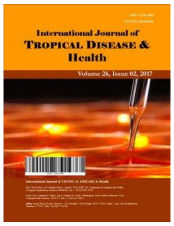

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Radiological Risks Associated with Gross Alpha and Beta Activity Concentrations of Water Resources within Salt Water Lakes, Ebonyi State, Nigeria

B. U. Nwaka[1*], G. O. Avwiri[2] and C. P. Ononugbo[2]

[1]*Department of Physics, Alvan Ikoku Federal College of Education, P.M.B. 1033, Owerri, Imo State, Nigeria.*
[2]*Radiation Research Group, Department of Physics, University of Port Harcourt, Rivers State, Nigeria.*

Authors' contributions

This work was carried out in collaboration between all authors. Author BUN designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors BUN, GOA and CPO managed the analyses of the study. Author BUN managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Background: The increasing fear on the radiological status of water sourced from proximity to salt water lakes in Ohaozara LGA, Ebonyi State, Nigeria has necessitated the need to evaluate the potential radiological risk contributions to the populace consuming the various drinking water sources.

Objectives: The study measured the radiological risk associated with gross alpha and beta activity concentrations in borehole water, Asu river, Atta stream and sachet water samples to evaluate if they are safe for drinking by the populace.

Methods: The study employed experimental research design to address the statement of the problem and achieve the aim and objectives of the study. Samples of water were collected from various sources in proximity to the salt lakes, prepared and counted for gross alpha and beta activity concentrations using a low background MPC 2000DP proportional counter. Appropriate mathematical modelling/equations were used to obtain reliable data sets.

**Corresponding author: Email: ben_de_req@yahoo.com, nwakabenjaminu@gmail.com;*

Results: Gross alpha activity concentrations of water samples (except Atta stream) were lower than World Health Organization, (WHO) reference limit of 0.5 $Bq\,L^{-1}$, whereas for gross beta activity concentrations, water samples (except Uburu sachet water) exceeded the WHO reference limit of 1.0 $Bq\,L^{-1}$. Weak but positive linear correlation ($\rho = 0.44$) was found between gross beta and gross alpha activity concentrations. Cancer risks and hereditary effects were calculated.
Conclusion: The obtained values of the mean annual effective dose due to ingestion of water showed that gross beta activity concentrations in various water samples were more responsible for ingestion radiation dose contributions since water samples (except Ugwulangwu borehole water and Uburu sachet water) exceeded the ICRP reference limit of 0.1 $mSv\,y^{-1}$. Preliminary study has been provided which advised that water samples should be consumed with caution.

Keywords: Gross alpha; gross beta; activity concentrations; annual effective dose; water.

1. INTRODUCTION

Gross alpha activity concentration in water describes the total activity of alpha emitters including ^{226}Ra once the radon ^{222}Rn gases have been eliminated, while gross beta activity concentration is the total activity of the entire beta emitters including ^{3}H, ^{14}C [1]. Among ^{238}U and ^{210}Po alpha emitters and ^{40}K and ^{210}Po beta emitters, ^{226}Ra with the half-life of 1600 years and ^{228}Ra with the half-life of 5.8 years are the predominant alpha and beta emitting radioactive element in water resources [2,3]. As alpha and beta particles interact with living cells primarily by ionization or excitation processes, they lose their energies to the cells on impact which may lead to the formation of chemical species and could alter the chromosomes since the particles carry energies. Exposure to ionizing radiation/particles at low doses for a long time may result in delayed deterministic effects, stochastic effects and genetic effects [4]. Some of the ionizing radiation sicknesses include skin burn, infertility, leukaemia, cataracts, and new cases of cancer.

Concern for gross alpha and beta status of water resources in different countries of the world has led to increased investigations to have and compare data and also create awareness for members of the public and radiation protection and measurements agencies/organization. [5], in Saudi Arabia, established that gross alpha activity concentrations of samples of drinking water were below the WHO reference limit 0.5 $Bq\,L^{-1}$ whereas gross beta values of two water samples exceeded the WHO reference limit of 1.0 $Bq\,L^{-1}$. Few other studies were carried out in Guilan, Iran [6]; South Serbia [7]; South – eastern Arabian [8] and Central Anatolia Region of Turkey [9]. Some of the studies carried out in Nigeria were in rocky areas of Dutse town, North – west Nigeria [10]; mining area of Plateau State [11]; steel processing companies in Delta State [12] and oil-producing area of Niger Delta Region [13].

Drinking water sourced from surface and ground water within the salt water lakes may be rich in radioactivity concentrations that could present radiological risk to human health. Relatively high level of gross beta activity in locally processed salt brands at Okposi Okwu and Uburu town had been established [14]. Interestingly, [15] reported that fracture in the bedrock formation influences saline water intrusion into fresh water aquifer of the study areas. Heavy metal concentrations including lead, copper and cadmium were reported in Okposi Okwu and Uburu salt water lakes [16]. However, studies on radiological contamination due to alpha and beta activity concentrations of the major drinking water resources in the study locations is either relatively scarce or not available, hence, the need for this study; to evaluate the potential gross alpha and beta activity concentrations, annual effective doses, lifetime fatality cancer risks and lifetime hereditary effects of water resources within the salt water lakes which could serve as preliminary and baseline report, subject to further investigations.

2. MATERIALS AND METHODS

2.1 Study Locations

The study locations are Okposi Okwu and Uburu salt lake water towns, Ohaozara LGA, Ebonyi State, Nigeria where salt water intrusion into the ground water aquifer has been reported [15,17, 18]. [15,19] had earlier reported on the geology and geophysical study of the study locations. Figs. 1 and 2 show coordinates of the study locations.

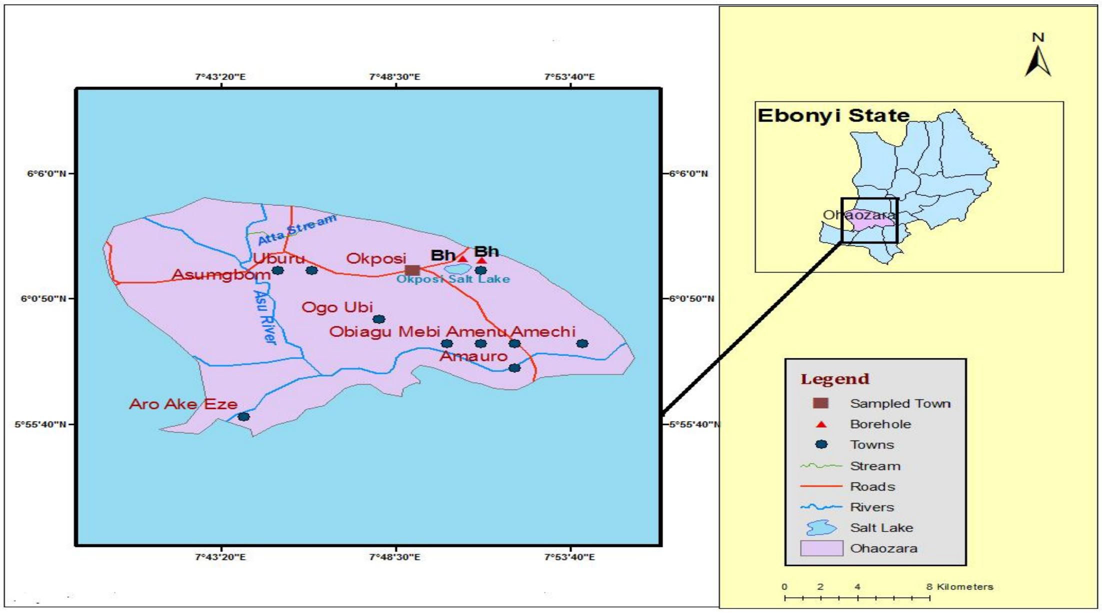

Fig. 1. Coordinates of Okposi Okwu Salt Lake in Ohaozara LGA, Ebonyi State Nigeria

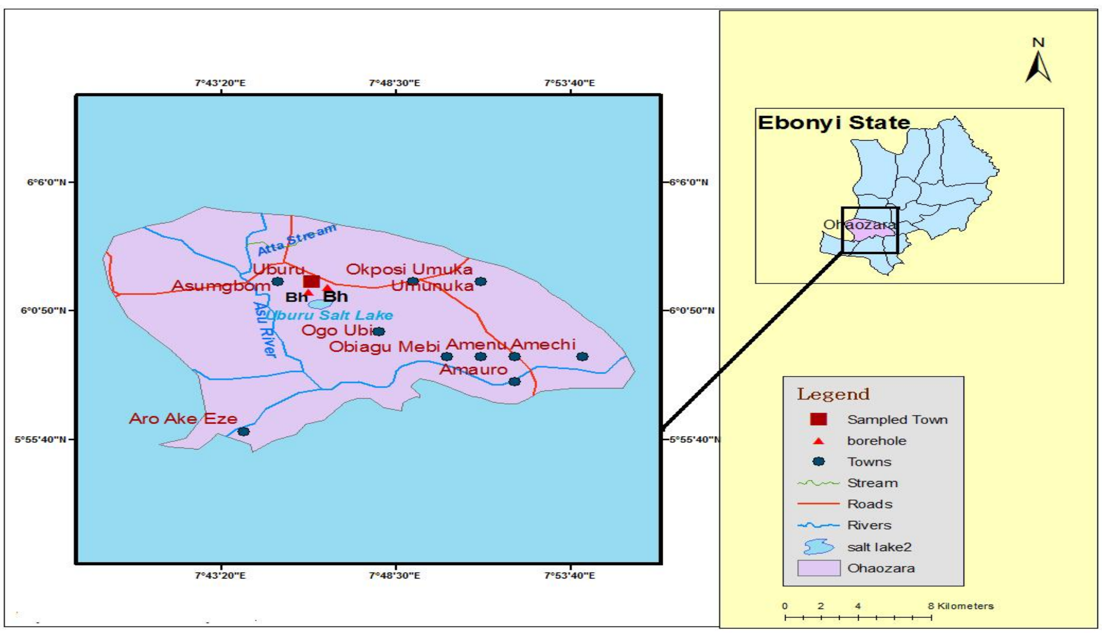

Fig. 2. Coordinates of Uburu Salt Lake in Ohaozara LGA, Ebonyi State Nigeria

2.2 Sample Collection and Preparation

A total of twenty – one (21) water samples were collected for the gross alpha and beta analyses These comprise of three (3) water samples each from borehole water from Okposi Okwu, borehole water from Uburu, borehole water from Ugwulangwu, Asu river, Atta stream and sachet water.

Five hundred milliliters (500 ml) of each water sample was acidified with 1 ml of concentrated trioxonitrate (V) acid (HNO_3), transferred into 600 ml beaker, heated to sub – boiling on electric hot plates to near dryness and thereafter the water samples of about 50 ml in the 600 ml beaker were transferred to an evaporating dish and few drops of vinyl acetate were added to the samples to act as a binder to prevent the residue formed from scattering during counting. Using a spatula, 0.077 g of the dried residue was transferred to a stainless sterilized planchet and both weighed. The planchet containing the residue was placed in a sample carrier which was thereafter placed in a sample drawer of the counting instrument and then slide into of the counter detector for gross alpha and gross beta counting.

2.3 The Proportional Counter for Gross Alpha and Beta Activity Concentrations

A low background counting system of MPC 2000DP proportional counter available in Center for Energy Research and Training (CERT), Ahmadu Bello University Zaria, Nigeria was used for gross alpha and beta counting. The equipment is a single sample counting system with manual loading for counting which incorporates an anticoincident guard counter that eliminates interference from high energy cosmic rays into the measuring environment. The chamber has a 4 lead shied and guard detector and the inside dimensions are 0.48 × 0.28 × 0.105 m^3 with stainless steel linings to prevent part of ambient gamma rays from entering the measuring environment. The set up for the counter includes ZnS scintillation dual phosphorus detector; high voltage supply for the detector; signal processing modules; preamplifier and amplifier; counter; displayer module; operation and display control board equipped with LCD display. The system was connected to a microprocessor (PC) to process downloaded data.

2.4 Determination of Gross Alpha and Beta Activity Concentrations

The high voltage was set at 1650 V to 1700 V and samples were counted for 25 cycle of 180 seconds per cycle and the results display as raw count rate (in count per minutes). Data were acquired for alpha and beta mode and alpha and beta count rate. These rates were obtained using equations 1 and 2 and thereafter the activity concentrations were calculated using the equations 3 and 4.

$$\text{Alpha/beta } (\alpha) \text{ count rate} = \frac{Raw\ alpha\ (\alpha) count}{Count\ time} \quad (1)$$

$$\text{Beta } (\beta) \text{ count rate} = \frac{Raw\ beta\ (\beta)\ count}{Count\ time} \quad (2)$$

Alpha activity

$$Bq\ L^{-1} = \frac{Sample\ count\ Rate\ (cpm) - \ background\ count\ rate\ (cpm)}{Sample\ efficiency \times detector\ efficincy \times sample\ Volume \times 60} \quad (3)$$

Beta activity

$$Bq\ L^{-1} = \frac{Sample\ count\ Rate\ (cpm) - \ background\ count\ rate\ (cpm)}{Sample\ efficiency \times detector\ efficincy \times sample\ Volume \times 60} \quad (4)$$

2.5 Determination of Annual Effective Dose (AED) in Drinking Water

In order to evaluate the potential health hazards associated with ingestion of drinking water to the populace the annual effective dose for adult age group due to gross alpha and beta activity concentrations in the water samples were determined using equation 5.

$$E_{mean\ (\alpha/\beta)} = A_{C\ (\alpha/\beta)} \times EDCF_{\alpha/\beta} \times AWCR \quad (5)$$

Where $E_{mean\ (\alpha/\beta)}$ is the mean annual effective dose for gross alpha and beta activity concentrations in water samples, $A_{C\ (\alpha/\beta)}$ is the gross alpha or beta activity concentrations in water samples, $EDCF_{\alpha/\beta}$ is the effective dose conversion factor ($mSv\ Bq^{-1}$) for alpha or beta ingestion for adult age group ($> 17\ years$) obtained from [20,21]. An estimate of 730 liters per year (730 $L\,y^{-1}$) was considered as the annual water consumption rate ($AWCR$) for adult age group. The [22,23] and [24] publications for dose conversion factors of $2.80 \times 10^{-4}\ mSv\ Bq^{-1}$ for ^{226}Ra (an alpha emitter) and $6.90 \times 10{-}4\ mSv\ Bq{-}1$ for ^{210}Po and ^{228}Ra (beta emitter) were used in the estimation.

2.6 Life Time Fatality Cancer Risk and Life Time Hereditary Effects to an Adult Member of the Public

Life time fatality cancer risk ($LFCR$) was determined using equation 6 [25].

$$LTFCR = TAED \times CRF \times 70 \quad (6)$$

Where $TAED$ represents the total annual effective dose ($mSv\ y^{-1}$), CRF represents the cancer risk factor (5.5×10^{-2}) recommended by ICRP for an adult member of the public.

Lifetime hereditary effect was determined using equation 7 [25].

$$LTHE = TAED \times HEF \times 70 \text{ years} \quad (7)$$

Where $TAED$ represents the total mean annual effective dose in $mSv\ y^{-1}$ and HEF represents the hereditary effect factor or coefficient, 0.2 × 10^{-2} [24].

3. RESULTS

Tables 1 and 2 show the results of radiological indices due to gross alpha and gross beta activity concentrations of water resources from the studied locations. Fig. 3 shows the regression plot between gross beta against gross alpha activity concentrations for the 21 water samples.

4. DISCUSSION

4.1 Mean Gross Alpha Activity Concentrations and Associated Radiological Indices in Water Resources from the Sampled Locations

As observed from Table 1, water samples from Atta stream (Atta ST) recorded the highest mean alpha activity concentration 0.924±0.146 $Bq\ L^{-1}$ while the lowest concentration 0.011±0.004 $Bq\ L^{-1}$ was recorded for Uburu sachet water samples (UBU SA). The order of Uburu borehole > Ugwulangwu borehole > Okposi Okwu borehole water samples were established for borehole water resources investigated in the study locations. Mean gross alpha activity concentrations for the 21 water samples were calculated as 0.1924±0.326 $Bq\ L^{-1}$ with coefficient of variation (CV) of 1.697. Water samples (except for Atta stream) were found lower than [23] reference limit of 0.5 $Bq\ L^{-1}$ which was in agreement with the results obtained in drinking water of Saudi Arabia [5]. Similar report was found in Gulian in Iran [6], where the mean gross alpha activity concentrations did not exceed the WHO reference limit. Furthermore, results of borehole samples, Atta stream and Asu river determined values were relatively higher than those obtained for drinkable water recorded around steel processing facilities located in Udu Local Government Area of Delta State [12]. In addition, the mean gross alpha activity concentrations of borehole water samples of Uburu somewhat agreed with 0.192 $Bq\ L^{-1}$ reported by [9] at Turkey. Moreover, though, the result obtained in this work for Asu river samples agreed positively with 0.085 $Bq\ L^{-1}$ established in borehole water of Duste town in North Western Nigeria [10]; however, the values for borehole water samples (except that of Uburu) differ.

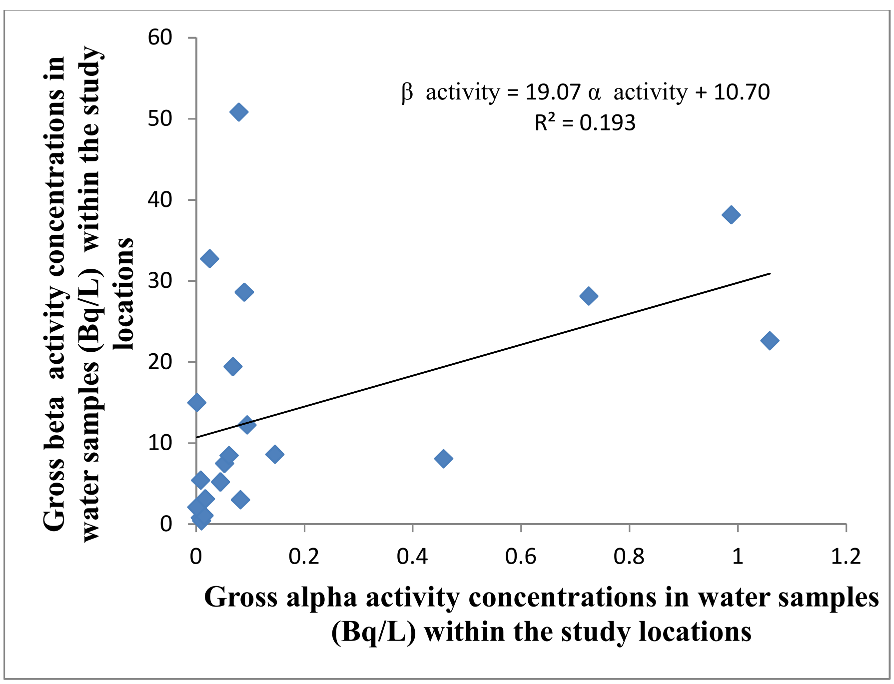

Fig. 3. Regression plot of gross beta activity concentrations against gross alpha activity concentrations in water samples (Coefficient of correlation, ρ = 0.44)

Table 1. Radiological indices associated with gross alpha activity concentrations of Water samples within Uburu and Okposi Okwu salt lakes

Sample codes	Number of samples	Minimum value	Maximum value	Mean±STDV gross alpha activity concentrations ($Bq\ L^{-1}$)	AED_{α} Adult ($mSv\ y^{-1}$)	$LTFCR_{\alpha}$ (10^{-3})	$LTHE_{\alpha}$ (10^{-5})
OKP BH	3	0.00151	0.05260	0.026±0.026	0.001	0.004	0.014
UBUBH	3	0.00858	0.45690	0.182±0.241	0.009	0.035	0.126
ASU RV	3	0.6810	0.9420	0.084±0.014	0.004	0.015	0.056
Atta ST	3	0.72500	1.05900	0.924±0.176	0.045	0.173	0.630
OKP SA	3	0.04510	0.14571	0.084±0.054	0.004	0.035	0.126
UBU SA	3	0.00802	0.01502	0.011±0.004	0.001	0.004	0.014
UGWU BH	3	0.00124	0.0821	0.034±0.043	0.002	0.008	0.028
[23]				0.5			
[24]					0.1		

STDV: Standard deviation, $Bq\ L^{-1}$: Becquerel per Liter, UBU SA: Uburu Sachet Water, OKP SA: Okposi Okwu Sachet Water, UBU BH: Uburu Borehole Water, OKP BH: Okposi Okwu Borehole Water, UGWU BH: Ugwulangwu Borehole Water, Atta ST: Atta Stream water, ASU RV: Asu river water

Table 2. Radiological indices associated with gross beta activity concentrations of Water samples within Uburu and Okposi Okwu salt lakes

Sample codes	Number of samples	Minimum value	Maximum value	Mean±STDV gross beta activity concentrations ($Bq\ L^{-1}$)	Mean sum of gross alpha and beta activity concentrations ($Bq\ L^{-1}$)	AED_{β} Adult ($mSv\ y^{-1}$)	$LTFCR_{\beta}$ (10^{-3})	$LTHE_{\beta}$ (10^{-5})
OKP BH	3	7.494	32.750	18.418±12.968	18.444±0.026	0.361	1.390	5.054
UBU BH	3	5.419	50.830	21.446±25.482	21.628±25.406	0.420	1.617	5.880
ASU RV	3	12.240	19.440	20.100±8.133	20.184±8.208	0.394	1.517	5.516
Atta ST	3	22.630	38.150	29.640±7.868	30.564±7.863	0.581	2.237	8.134
OKP SA	3	5.215	8.623	7.441±1.929	7.522±1.965	0.146	0.562	2.044
UBU SA	3	0.429	1.065	0.763±0.319	0.774±0.322	0.015	0.058	0.210
UGWU BH	3	2.095	3.126	2.745±0.566	2.778±0.591	0.050	0.193	0.700
[23]				1.0				
[24]						0.1		

Mean annual effective dose (AED_{α}) due to gross alpha activity concentrations in water samples was highest for Atta stream samples which recorded 0.045 $mSv\,y^{-1}$ and lowest for Uburu sachet water and Okposi Okwu borehole water samples which recorded 0.001 $mSv\,y^{-1}$ and 0.01 $mSv\,y^{-1}$ respectively as observed in Table 1. Corresponding results were obtained for lifetime fatality cancer risk due to alpha activity concentrations ($LTFCR_{\alpha}$) and lifetime hereditary effects ($LTHE_{\alpha}$) due to alpha activity concentrations. These results revealed that the greatest radiological risk due to alpha activity concentrations is associated with Atta stream samples among other water samples investigated.

The result of annual committed effective dose (except for Atta stream samples), compare well with [12] who reported similar results of 0.0068 $mSv\,y^{-1}$, 0.0026 $mSv\,y^{-1}$, 0.0053 $mSv\,y^{-1}$, 0.0073 $mSv\,y^{-1}$ respectively at Aladja, Ovwian, DSC Town, and Warri in Delta State, Nigeria. However, the present results differ with the study carried out in water samples from mining area of Plateau State where [11] reported higher annual effective dose than the ICRP reference limit of 0.1 $mSv\,y^{-1}$. Furthermore, both sachet water samples sold at Okposi Okwu and Uburu were found having annual effective dose due alpha activity concentrations lower than the sachet water samples sold in Birnin Kebbi, Kebbi State Nigeria [26].

4.2 Mean Gross Beta Activity Concentrations and Associated Radiological Indices in Water Resources from the Sampled Locations

As observed from Table 2, the highest mean beta activity concentrations of 29.640±7.868 $Bq\,L^{-1}$ was recorded in water samples from Atta stream (Atta ST) while the lowest mean of 0.763±0.319 $Bq\,L^{-1}$ was recorded in Uburu sachet water samples (UBU SA). The order of Uburu borehole > Okposi Okwu borehole > Ugwulangwu borehole water samples was observed for borehole water resources examined in the study locations. Mean gross beta activity concentrations for the 21 water samples were calculated as 14.364±14.150 $Bq\,L^{-1}$ with coefficient of variation (CV) of 0.985 while the mean sum of gross alpha and beta activity concentrations for the 21 water samples were calculated as 14.557±14.296 $Bq\,L^{-1}$ with coefficient of variation (CV) of 0.982.

Water samples (except for Uburu sachet water) were found higher than [24] reference limit of 1.0 $Bq\,L^{-1}$ which fairly correspond with the study carried out in Saudi Arabia [5] where only two samples exceeded the [23] reference limit. In addition, the results of the present study were found higher than the results reported in drinking water of Guilan, Iran where all water samples were below the reference limit [6]; higher than the results recorded for drinkable water around steel processing facilities in Udu Local Government Area of Delta State, Nigeria [12] and 0.579$Bq\,L^{-1}$ reported in ground water samples in Nevşehir Province of Central Antolia Region of Turkey [9]. Interestingly, gross beta activity concentrations of Okposi Okwu borehole water (OKP BH) agreed favourably with 18.60 $Bq\,L^{-1}$ established in borehole water of Duste town in North Western Nigeria [10].

The highest mean annual effective dose (AED_{β}) due to gross beta activity concentrations was found in Atta stream samples which recorded 0.581 $mSv\,y^{-1}$ while the lowest was found in Uburu sachet water which recorded 0.015 $mSv\,y^{-1}$. Likewise results were obtained for lifetime fatality cancer risk due to beta activity concentrations ($LTFCR_{\beta}$) and lifetime hereditary effects ($LTHE_{\beta}$) due to beta activity concentrations. These results revealed that the greatest radiological risk due to beta activity concentrations is associated with Atta stream samples while the least was found in Uburu sachet water samples.

The mean results of annual committed effective dose calculated for Okposo Okwu and Uburu borehole water samples, Asu river, Atta stream samples were found higher than the results obtained at Aladja, Ovwian, DSC Town, and Warri in Delta State, Nigeria which recorded 0.061 $mSv\,y^{-1}$, 0.063 $mSv\,y^{-1}$, 0.038 $mSv\,y^{-1}$ and 0.023 $mSv\,y^{-1}$ [12]. However, agreed the study carried out in water samples from mining area of Plateau State where [11] reported higher annual effective dose than the ICRP reference limit of 0.1 $mSv\,y^{-1}$. Furthermore, both sachet water samples sold at Okposi Okwu and Uburu were found having annual effective dose due beta activity concentrations lower than the sachet water samples sold in Birnin Kebbi, Kebbi State Nigeria [26].

4.3 Statistical Analyses

Positive but weak correlation (correlation coefficient, $\rho = 0.44$) was deduced from the scatter plots between gross beta and gross alpha activity concentrations. The implication is that contributions of radionuclides were from different alpha and beta emitting radionuclides sources in the environment. This result was in good agreement with $\rho = 0.23$ between gross alpha and beta activity concentrations in borehole water from Duste Town, North – west Nigeria [10]. The CV value for gross alpha (1.697) was higher than gross beta (0.985) activity concentrations for the 21 water samples which revealed more widely dispersed distribution of data sets obtained for gross alpha than gross beta activity concentrations.

Skewness and kurtosis statistics were determined using SPSS software package version 21. Skewness statistic measures the symmetry or asymmetry of a distribution, while kurtosis is a measure of whether the data sets have heavy – tailed (outliers) or light – tailed relative to a normal distribution and nothing about the peak of the distribution. Positive skewness (2.018) and Kurtosis (2.859) were deduced for gross alpha activity concentrations. Likewise, Positive skewness (1.163) and Kurtosis (0.641) were deduced for gross beta activity concentrations. Similar positive results for skewness and kurtosis distribution were also deduced for the sum of gross alpha and beta activity concentrations. The positive skewness is an indication that right tail is longer than the left and the bulk of the data is at the left while positive kurtosis with a value less than 3 implies a platykurtic distribution, which signifies that the distribution produces fewer and less outliers than the normal distribution.

4.4 General Discussion

Variation in measuring equipments and calibrations, human activities, possible contamination from the environment, local lithology as well as of rock – water interaction could be responsible for variation in the results of the study locations with some result reported in the literature. It appears that surface and ground water samples are contaminated due to elevated concentrations of beta emitting radionuclides in the environment. This could be traceable to saline water movement into the aquifer of the study locations. Saline water intrusion occurs naturally to some degree in most coastal aquifers owing to hydraulic connection between ground water and sea water [27,28]. Salt water has higher dissolved salts and minerals than freshwater, therefore, is denser than fresh water. As a result of its higher hydraulic head than fresh water, it could push beneath the fresh water sources leading to contamination and other consequences of health risk if the water is not treated before consumption.

5. CONCLUSION

This study is carried out to determine if water resources were contaminated by alpha and beta emitting radionuclides/radioisotopes. Results showed variations in gross alpha and activity concentrations among different water samples investigated. The annual effective dose calculated for beta activity concentrations showed that water samples should be consumed with cautions since majority exceeded the WHO reference limit. Furthermore, results of lifetime fatality cancer risk and lifetime hereditary effects showed that sampled water from Atta stream has higher potential probability to cause cancer and hereditary effects among others. Preliminary and baseline study has been established. This study, therefore, advise that water samples should be treated for radionuclides, among other possibly contaminations, before consumption.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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