Original Research Article

NATURAL RADIOACTIVITY AND RADIOLOGICAL RISK ESTIMATION OF DRINKING WATER FROM OKPOSI AND UBURU SALT LAKE AREA, EBONYI STATE, NIGERIA.

ABSTRACT

Aim: The objectives of this study was to measure the activity concentration of natural radionuclides in different drinking water sources and determine the associated radiological health risk due to ingestion of such water. **Study design**: the design of this study is purely experimental. **Place and duration**: This study was carried out on water resources around Uburu and Okposi salt lakes areas of Ebony state between April and September, 2016. **Methodology:** Various sachet waters, borehole water, stream and river waters were collected and chemically treated by adding few drops of nitric acid to each of the samples and then pre-concentrated and kept in a marinelli container for four weeks. The activity concentration of ^{238}U, ^{232}Th and ^{40}K in all the water samples was measured using the High- Purity Germanium detector. **Results**: The specific activity concentration of ^{238}U and ^{232}Th ranged from BDL to 1.11± 0.62 Bql^{-1} and 0.14 ± 0.03 to 0.54 ± 0.11 Bql^{-1} respectively in sachet water. The activity concentration of ^{238}U, ^{232}Th and ^{40}K in borehole water ranges from BDL to 0.97±0.27, BDL to 2.22±1.35 and BDL to 4.22±0.30 Bql^{-1} respectively. Furthermore the activity concentration of ^{238}U and ^{232}Th in stream water ranges from 1.16±0.57 to 2.88±1.32 Bql^{-1} and BDL to 0.25±0.04 Bql^{-1} respectively, while that for river water ranges from 0.03±0.01 to 2.0±0.61 Bql^{-1} and 0.55±0.10 to 0.86±0.44Bql^{-1} respectively. The mean values of annual effective dose obtained for infants, children and adults are 0.22, 0.10 and 0.15 mSvy^{-1} respectively. The life-long cancer risk and hereditary effects due to ingestion of radionuclides by adults show that 29 out of 10,000 may suffer some form of cancer fatality and 532 out of 100,000 may suffer some hereditary effects. **Conclusion**: all the radiological health risk data obtained were within their safe values. Therefore, it is important to note that the various water samples studied does not contain high activity concentration of ^{238}U, ^{232}Th and ^{40}K and will not pose any immediate health problem

***Keywords**: Radioactivity, High-purity Germanium, Effective dose, Radiological risk, Uburu and Okposi)*

1. INTRODUCTION

Natural radionuclide present in water beyond the safe levels are considered to have potential risks to man. Higher concentrations of radioactivity in environmental media are linked with radiation related sicknesses such as kidney autrophy, mutagenicity, leukemia as well as cancer of the bladder, kidney, testis and lungs [1]. The internal exposure of humans to ionizing radiation is through inhalation and ingestion. When the radioisotope enters the body, through inhalation and ingestion, it accumulates in the tissue of body organ. The rate of clearance of such radionuclide from the tissue or organ is dependent on the biological half-life. The retention of radioisotope in the tissue or body organ can be expressed by the relationship given by Onoja and Akpa [2] as:

$$A = A_o e^{-\lambda\varepsilon\tau} \quad (1)$$

Where A is the activity remaining at time after the depositions of activity A_o and ε is the effective clearance constant. For practical purposes, the limiting values are reached after about half lives. At this steady state condition, the activity deposited will be equal to the activity eliminated. This defines the maximum concentration of any radionuclide type in drinking water. The levels of concentrations of radionuclides according to nature in ground waters are mainly due to uranium and thorium bearing soil and rock minerals or with uranium, thorium and radium deposits. Therefore studies has shown that natural radioactivity in water depends on the local geological characteristics of the source, soil or rock [3, 4, 5].

Increased concern for the radiological status of drinking water has led to an increased demand for data on water quality. In WHO [6], the recommended reference dose level (RDL) of committed effective dose is 100 µSv from one year consumption of drinking water. Gamma rays can enter the skin and interact with tissues or organs. Uranium and radium found in water and do not emit strong gamma radiation, so showering with that water will not pose any significant risk. However, if this radionuclide are inhaled or ingested through eating and drinking, the emissions can come into direct contact with sensitive tissues or organs in the body [7]. Studies have shown that long-term exposure to uranium in drinking water may cause toxic effects to the kidney and can lead to cancer [8, 7, and 9]. Higher amounts of activity concentration of nuclides in the environmental media are related to health risks to humans and high radiation damage such as kidney autrophy, leukeamia as well as cancer of the bladder, kidney and lungs [1].

Measurement of natural radioactivity levels in drinking water is relevant in assessing the radiological risk to humans due to water ingestion [10]. Studies of natural radioactivity of bottled water, mineral waters, ground and surface water have been the subject of numerous studies. For instance, the measurement of radium isotopes (^{226}Ra, ^{228}Ra), ^{222}Rn and ^{40}K concentration in bottled water and mineral water for Poland, Autria, Romania and Algeria were presented by Nguyen et al.,[11], Wallner *et al.,* [12], Elena Botezatu *et al.,*[13]. In Nigeria studies related to natural radioactivity monitoring in ground water and surface water has been carried out [14, 15] but no work has been done on sachet water, ground water and surface water from Uburu and Okposi salt lake areas of Ebonyi State.

The aim of this work therefore is to measure the radioactivity concentration in various water samples and determine the associated effective dose for different age groups due to ingestion of water. The radiation caner and non-cancer risks due to intake are also evaluated from the adult annual effective dose.

2. MATERIAL AND METHODS

2.1 STUDY AREA

The study area is Okposi Okwu and Uburu town located in Ohaozara LGA and are found in Lower Benue Trough which is the southern portion of Benue Trough; others are Upper Benue and Middle Benue Trough. The geology of Lower Benue Trough is associated with tectonic activities that were recorded during the Cenomanian [16]. Lead – zinc – barites mineralization in the Trough is believed to be hydrothermal in origin and it is associated with brine spring [17]. The two towns lie within latitude 06° 02′ N to 6° 07´ N and Longitude 7° 42´ 31″ E to 7° 51´ 37″ E. The bedrock of the area is made up of sedimentry rocks belonging to the Asu – River group of Albian age [18, 19,20, 21].The portable drinking water problem worsened during dry season when water levels and discharge from surface and ground water falls due to the intense drought. Okposi Okwu salt, though believed to be medicinal and relatively expensive than the normal salt and that of Uburu sold in the localities form the bulk of the supply in the local markets. The salt lakes gave Ebonyi State its slogan as the ″Salt of the Nation″. Figures 1aand 1b shows the map of Okposi Okwu and Uburu salt.

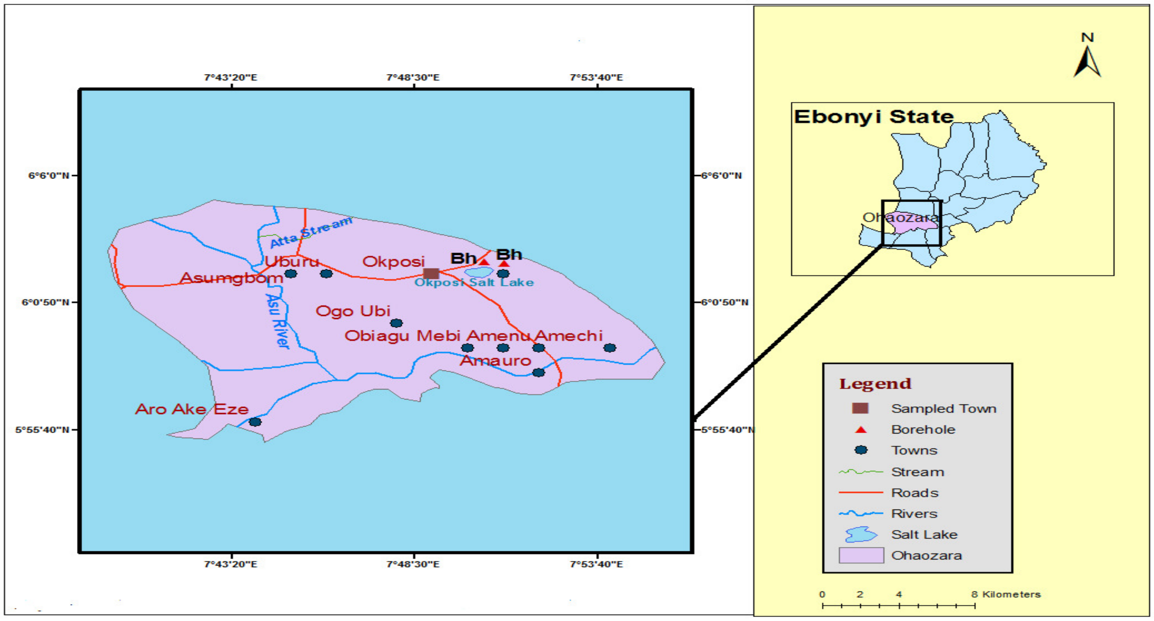

Fig. 1a: Map showing Okposi Okwu salt lake in Ohaozara LGA, Ebonyi state Nigeria

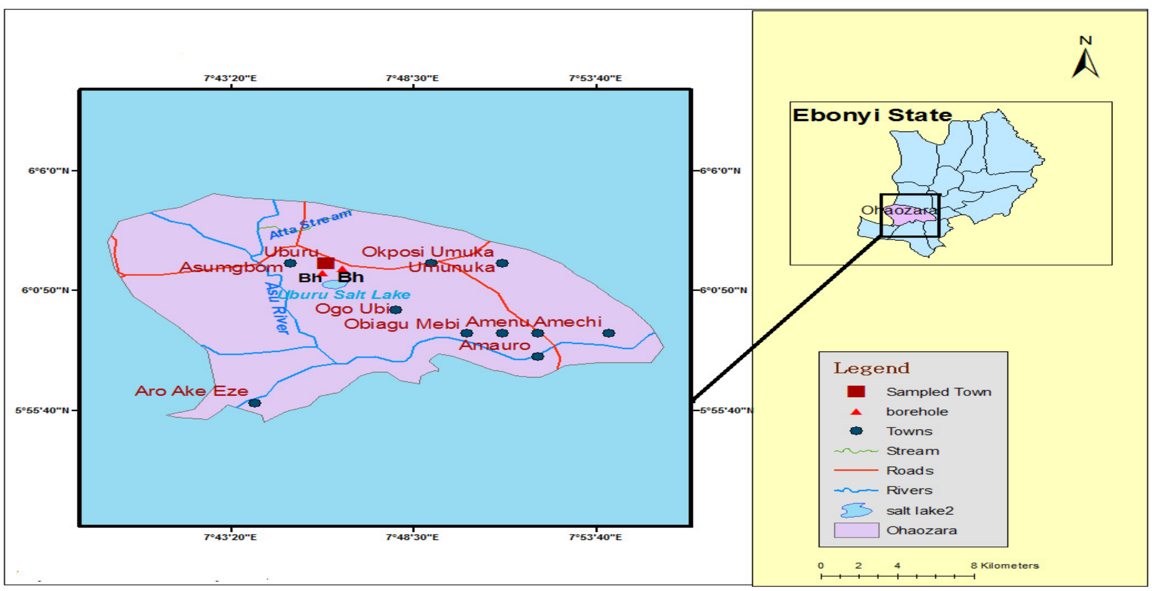

Fig. 1b: Map showing Uburu salt lake in Ohaozara LGA, Ebonyi state Nigeria

2.2 Sampling and Sample Preparation

In order to measure the natural radioactivity in various water samples collected from Uburu and Okposi lake environs, a total of twelve water samples randomly collected from borehole water in Okposi Okwu and Uburu, Atta stream and Asu river and also two brands of sachet water majorly distributed in the area were prepared and used for the study.Water samples were collected using 2 litres well labeled homogenous plastic containers. All the water samples were acidified with few drops of concentrated trioxonitrate (v) acid (HNO_3) for each 2 litres container to obtain a pH value less than 2 ($pH < 2$) in order to avoid adsorption of radionuclides on the walls of the container and also to prevent microbial activities.

The method adopted for the determination of environmental natural radioactivity level required relatively large volume of water up to 20 l in total per each water type. Concentration was carried out by gradual evaporation of each water sample in an oven at a temperature of 70 ^{o}C and 120 ml of the residue was transfer into a thoroughly washed and dried 120ml cylindrical container and hermetically sealed with a plastic tape to ensure air tight and kept for 30 days to establish secular equilibrium between ^{238}U, ^{232Th} and ^{40}K and their daughter progenies [25].

2.3 Experimental Setup

The gamma ray spectrometry analyses for the water samples were carried out at the National Institute of Radiation Protection and Research (NIRPR) in University of Ibadan, Ibadan, Nigeria. After the in-growth period, each water samples was subjected to a low background gamma-ray spectrometer of type; High Purity Germanium (HPGe) P – type detector. The well calibrated, lead shielded HPGe detector (with model number, GC8023) manufactured by CANBERRA Industries Inc, with serial number: 9744 has a length and diameter of 69.8 mm and 78 mm respectively. For the water analysis, the detector was connected through a preamplifier (model number: 2002CSL and serial number 13000742), and a PC – based Multichannel Analyzer (MCA). The gamma spectrum peak area and quantification was carried out using Genie 2K and 16K software. HPGe detector used in this work has relatively higher energy resolution with relative efficiency of 80%.
The standard source used for calibration was CANBERRA Multi Gamma ray Standard (MGS6M315). The energy and efficiency calibrations of the detector was carried out using 1.33MeV gamma line of ^{60}Co resulting to energy resolution of 2.3 KeV Full Width at Half Maximum (FWHM) which is considered adequate to distinguish the gamma ray energies of interest in the present study.

For the purpose of identifying the various radionuclides that may be present in the water samples through the gamma energies they emit, the energy calibration of the detector was performed using standard sources of known radionuclides with well – defined energies. The ^{226}Ra and ^{232}Th (^{228}Ra) activity concentrations were determined indirectly through their activities of their decay products. Therefore, the ^{238}U content of the water samples was determined from the intensity of 609KeV gamma ray peak (gamma ray lines) of ^{214}B; ^{232}Th (^{226}Ra) content from the intensity of 911KeV gamma ray peak of daughter radionuclides ^{208}Ti, while ^{40}K content of the water samples was also determined by measuring the 1460.8 KeV gamma rays emitted during the decay of ^{40}K. The detection limits of radionuclides with their respective energies (KeV) and activities (Bq/l) are shown in Table 1.

Table 1: Detection Limits, Energy and Respective activities For Water samples

Radionuclides	Energy (KeV)	Activity (Bq/L)
Uranium – 238 (^{238}U)	609	0.003
Thorium – 232 (^{232}Th)	911	0.0013
Potassium – 40 (^{40}K)	1460.8	0.0012

The background count was determined by counting the empty plastic container volume for 10 hours, thereafter water samples (120 ml) contained in the same container volume were counted in the HPGe detector for a period of 10 hours (36, 000 seconds) each to determine the radionuclides of interest. The net area count under the corresponding photo peaks of each of the radionuclide in the energy spectrum was computed by subtracting counts due to Compton scattering of higher peaks and the background sources from the total area of the peaks. From the measured net counts, the activity concentrations of the radionuclides in the water samples were calculated in BqL^{-1} using equation (2).

$$A\left(\frac{Bq}{L}\right) = \frac{C_n}{\varepsilon_\gamma . P_\gamma . t_c . V} \qquad (2)$$

where C_n is the net peak area at gamma ray energy, ε_γ is the efficiency of the detector, P_γ is the emission probability of the radionuclides of interest, t_c is the total count time(s) and V is the sample volume in litres.

3 Radiological Risk Assessment

The annual effective dose from ingestion of radionuclide in water samples was estimated on the basis of the mean activity concentration of the radionuclides. This was done for different age categories. Assumptions on the rate of ingestion of water were made. In this work, the rate of water intake rates based on UNSCEAR [26] recommendation of0.5 l/d and 1.0 l/d for infants (0-1 years) and children (10 years) respectively, and 2 l/d for adults (≥ 17 years) were used for calculations.
The annual effective dose due to ingestion of water was computed using the following formula [27, 25].

$$H_{ing}\,(mSvy^{-1}) = \sum_{i=1}^{i=3} DCF_{ing}\,(i) \times Ai \times I \qquad (3)$$

Where DCF_{ing} (i) is the dose coefficient of a particular radionuclide in Sv/Bq for a particular age categories (Table 2). $A_i$is the specific activity concentration of radionuclide in the water sample measured in Bq/l and I, the radionuclide intake in liters per year for each age categories.

In addition to the estimated annual effective dose, the cancer and hereditary risk due to low dose without any threshold doses known as stochastic effect were estimated using the ICRP cancer risk methodology [28]. Radiation risks to members of the public results from exposure to low dose radiation are normally known as chronic risk of somatic or hereditary damage of human tissues, thus much emphasis is always placed on the reduction of these radiological risks to natural radiation. The nominal lifetime risk coefficient of fatal cancer recommended in the 2007 recommendations of the members of the public is 5.5×10^{-2} Sv^{-1}. For hereditary effects, the detriment-adjusted nominal risk coefficient for the whole population as stated in ICRP [28] for stochastic effects after exposure to low dose rates was estimated at 0.2×10^{-2} Sv^{-1}. The risk to population was then estimated using the 2007 recommended risk coefficient of ICRP report and assumed 70 years lifetime of continuous exposure of the population to low level radiation. According to ICRP methodology;

Cancer Risk = Total annual Effective Dose (Sv) × Cancer risk factor (4)

Hereditary Effects = Total annual Effective Dose (Sv) × Hereditary effect factor (5)

The recommended reference levels of the effective dose for infants, children and adults corresponding to one year consumption of drinking water are 0.26, 0.20 and 0.1 $mSvy^{-1}$ respectively.

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Table 2: Effective Dose Coefficients for ingestion of Radionuclides for members of the public to 70 years of age (ICRP, 2012; Publication 119)

S/N	Radioisotopes	Infant ≤ 1 year	Children 10 years	Adult ≥17 years
1	^{238}U	1.4 E-07	6.8 E-08	4.5 E-08
2	^{232}Th	1.6 E-06	2.9 E-07	2.3 E-07
3	^{40}K	5.2 E-05	1.3E-08	6.2 E-09
Water intake		0.5 L/day	1.0 L/day	2.0 L/day

4 RESULTS AND DISCUSSION

The activity concentrations of ^{238}U, ^{232}Th and ^{40}K and annual effective dose for different age groups measured in water samples collected from different locations near Okposi Okwu and Uburu salt lake area are presented in Table 3 while Table 4 gives the estimated cancer Risks and the Hereditary Effects of Adult member of the public. Table 5 shows the comparison of the results of the present study with results of other research works.

Table 3: **Activity Concentration of ^{238}U, ^{232}Th and ^{40}K in Water Samples and Annual Effective Dose for Different Age Categories**

S/N	Sample ID	Location	Activity Concentration (Bq/l)			Annual (mSv/y)	Effective	Dose
			^{238}U	^{232}Th	^{40}K	Infant	Children	Adult
1	Ubu SA 01	N06^0 02′ 49″ E007^{0}45′ 20.1″	BDL	0.54±0.11	BDL	0.158	0.057	0.091
2	Ubu SA 02	N06^0 02′ 19.0″ E007^{0}46′ 07.9″	BDL	BDL	BDL	0.000	0.000	0.000
3	Ubu BH 01	N06^0 03′ 12.4″ E007^{0}45′ 14.4″	BDL	2.22±1.35	BDL	0.650	0.235	0.373
4	Ubu BH 02	N06^0 03′ 13.7″ E007^{0}45′ 23.9″	0.97±0.27	1.07±0.46	4.22±0.30	0.338	0.137	0.212
5	Okp SA 01	N06^0 02′ 02.2″ E007^{0}49′ 06.5″	BDL	BDL	BDL	0.000	0.000	0.000
6	Okp SA 02	N06^0 02′ 04.4″ E007^{0}49′ 15.3″	1.11±0.62	0.14±0.03	BDL	0.069	0.042	0.060
7	Okp BH 01	N06^0 02′ 07.5″ E007^{0}48′ 14.7″	0.86±0.26	0.45±0.09	BDL	0.154	0.069	0.104
8	Okp BH 02	N06^0 02′ 02.4″ E007^{0}49′ 07.5″	BDL	BDL	BDL	0.000	0.000	0.000
9	Atta ST 01	N06^0 01′ 56.4″ E007^{0}48′ 30.7″	1.16±0.57	BDL	BDL	0.030	0.029	0.038
10	Atta ST 02	N06^0 01′ 58.5″ E007^{0}48′ 28.2″	2.88±1.32	0.25±0.04	BDL	0.147	0.098	0.137
11	AsuRv 01	N06^0 03′ 59.4″ E007^{0}44′ 32.1″	0.03±0.01	0.86±0.44	BDL	0.253	0.092	0.145
12	AsuRv 02	N06^0 04′ 59.4″ E007^{0}44′ 32.1″	2.0±0.61	0.55±0.10	BDL	0.212	0.108	0.158
					mean	**0.22**	**0.10**	**0.15**
	WHO, 2004; IAEA,2000		**10.0**	**0.1**	**10.0**	**0.26**	**0.20**	**0.10**

Ubu SA: Uburu sachet water samples, **Ubu BH:** Uburu borehole water samples, **Okp SA:** OkposiOkwu sachet water samples, **Okp BH:** Okposi Okwu borehole water samples, **Atta ST:** Atta stream water samples, AsuRv: Asu River water samples, .**BDL** = Below Detection Limit (Table 1)

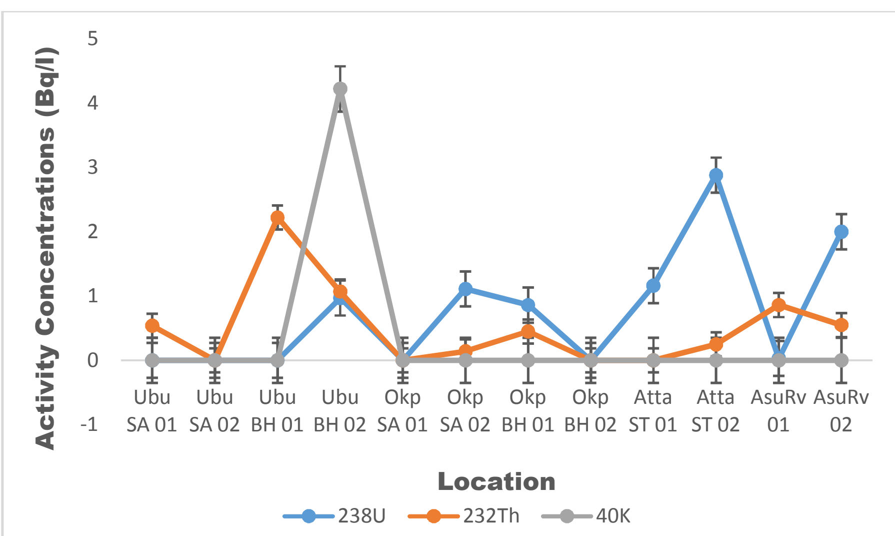


Fig. 2: Activity Concentration ^{238}U, ^{232}Th and ^{40}K in various water sources

Table 4: Estimated Cancer Risks and Hereditary Effects of Adult Member of the Public

S/N	Sample ID	Location	Total Annual Effective Dose (mSv/y)			Fatality cancer risk to Adult per year	Lifetime fatality cancer risk	Severe hereditary Effects in Adult per year	Estimated lifetime hereditary Effects
			Infant	Children	Adult	$\times 10^{-6}$	$\times 10^{-4}$	$\times 10^{-7}$	$\times 10^{-5}$
1	Ubu SA 01	N06^0 02′ 49″ E007^{0}45′ 20.1″	0.158	0.057	0.091	5.005	3.50	1.82	1.27
2	Ubu BH 01	N06^0 03′ 12.4″ E007^{0}45′ 14.4″	0.650	0.235	0.373	20.52	14.36	7.46	5.22
3	Ubu BH 02	N06^0 03′ 13.7″ E007^{0}45′ 23.9″	4.405	0.157	0.760	41.80	29.26	15.20	1.06
4	Okp SA 02	N06^0 02′ 04.4″ E007^{0}49′ 15.3″	0.069	0.042	0.060	11.66	8.16	4.24	2.97
5	Okp BH 01	N06^0 02′ 07.5″ E007^{0}48′ 14.7″	0.154	0.069	0.104	5.72	4.004	2.08	1.46
6	Atta ST 01	N06^0 01′ 56.4″ E007^{0}48′ 30.7″	0.030	0.029	0.038	2.09	1.46	760.0	532.0
7	Atta ST 02	N06^0 01′ 58.5″ E007^{0}48′ 28.2″	0.147	0.098	0.137	7.54	5.27	2.74	1.92
8	AsuRv 01	N06^0 03′ 59.4″ E007^{0}44′ 32.1″	0.253	0.092	0.145	7.98	5.59	2.90	2.03
9	AsuRv 02	N06^0 04′ 59.4″ E007^{0}44′ 32.1″	0.212	0.108	0.158	8.69	6.08	3.16	2.21

From Table 3, the specific activity concentration of ^{238}U and ^{232}Th ranged from BDL to 1.11± 0.62 Bql^{-1} and 0.14 ± 0.03 to 0.54 ± 0.11 Bql^{-1} respectively in sachet water. The average activity concentration of^{238}U and ^{232}Th in sachet water produced in Okposi Okwu and Uburu are found to be higher than 0.02 Bql^{-1} and 0.03 Bql^{-1} in mineral bottled water produced in Cameroon [25] except for ^{40}K.The activity concentration of ^{238}U, ^{232}Th and ^{40}K in borehole water ranges from BDL to 0.97±0.27, BDL to 2.22±1.35 and BDL to 4.22±0.30 Bql^{-1} respectively. Furthermore the activity concentration of ^{238}U and ^{232}Th in stream water ranges from 1.16±0.57 to 2.88±1.32 Bql^{-1} and BDL to 0.25±0.04 Bql^{-1} respectively, while that for river water ranges from 0.03±0.01 to 2.0±0.61 Bql^{-1} and 0.55±0.10 to 0.86±0.44Bql^{-1} respectively. The variations in activity concentrations of these radionuclides are due to the variations in the chemical composition of local geological formations and the aquifer geochemistry from where the drinking water originate.

^{40}K was identified in borehole water only (Ubu BH02) but was below detection limit in all other water resource as shown in Figure 2. This could be due to agricultural farm near the borehole since other borehole water samples from this same geological area recorded value below the detectable limit of the detector. This implies low concentration of natural potassium in the water aquifer of the area. The highest values of ^{238}U (2.88 ±1.32) was recorded in stream water (Atta ST02) which could be due to run off from the salt lakes and other activities in the area. The activity concentrations of ^{238}U, ^{232}Th and ^{40}K obtained in all the different water resources except boreholes of the area were within the reference value recommended by WHO [6] but compared well with the results of other researcher as shown in Table 5.The average results of both Okposi Okwu and Uburu borehole water samples were lower than the Tap water results measured by Ononugbo *et al.,*[29] at Ogba/Egbema/Ndoni LGA of Rivers State in oil producing communities, Niger Delta Region of Nigeria due to different geological composition the areas and the oil producing activities in Onelga. However, the obtained results were higher than the results of Osman *et al.,* [30] work conducted in ground waters of Kuhliate and Miri Bara in Kadugli, Saudi. The variation in the results is traceable to their local geology and geochemistry of the aquifer as well as the environmental management practices. The levels of gamma radiation in ground water sources could directly be associated with the mineralogical compositions and activity concentrations of radionuclide in aquifer bedrock and the age of the ground water in the aquifer.

Activity concentration of ^{238}U and ^{232}Th concentration in Uburu and Okposi Okwu borehole water samples are about 16.5 and 2.3 times higher than the WHO,[6] recommended safety standards of 1.0 Bql^{-1} and 0.1 $Bql^{-1}$for drinking water respectively. This implies that borehole water sources are unsafe for drinking and should be treated for radionuclide before use in the locality. The result of this study also show that the activity concentration of $^{238}U$is higher in Atta stream than Asu river while activity concentration of ^{232}Th in Asu river is higher than that of Atta Stream and also high than higher than the result obtained by Jibiri *et al.,* [31] from Obafemi – Owode area in Abeokuta, Nigeria.

The annual effective dose due to ingestion of the various water sampled was estimated for three different age groups: Infants, children and adults; considering only the ingestion of ^{238}U and ^{232}Th since ^{40}K was below detection limit in all the water samples except one borehole water (Ubu BH02) and therefore were not considered during the calculation of the radiation dose because the absorption of the potassium element is under homeostatic control [25] and takes place mainly from ingested food. The contribution of ^{40}K to dose from ingestion of water will be insignificant considering its relatively low dose conversion factor. The calculated annual effective dose for different age groups as shown in Table 4 ranged from 0.03 to 0.65 $mSvy^{-1}$ for infants, 0.029 to 0.24 $mSvy^{-1}$ for children and from 0.038 to 0.212 $mSvy^{-1}$ for adult with average values of 0.223, 0.096 and 0.146 $mSvy^{-1}$ respectively. It can be observed that the radiation dose received by infants is relatively higher than that received by children and adults. The WHO [6] and UNSCEAR [26] reference levels of the effective dose for infants, children and adult due to one year continuous ingestion of various drinking water are 0.26,0.20 and 0.10 $mSvy^{-1}$ respectively.

The effective doses obtained were higher than the reference values for infants, children and adults that consume borehole water. Also for adults that ingest Asu River, the effective dose is slightly higher than the reference value. The effective doses obtained in all other water samples are lower than the safe values and from the radiation protection point of view, life-long ingestion of these sampled drinking waters may not cause significant radiological health risk except for borehole water which may cause some detrimental health problems.

In order to determine the radiation risk due to ingestion of ^{238}U, ^{232}Th and ^{40}K in drinking water, ICRP [32] methodology was adopted in the study and the results are shown in Table 4. The results of the cancer and non-cancer risk components were evaluated from the estimated total annual effective dose of the various age groups. The result of the estimated fatal cancer risk to adult per year in each of the drinking water sampled ranged from 2.09×10^{-6} (Atta ST01) to 41.80×10^{-6} (Ubu BH02) with the associated lifetime fatality cancer risk of 1.46×10^{-4} to $29.26 \times 10^{-4.}$ The estimated hereditary effect to adult per year varied from 1.82×10^{-7} to 760×10^{-7} with its associated lifetime hereditary effect in adult of 1.27×10^{-5} (Ubu SA01) to 532.0×10^{-5} (Atta ST01). This means that in terms of the lifetime fatality cancer risk to adult approximately 29 out of 10,000 may suffer some form of cancer fatality and for the lifetime hereditary effect approximately 532 out of 100,000 may suffer some hereditary effects. The negligible cancer fatality risk value recommended by USEPA is in the range of 1.0×10^{-6} to 1.0×10^{-4} (ie 1 person out of 1 million to 10,000 persons suffering from some form of cancer fatality is considered trivial).

Comparing the estimated results of the lifetime fatality cancer risk in the present study with the acceptable risk factor, it can be seen that all estimated results of the lifetime fatality risk in adult member of the Nigerian population due to ingestion of radionuclide in the studied drinking water are within the range of acceptable risk value recommended by USEPA except those associated with borehole water and stream.

5. STATISTICS

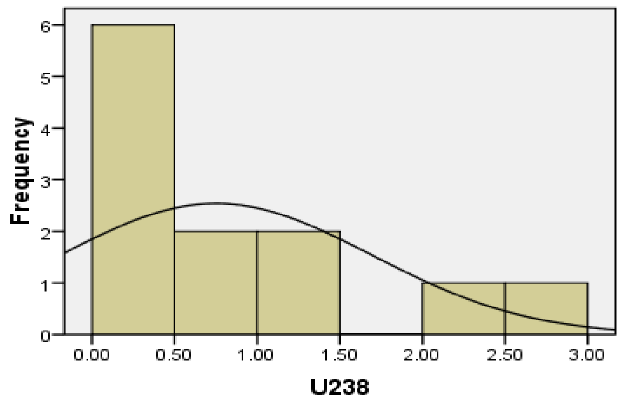
Statistical analysis of the measured activity concentration of ^{238}U, ^{232}Th and ^{40}K in water samples are Presented in Table 5 while the histograms are presented in figure 3. When the standard deviation is higher than the mean value, it shows low degree of uniformity and vice versa. In this present study, standard deviation values of activity concentrations of ^{238}U, ^{232}Th and ^{40}K are higher than the mean values indicating low degree of uniformity. Skewness refers to asymmetric nature of the shape of frequency distribution. Skewed distribution could either be positively or negatively skewed [34]. From Table 5, the skewness of the activity concentration of ^{238}U, ^{232}Th and ^{40}K are positive which shows that their distributions are asymmetric.

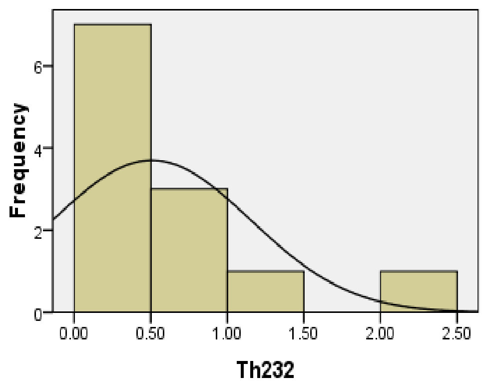
Table 5: DESCRIPTIVE STATISTICS

Variables	^{238}U	^{232}Th	^{40}K
Mean	.7508	.5067	.3517
Std. Deviation	.94333	.64745	1.21821
Variance	.890	.419	1.484
Skewness	1.200	1.875	3.464
Kurtosis	.920	4.055	12.000
Range	2.88	2.22	4.22
Minimum	.00	.00	.00
Maximum	2.88	2.22	4.22
Sum	9.01	6.08	4.22

Kurtosis is a measure of peakedness of the distribution curve. Kurtosis are classified into mesokurtic, leptokurtic and platy kurtic depending on the peakedness of the curve. If the value of kurtosis is zero, it is known as normal curve or mesokurtic. When the kurtosis value is positive, the curve is more peaked than normal and is called lepkurtic. The negative value of kurtosis indicates less peaked than normal curve and is called platy kurtic [34]. In this study, all the radionuclides have positive kurtosis that is their distribution curve are more peaked than the normal curve.

In order to determine the mutual relationships and strength of association between pairs of variables, correlation between them were drawn using SPSS 16.0 software as shown in Table 6. Low positive correlation was observed between ^{238}U and ^{40}K and ^{232}Th and ^{40}K. This is due to the fact that ^{238}U and ^{232}Th comes natural decay series whereas ^{40}K, though a naturally occurring radionuclide is not part of any such decay series. This indicates that ^{40}K concentrations may not be related with the presence of ^{232}Th and ^{238}U bearing minerals. Weak negative correlation coefficient was observed between ^{238}U and ^{232}Th showing their sources in the environment differs.





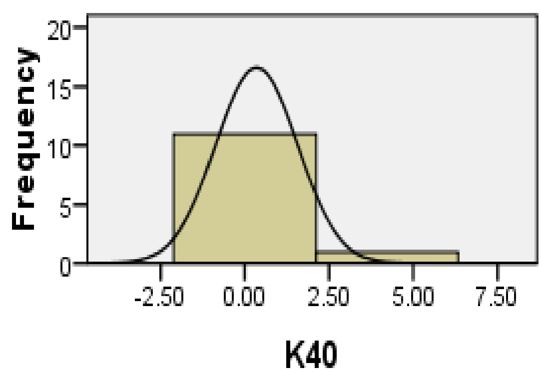


Fig.3: Frequency distributions of ^{238}U, ^{232}Th and ^{40}K in various water resources

Table 6: Pearson's Correlation Coefficient Analysis

	^{238}U	^{232}Th	^{40}K	Infant	Children	Adult
^{238}U	1					
^{232}Th	-0.16953	1				
^{40}K	0.073166	0.274005	1			
AEDEinfant	-0.04292	0.991892	0.286999	1		
AEDEchildren	0.172224	0.941597	0.297432	0.976756	1	
AEDEadult	0.117	0.958919	0.298016	0.987191	0.998433	1

6. CONCLUSION

The natural radioactivity level of ^{238}U, ^{232}Th and ^{40}K have been estimated in various water resources of Uburu and Okposi salt lake area of Ebonyi state using high purity Germanium based gamma spectroscopy. The activity concentration of ^{238}U, ^{232}Th and ^{40}K exhibited a low profile except in borehole and stream water that recorded high values. ^{40}K was not detectable in all the water samples except one sample of borehole water. This means that the geological composition of radionuclides haslow potassium content unlike most geological composition of the Niger Delta that is rich in potassium.

The annual effective dose due to ingestion of those water resources for different age groups showed a higher value for infants than children and adults. The average value of the effective doses for infant, children and adult are within the stipulated safe values of 0.26, 0.20 and 0.10 mSvy^{-1} respectively by UNSCEAR, [26] but were higher than some results obtained by other researchers in the other parts of the world. The estimated lifetime fatality risk in adult member of the public in the area due to ingestion of radionuclide in the sampled water are within the range of acceptable risk values recommended by USEPA,[33] except for the borehole water.

We therefore, conclude that the water samples studied does not contain high activity concentration of ^{238}U, ^{232}Th and ^{40}K and will not pose any immediate health problem. Though borehole water need radioactive treatment technology (ie reverse osmosis or ion exchange incorporated into the borehole) to reduce the level of ^{238}U and ^{232}Th which may cause potential radiological risk related to life-long consumption if nothing is done. This study provided a data base on environmental radioactivity burden of the water resources of the study area.

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