{40}K in all the water resources of the area are higher than that from other locations like the river Pra in Ghana due to gold mining [25], drinking water from oil mill communities in Nigeria due to oil mining activities as well as lakes in Turkey [26]. The activity concentrations in borehole water studied was however higher than the activity concentrations of ^{238}U and ^{232}Th in drinking water from boreholes in Kumasi [27].

3.2 Radium Equivalent Activity (Ra_{eq})

To represent the activity levels of ^{238}U, ^{232}Th and ^{40}K which take into account the radiological hazards associated with them, a common radiological index has been introduced. This index is called radium equivalent activity (Ra_{eq}) and is mathematically defined by UNSCEAR, [14].

$$Ra_{eq}\,(Bql^{-1}) = A_U + 1.43A_{Th} + 0.077A_K \qquad (2)$$

Where A_K, A_U and A_{Th} are the activity concentrations of ^{40}K, ^{238}U and ^{232}Th in Bql^{-1} respectively. This is the weighted sum of activities of the studied radionuclide and is based on the fact that 370 Bq/L of ^{238}U, 259 Bq/L of ^{232}Th, and 4810 Bq/L of ^{40}K produce the same gamma radiation dose rate [24]. For safety, the value of Ra_{eq} should be less than 370 Bq/L. The estimated radium equivalent in borehole water ranges from 13.1 to 110.9 Bql^{-1} with mean value of 63.16 Bql^{-1} while the radium equivalent for river water ranges from 0.5 to 37.5 Bql^{-1} with an average value of 13.44 Bql^{-1}. In hand dug well water, it ranges from 9.3 to 106.5 Bql^{-1} with an arithmetic mean of 53.54 Bql^{-1}.

Radionuclide may reach the gastrointestinal tract directly by ingestion or indirectly by transfer from the respiratory tract [28]. From small intestine (S1), the radionuclide can be absorbed to the body fluids. The annual committed effective dose due to intake of borehole, river and hand dug well water was determined by averaging the individual annual committed effective doses contributed by ^{238}U, ^{232}Th and ^{40}K of the naturally occurring radionuclide [29]. The annual committed effective dose due to the ingestion of water was estimated using the equation [19].

$$C_{eff} = \sum A_i \times DCF_i \times 730 \text{ (for Adult)} \qquad (3a)$$

$$C_{eff} = \sum A_i \times DCF_i \times 183 \text{ (for Infant)} \qquad (3b)$$

Where C_{eff}. Dose is the annual committed effective dose, A_i is the activity concentration of individual radionuclide present in water samples and DCF_i is the dose conversion factor in Sv/Bq for ingestion of the individual radionuclide. From EPA [30] report, it was assumed that adult consume a minimum of 2L of water per day resulting in annual consumption rate of 730 litres per year while infant consumes half litre of water per a day (1/2 l/d) resulting in annual intake rate of 183 litres per year. For calculations, the dose coefficient for ingestion of radionuclide by adults member of the public in Sv/Bq is 4.5×10^{-5} for ^{238}U, 2.3×10^{-4} for ^{232}Th and 6.2×10^{-9} for ^{40}K [31] were used. While for infants, 1.2×10^{-7} for ^{238}U, 4.5×10^{-7} for ^{232}Th and 4.2×10^{-8} for ^{40}K were used [32].

The committed effective dose for infants and adult consuming borehole water ranges from 0.48 to 5.95 mSvy-1 with mean value of 3.21 mSvy-1 and 3.47 to 15.60 mSvy-1 with mean value of 10.25 mSvy-1 respectively. The total committed effective dose for infants and adults that consume river water ranges from 0.22 to 2.99 mSvy-1 with mean value of 1.13 mSvy-1 and 1.17 to 3.29 mSvy-1with mean value of 2.14 mSvy-1 respectively while the total committed effective dose for infant and adult that consume hand dug well water ranges from 0.20 to 5.33 mSvy-1 with mean value of 3.11 mSvy-1 and 3.01 to 16.78 mSvy-1 with mean value of 7.36 mSvy-1 respectively. The estimated mean committed effective doses are higher than 0.1 mSvy-1 reference level [32]. The committed effective dose values obtained compare well with values obtained in the literatures as reported [33,29].

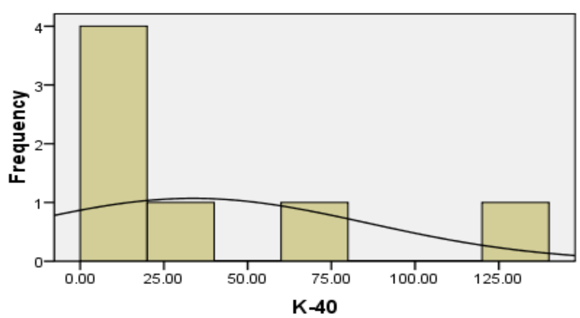

Fig. 4. Frequency distribution of ^{40}K in borehole water samples

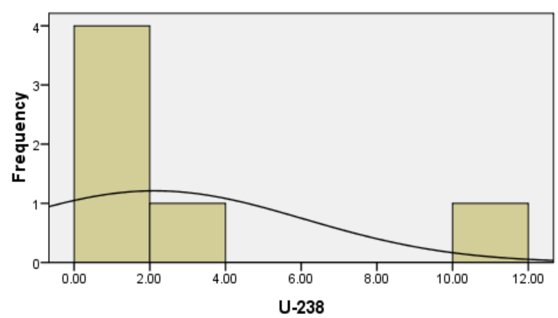

Fig. 5. Frequency distribution of ^{238}U in river water samples

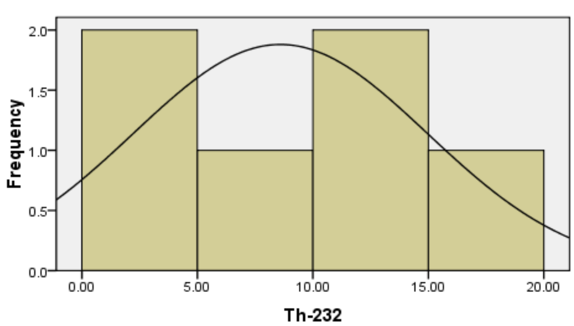

Fig. 6. Frequency distribution of ^{232}Th in river water samples

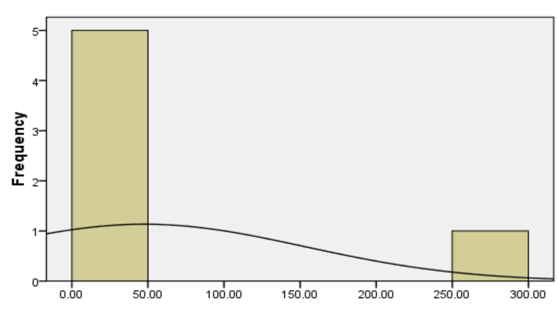

Fig. 7. Frequency distribution of ^{40}K in river water samples

Table 2. Total committed effective doses from ^{238}U, ^{232}Th and ^{40}K for various age brackets

S/N	Sampling point	Infants ($mSvy^{-1}$)			Adult ($mSvy^{-1}$)			Total E_{eff} Infant ($mSvy^{-1}$)	Total E_{eff} Adult ($mSvy^{-1}$)
		^{238}U	^{232}Th	^{40}K	^{238}U	^{232}Th	^{40}K		
			Tap water			**Tap water**			
1	Kugbo	2.68E-04	5.68E-3	0	4.01	11.59	0	5.95	15.60
2	Adibom	2.54E-04	0.43E-2	0	3.79	8.71	0	4.52	12.50
3	Arughunya	5.79E-04	0.30E-2	1.05E-03	8.66	6.15	6.2E-04	4.63	14.81
4	Abua cent	5.41E-04	0.22E-2	0	8.09	4.52	0	2.76	12.60
5	Okpeden	3.11E-04	0	5.11E-04	4.65	0	3.0E-04	0.82	4.65
6	Otapha	2.32E-04	0	2.48E-04	3.47	0	1.5E-04	0.48	3.47
7	Emughan	1.01E-04	0.32E-2	0	1.50	6.58	0	3.33	8.09
						Mean		3.21	10.25
			River water			**River water**			
8	Kugbo	1.43E-05	9.61E-4	2.01E-03	0.214	1.96	1.19E-03	2.99	2.17
9	Adibom	4.55E-05	2.40E-3	0	0.680	0.49	0	0.29	1.17
10	Arughunya	0	0.11E-2	0	0	2.23	0	1.09	2.23
11	Abua cent	0	0.058	0	0	1.20	0	0.59	1.20
12	Okpeden	2.20E-04	0	0	3.29	0	0	0.22	3.29
13	Otapha	0	0.14E-2	1.75E-04	0	2.78	1.04E-04	1.58	2.78
						Mean		1.13	2.14
			Well water			**Well water**			
14	Kugbo	4.06E-05	0.36E-2	1.05E-03	0.608	7.29	6.16	4.69	7.89
15	Arughunya	2.06E-04	0	4.64E-03	3.08	0	2.73	4.85	3.08
16	Abua cent	1.39E-04	0.19E-2	0	2.08	3.86	0	2.03	5.94
17	Okpeden	3.33E-04	0.12E-2	0	4.78	2.44	0	1.53	7.42
18	Otapha	2.01E-04	0	0	3.01	0	0	0.20	3.01
19	Emughan	3.71E-04	0.50E-2	0	6.66	10.11	0	5.33	16.78
						Mean		3.11	7.36

This result showed that borehole water samples give much higher internal exposure than the reported world average value of 0.12 mSvy-1 and WHO [6] and ICRP preference limit of 0.1 mSvy-1 and 1.0 mSvy-1 respectively [32]. The higher activities recorded in bore hole water show that the purification technology is not effective.

3.3 Statistical Analysis of Measured Data

The statistical behaviour of the measured data in borehole water, river water and hand dug well water is presented in Table 3-5. This includes mean, median, variance, skewness, kurtosis and frequency distribution for the identified radionuclide. The basic statistics (Table 3-5) show that arithmetic mean (AM) of activity concentrations of ^{238}U, ^{232}Th and ^{40}K are different from each other but are close within the standard deviation (SD). According to Gandhi et al. [31], skewness is a measure of the asymmetry of the probability distribution of a real valued random variable. Many models assume normal distribution; that is data are symmetric about the mean. Skewness of zero indicates a normal distribution but in reality data points may not be perfectly symmetric. Therefore, an understanding of the skewness of the data set indicates whether a deviation from the mean is going to be positive or negative [33]. Positive skewness indicates a distribution with an asymmetric tail extending towards values that are more positive while negative skewness indicates a distribution with an asymmetric tail extending towards values that are more negative. ^{238}U and ^{40}K have positive skewness in all the water resources (Tables 3-5) which indicate asymmetric distribution.

Table 3. Descriptive statistics of radiological parameters in borehole water

Statistics					
		U-238	**Th-232**	**K-40**	**Raeq**
N	Valid	7	7	7	7
	missing	6	6	6	6
Mean		14.8643	31.9414	33.7057	63.1571
Std. error of mean		2.96945	9.65072	1.97209E1	1.37202E1
Median		12.2000	36.6100	.0000	63.1000
Mode		4.58[a]	.00	.00	13.10[a]
Std. deviation		7.85644	2.55334E1	5.21765E1	3.63002E1
Variance		61.724	651.954	2.722E3	1.318E3
Skewness		.591	-.083	1.627	-.350
Std. error of skewness		.794	.794	.794	.794
Kurtosis		-.711	-.862	2.222	-1.127
Std. error of kurtosis		1.587	1.587	1.587	1.587
Range		21.79	69.02	137.20	97.80
Minimum		4.58	.00	.00	13.10
Maximum		26.37	69.02	137.20	110.90
Sum		104.05	223.59	235.94	442.10

a. Multiple modes exist. The smallest value is shown

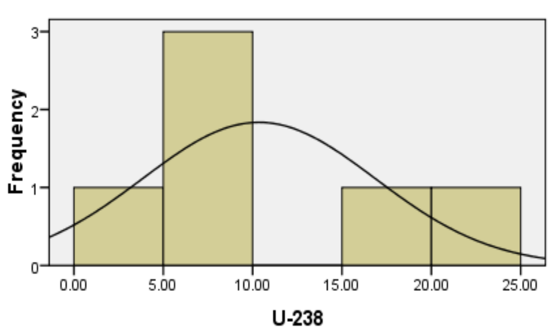

Fig. 8. Frequency distribution of ^{238}U in hand dug well water samples

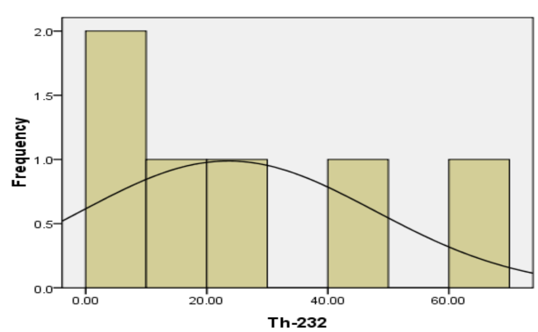

Fig. 9. Frequency distribution of ^{232}Th in hand dug well water samples

Table 4. Descriptive statistics of radiological parameters in river water

Statistics					
		U-238	**Th-232**	**K-40**	**Raeq**
N	Valid	7	7	7	7
	missing	6	6	6	6
Mean		14.8643	31.9414	33.7057	63.1571
Std. error of mean		2.96945	9.65072	1.97209E1	1.37202E1
Median		12.2000	36.6100	.0000	63.1000
Mode		4.58[a]	.00	.00	13.10[a]
Std. deviation		7.85644	2.55334E1	5.21765E1	3.63002E1
Variance		61.724	651.954	2.722E3	1.318E3
Skewness		.591	-.083	1.627	-.350
Std. error of skewness		.794	.794	.794	.794
Kurtosis		-.711	-.862	2.222	-1.127
Std. error of kurtosis		1.587	1.587	1.587	1.587
Range		21.79	69.02	137.20	97.80
Minimum		4.58	.00	.00	13.10
Maximum		26.37	69.02	137.20	110.90
Sum		104.05	223.59	235.94	442.10

a. Multiple modes exist. The smallest value is shown

Table 5. Descriptive statistics of radiological parameters in hand dug well water

Statistics					
		U-238	**Th-232**	**K-40**	**Raeq**
N	Valid	6	6	6	6
	missing	7	7	7	7
Mean		2.1233	8.5900	47.4667	13.4367
Std. error of mean		1.61304	2.59929	4.30549E1	6.07793
Median		.3250	9.4000	.0000	8.1100
Mode		.00	.00[a]	.00	.50[a]
Std. deviation		3.95111	6.36692	1.05463E2	1.48878E1
Variance		15.611	40.538	1.112E4	221.647
Skewness		2.240	-.216	2.410	1.013
Std. error of skewness		.845	.845	.845	.845
Kurtosis		5.107	-1.549	5.838	-.400
Std. error of kurtosis		1.741	1.741	1.741	1.741
Range		10.02	16.53	261.93	37.00
Minimum		.00	.00	.00	.50
Maximum		10.02	16.53	261.93	37.50
Sum		12.74	51.54	284.80	80.62

a. Multiple modes exist. The smallest value is shown

Kurtosis is a measure of the peakedness of the probability distribution of a real valued random variable [32]. Positive kurtosis shows a relatively peaked distribution while negative kurtosis indicates a relatively flat distribution. In this study, ^{238}U and ^{232}Th have negative kurtoses which indicate relatively flat distribution in Borehole and river water samples while ^{40}K has positive kurtosis which is relatively peaked distribution in all the water resources. ^{238}U showed positive kurtosis (relatively peaked distribution) in hand dug well water samples.

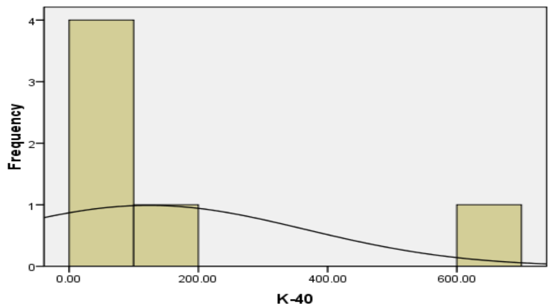

Fig. 10. Frequency distribution of ^{40}K in hand dug well water samples

Frequency distribution of ^{238}U, ^{232}Th and ^{40}K in all the water samples were analyzed, where the histograms are given in Figs. 2-10. The graph of ^{232}Th showed a normal (bell-shaped) distribution. But ^{238}U and ^{40}K exhibited some degree of multi-modality. The multi-modality feature of these elements demonstrates the complexity of radionuclide in ground water and surface water resources.

4. CONCLUSION

The activity concentration of ^{238}U, ^{232}Th and ^{40}K radionuclide in the borehole water, river water and hand dug well water in Abua/Odua local Government areas of Rivers state, Nigeria were assessed using sodium thallium activated Iodide detector (NaI (Tl)). The mean activity concentrations of ^{238}U, ^{232}Th and ^{40}K in borehole water and hand dug well water were higher than that in river water samples. This is because radionuclide concentration is higher in ground water than in surface water due to infiltration of nuclides from topsoil. The purification systems in boreholes were ineffective in removing radionuclide from the water which is evident in the activity concentration of all the radionuclide recorded. The committed effective dose estimated from the activity concentrations of these radionuclide for infant and adult showed that ^{238}U and ^{232}Th contributed more to the effective doses than ^{40}K. The values are higher than the allowed dose contribution from drinking water which is 1.0 mSvy^{-1} [32]. Moreover, all the water sources studied in Abua/odua province are not safe to be used by humans in its present state, either as drinking water or daily routine activity. The researchers therefore recommend incorporation of reverse osmosis or ion exchange technology in the boreholes systems of the study area in order to reduce the internal exposure of individuals utilizing borehole water in the area studied.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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