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Gross Alpha and Beta Activity Concentrations in Locally Processed Salt from Ebonyi State, Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Both authors designed the study, wrote the protocol and wrote the first draft of the manuscript. Both authors managed the literature searches. Author BUN managed the experimental process and author PIE performed the spectroscopy analysis. Both authors read and approved the final manuscript.

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ABSTRACT

Salt lakes and small – scaled salt production in Ebonyi State, Nigeria have long interesting history and the need to be informed of the radiological quality of the salt is essential to radiation measurement and protection agencies. Gross alpha and beta activity concentrations have been determined in locally processed salt samples and iodized sachet salt samples consumed in Ohaozara Local Government Area and neighboring towns in Ebonyi State using Protean Instrument Corporation (PIC) MPC 2000 DP proportional counter. The gross alpha and beta activity concentrations in Okposi Okwu salt were found to vary from 0.0057 to 0.0082 $Bq\ g^{-1}$ with a mean of 0.0063±0.0002 Bq/g and from 0.2393 to 12.12 $Bq\ g^{-1}$ with a mean of 1.763±1.160 Bq/g respectively; for Uburu salt between 0.0058 to 0.0068 $Bq\ g^{-1}$ with a mean of 0.0061±0.0001 Bq/g and from 0.2204 to 63.46 $Bq\ g^{-1}$ with a mean of 20.0150±8.1065 Bq/g for gross alpha and beta activity respectively; while the gross alpha and beta activity concentrations of the iodized sachet salt ranged from 0.0055 to 0.0067 $Bq\ g^{-1}$ with a mean of 0.0059±0.0001 Bq/g and 2.136 to

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$25.92 Bq\ g^{-1}$ with a mean of 7.217±0.0001 Bq/g respectively. Findings showed that the mean gross alpha activity results for the three brands were in good agreement whereas, gross beta activity concentrations for Uburu salt and iodized sachet salt were respectively about 13.37 and 4.09 times higher than that of Okposi Okwu salt. The trend of the mean of gross alpha activity concentration of the three brands of salt in this study shows that Okposi Okwu salt > Uburu salt > industrial sachet salt while that of gross beta activity shows that Uburu salt > industrial sachet salt > Okposi Okwu salt. The results of the gross beta and, sum of gross alpha and beta activity concentrations are greater than the standard activity limit for general consumed foods which is given as 0.1 Bq/g. High consumption of Okposi Okwu salt brand by the populace may have radiological impact on them as a result of the relatively high level of beta radiation. It is suggested that as a means of radiological protection, These salt brands should be screened for radioactivity concentration before consumption.

Keywords: Gross alpha and beta; activity concentration; salt lakes; Ebonyi state.

1. INTRODUCTION

In Nigeria, we can find deposits of spring salt in Okposi and Uburu salt lakes, Ebonyi State and salt springs in Awe, Plateau State [1,2]. Generally, a number of salt types are used in the manufacture of many industrial, agricultural, and consumer substances like chlorine gas, fertilizers and laxatives. The focus of this study is sodium chloride salt commonly known as table salt and one of the examples of normal salt. It is used for cooking of food, as food preservatives and as a drying agent. Most table salts used in Nigeria may not have been screened to ascertain the concentrations of natural radionuclides as a result of primary interactions with radiation prone minerals due to geophysical and geochemical characteristics of the sources (as is the case in the surveyed area where lead- zinc mineralization is predominant and also serves as channels/conduit for salt ground water) [3]. The knowledge of radionuclide activity concentrations in table salts is desirable and very important so as to be informed of the potential radiological status and associated risk or otherwise when such salts are ingested via food intake over a long period of time.

Since naturally occurring radionuclides of uranium series, thorium series and radioisotopes of potassium are found in environmental media including rock, soil, seas and oceans; the salt lakes may contain both alpha emitters (such as; ^{238}U, ^{226}Ra and ^{210}Po) and beta emitters (such as; ^{40}K, ^{228}Ra and ^{210}Pb) which could contribute significantly to ingested dose of radiation [4].

Several researches on gross alpha and beta activity concentrations on materials have been conducted and reported, however data and information on gross alpha and beta activity concentrations in salt samples are relatively scarce. Previous researchers have reported the ranges of values of 0.5 to 1.3 Bq/kg, 0.4 to 0.9 Bq/kg and 15.0 to 34.0 Bq/kg for activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K respectively in rock salt samples collected from Pakistan which resulted to the value of 0.0638±0.015 mSv/y as the mean annual effective dose due to the intake of the radionuclides [5]. Salt samples collected from Khewra Salt Mine located about 160 km South of Islamabad, Pakistan had been investigated for the activity concentration of three radionuclides; ^{40}K, ^{226}Ra and ^{232}Th using high purity germanium (HPGe) detector. The results showed that mean activity concentration of 36±20 Bq/kg was recorded in ^{40}K radionuclide while below detection limits (BDL) was reported for ^{226}Ra and ^{232}Th respectively [6]. Furthermore, the computed annual effective dose due to intake of ^{40}K contained in the salt was found to be 20±11 μSv/year which is below 290 μSv/year recommended in [7]. It was reported that the annual effective dose to an adult individual in Accra Metropolis, Ghana due to intake of natural radionuclide in salt is insignificant to cause radiological health hazards [8]. It was established that gross alpha activities were higher in the Single Super Phosphate (SSP) fertilizers than the Nitrogen Phosphorus and Potassium (NPK) fertilizers while there were more beta activities in NPK fertilizers than in SSP fertilizers used in Nigeria [9]. Studies on gross alpha and beta activity concentrations in surface water from mining areas of Plateau State, Nigeria reported high annual committed effective dose for all age groups above the International Commission on Radiological Protection (ICRP) acceptable standard [10]. Previous researches had reported the presences of metallic and non – metallic ions in Uburu salt lake of Ebonyi State [11]. Also, hepatotoxicity of the Okposi and Uburu salt lakes has been demonstrated in [12]. The Japanese Department of Food safety has placed a new standard limit for activity concentration of radionuclides in general food to be 0.1 Bq/g [13].

Despite the high consumption of salt from the surveyed salt lakes, studies on the gross alpha and beta activity concentrations of these commonly consumed salts have not been carried out to allay the fears of possible intrusion of alpha and beta emitting radionuclides from natural sources into the salt deposits, and to ascertain if the table salts consumed from the surveyed sources do not have activity concentrations exceeding the permissible limits. This work was therefore considered relevant in order to address the aforementioned issues.

2. MATERIALS AND METHODS

2.1 Study Area

Okposi and Uburu (the study areas) are neighboring towns situated in Ohaozara Local Government Area of Ebonyi State, Nigeria and lie between 06° 02′ 20″N; 007° 48′ 37″E and 06° 02′ 60″N; 007° 44′ 52″E respectively. The salt lakes found in the two towns gave Ebonyi State its slogan as the “Salt of the Nation” in Nigeria. The study areas are made up of sedimentary rock of Asu River Group of the Albian age. The hydrogeology of the area is controlled by the bedrock lithology and structural trend of the study area [14]. It had been reported that the occurrence of the saline brines in this area is associated with the fracture system within the bedrock; in addition, the well- developed folds and fractures of the lower Benue trough form host to lead- zinc mineralization predominant in the area and also serve as channels/conduit for salt ground water [3]. The Map showing Okposi Okwu and Uburu salt lakes are presented in Figs. 1 and 2 respectively. Small – scale salt production among elderly women and large scale farming activities have been identified as the major occupations of people living within the salt lakes. The saline water from the salt lakes is used in the production of salt and the processes include collection of saline water with a special pot, transferring into a container (usually a basin), heating to evaporate water, and living behind crystals of salt in the container.

Okposi Okwu and Uburu salt brands have been superstitiously reported by the consumers to relief feverish condition and detoxicate toxins in the body system which could be the reason it is relatively expensive and highly consumed in the locality compared with the commonly sold iodized sachet salt registered with National Agency for Food and Drug Administration and Control (NAFDAC). However, these claims have not been evaluated by NAFDAC and Standard Organisation of Nigeria (SON).

2.2 Sample Collection and Pelletisation

Three brands of salt were considered; the Okposi Okwu brand, Uburu brand and the sachet iodized salt commonly sold by the local marketers. Ten samples each of the three brands were collected with plastic containers sealed, labeled and transported to the laboratory for preparation and analyses.

Each labeled sample was ground into a fine particle using electric grinding machine and small portion of the samples transferred into agate mortar and ground further to a grain size of about 125 μm and about 0.5 g weighed using analytical weighing balance. Three drops of liquid binder were added and ground until the liquid binder evaporates into the atmosphere. Thereafter, it was put into a set of dyne of about 19mm in diameter to give it the pellet shape. Each sample was placed in a hydraulic press gauge and about 10 tons of pressure was exerted on it to produce a pellet. Finally all the thirty (30) prepared pellets were subjected to gross alpha and beta radioactivity count at a preset time of 45minutes each.

2.3 Counting Equipment and Calibration of the Detector

Protean Instrument Corporation (PIC) MPC 2000 DP proportional counter (a low background alpha and beta detector: 0.05 CPM Alpha; 50 CPM Beta) available in Centre for Energy Research and Training (CERT), Ahmadu Bello University (ABU) Zaria, Nigeria was used for the gross alpha and beta measurements. This equipment is a non-gas proportional counter with an ultra thin window. For the gross alpha activity measurements, the standard used was ^{239}Pu alpha source with half life of 24,110 years while for the beta activity measurements, the standard used was ^{90}Sr beta source with half life of 28 years [15]. The detector efficiencies of the equipment are 87.95% and 42.06% for gross alpha and beta counts respectively. The sample efficiency (S_E) and, the alpha and beta activity concentrations ($A_{\alpha/\beta}$) in Bq g^{-1} for all the samples were determined using equations (1) and (2).

$$S_E = \frac{W_{B+S} - W_B}{0.077} \times 100 \quad (1)$$

Where W_{B+S} is the weight of the planchet plus sample after evaporation, W_B is the weight of the empty planchet and 0.077g is the mass of the residue transferred to the planchet before evaporation.

$$A_{\alpha/\beta} = \frac{count\ rate\ (alpha\ or\ beta) - background\ count\ rate\ (alpha\ or\ beta)}{S_E \times \text{detector efficiency} \times V \times 60} \quad (2)$$

(The measured background count rates with empty planchets were 0.13 cpm and 78.49 cpm for gross alpha and beta respectively). Also, according to Protean Instrument's specification, MPC 2000 DP has nearly 0.0% spill-over. Therefore, the gross beta count rate was not affected by spill-over effect.

2.4 Data Analyses

All the data analyses were performed using MINITAB (Release 14) Statistical Software. This software aided us in computing the sample mean (Sm), standard error of the mean (SEM), standard deviation (σ) and t-test based on equations (3), (4), (5) and (6) respectively. We plotted frequency distribution histograms to account for the specific activity distribution of the samples and regression curves to ascertain the nature of correlation between the trends of gross alpha and gross beta radiations.

$$S_m = \frac{\sum_1^n S}{n} \quad (3)$$

$$SEM = \frac{\sigma}{\sqrt{n}} \quad (4)$$

$$\sigma = \sum \sqrt{\frac{(S - S_m)^2}{n}} \quad (5)$$

We went further to perform a t-test at 95 % Confidence Interval (CI) so as to obtain the Interval Estimates for the Sample Mean (IESM) because, for each location, our sample size is n< 30. This test was carried out to reduce the level of uncertainty of the calculated mean which was based on a relatively small sample size. The Interval Estimates for the Sample Mean (IESM) was calculated as;

$$IESM = S_m \pm t(SEM) \quad (6)$$

Where t is the t-table value for 'n-1' degrees of freedom.

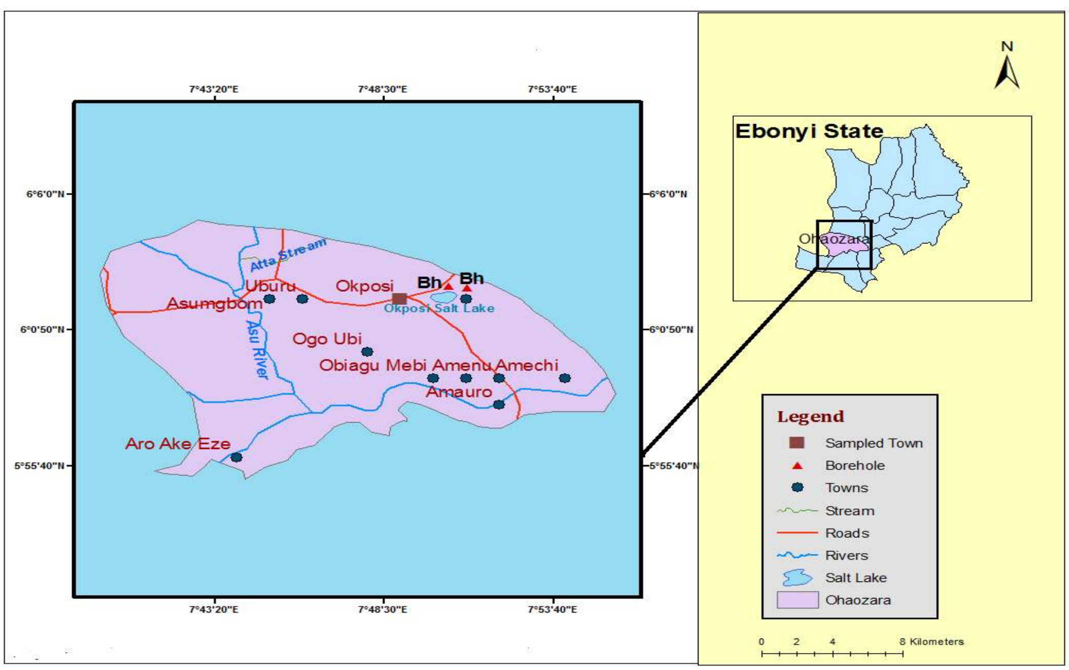

Fig. 1. Map showing Okposi Okwu salt lake in Ohaozara LGA, Ebonyi State Nigeria

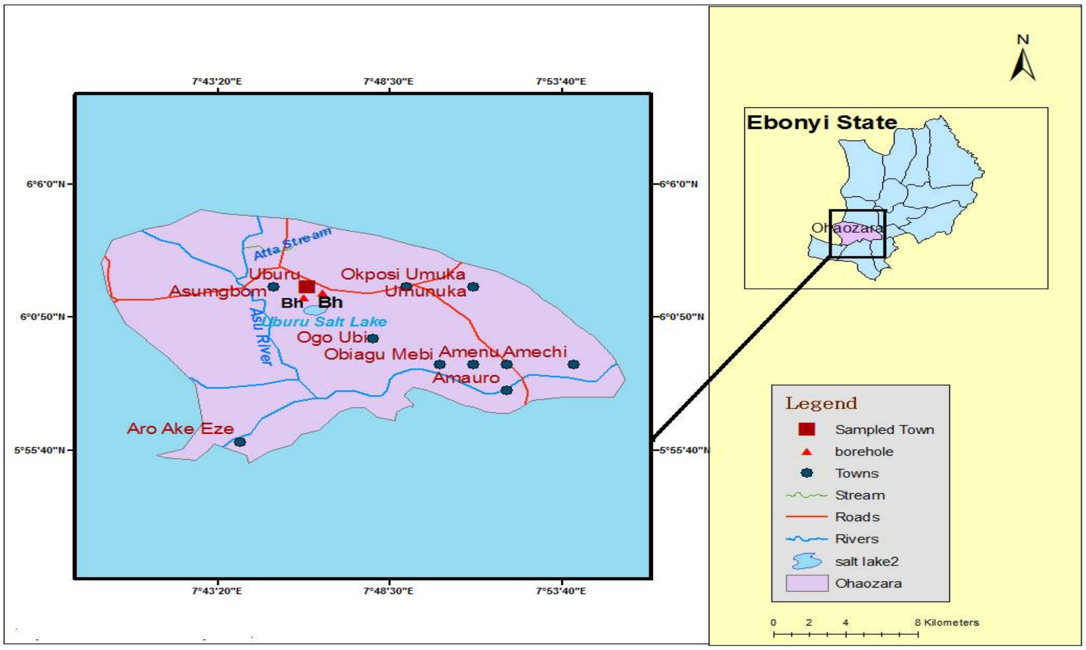

Fig. 2. Map showing Uburu salt lake in Ohaozara LGA, Ebonyi State, Nigeria

3. RESULTS AND DISCUSSION

3.1 Results

The results of the gross alpha and beta activity concentrations (Bq/g) in Okposi Okwu salt, Uburu salt and the sachet iodized salt brands are presented in Tables 1, 2 and 3 respectively. Summary of the Statistical Analyses of the Results of Surveyed Sample and Comparison of the Results with Standard Activity Limit for General Foods Consumed are presented in Tables 4 and 5 respectively. The frequency distribution histogram for the total gross alpha and beta activity concentrations in Okposi Okwu salt brand, Uburu salt brand and common iodized salt brand consumed in the surveyed area are presented in Figs. 3, 4, 5 respectively. Figs. 6, 7 and 8 show the regression plots to determine the correlation coefficients between gross alpha and beta activity concentrations in Okposi Okwu, Uburu and iodized sachet salts respectively.

Table 1. Gross alpha and beta activity concentrations (measured in Bq/g) in locally processed salt brand from Okposi Okwu Salt Deposit

Samples	Alpha activity	Beta activity	Total activity (Alpha + Beta)
OKP SALT 01	0.0062	0.4032	0.409
OKP SALT 02	0.0082	12.1200	12.128
OKP SALT 03	0.0059	0.6922	0.698
OKP SALT 04	0.0059	0.2393	0.245
OKP SALT 05	0.0060	0.6273	0.633
OKP SALT 06	0.0063	1.4130	1.419
OKP SALT 07	0.0058	0.4298	0.436
OKP SALT 08	0.0059	0.4936	0.499
OKP SALT 09	0.0066	0.5056	0.512
OKP SALT 10	0.0057	0.7025	0.708
Mean	0.0063	1.763	1.769
Standard deviation (σ)	0.000735	3.653	3.654
Standard error (SEM)	0.000232	1.160	1.160

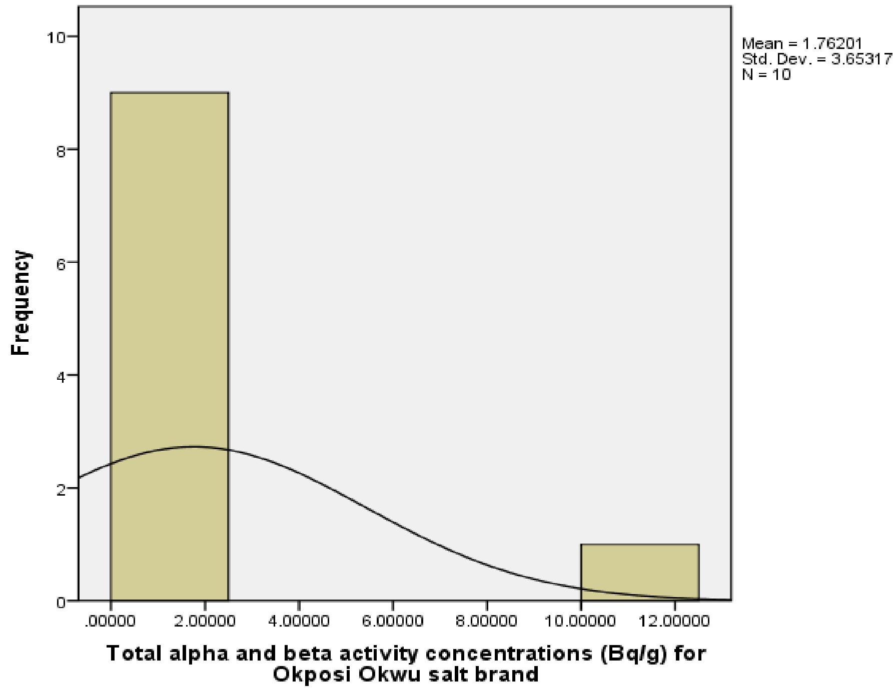

Fig. 3. Frequency distribution histogram for total alpha and beta activity concentrations in Okposi Okwu salt brand

Table 2. Gross alpha and beta activity concentrations (measured in Bq/g) in locally processed salt brand from Uburu salt deposit

Uburu samples	Alpha activity	Beta activity	Total activity (Alpha + Beta)
UBU SALT 01	0.0058	5.8490	5.8550
UBU SALT 02	0.0060	0.4098	0.4160
UBU SALT 03	0.0059	0.3586	0.3650
UBU SALT 04	0.0058	0.4504	0.4560
UBU SALT 05	0.0059	0.2451	0.2510
UBU SALT 06	0.0059	44.4200	44.4800
UBU SALT 07	0.0068	0.2204	0.2270
UBU SALT 08	0.0068	54.5200	54.5900
UBU SALT 09	0.0059	30.2200	30.2800
UBU SALT 10	0.0060	63.4600	63.5200
MEAN	0.0061	20.0150	22.0440
Standard deviation (σ)	0.000385	25.6350	27.2780
Standard error (SEM)	0.0001	8.1065	8.6261

3.2 Discussion

3.2.1 Okposi okwu salt

Table 1 shows that the gross alpha activity of locally made salt from Okposi Okwu ranged from 0.0057 to 0.0082 $Bq\,g^{-1}$ with a mean of 0.0063±0.0002 Bq/g (and with a range of Sample Mean of 0.0058 - 0.0068 Bq/g computed at 95% CI). The gross beta activity concentrations ranged from 0.2393 to 12.12 $Bq\ g^{-1}$ with a mean of 1.763±1.160 Bq/g (and with a range of Sample Mean of -0.85020 to 4.3762 Bq/g computed at 95% CI). The results of the sum of gross alpha and beta activity concentration ranged from 0.245 to 12.128 Bq/g with a mean of 1.769±1.160 Bq/g (and with a range of Sample Mean of -0.8449 to 4.3829 Bq/g computed at

95% CI). The results of the gross beta and, sum of gross alpha and beta activity concentrations are greater than the the standard activity limit for general consumed foods which is given as 0.1 Bq/g in Table 5. This implies that high consumption of Okposi Okwu salt brand by the populace may have radiological impact on them as a result of the relatively high level of beta radiation.

Fig. 3 shows that the frequency distribution histogram for total alpha and beta activity concentrations from Okposi Okwu salt brand is positively skewed with the hump on the left side indicating that few of the samples had high activity concentrations and majority of the samples had low activity concentrations.

From Fig. 6, the linear regression plot of gross beta versus alpha activity concentrations of Okposi Okwu salt brand gave a high R-square value of 0.876. High R^2 value is an indication that the concentrations of gross alpha and gross beta are linearly related. The strong positive correlation between alpha and beta activity in Okposi salt could be an indication that the source of gross alpha and beta activities may be from the same natural radionuclides. This relationship between alpha and beta activities was similarly reported in [16], with R^2 = 0.84.

Table 3. Gross alpha and beta activity concentrations (measured in Bq/g) in iodized sachet salt brand consumed in the surveyed area

Iodised sachet salt samples	Alpha activity	Beta activity	Total activity (Alpha + Beta)
SACH SALT 01	0.0057	2.136	2.142
SACH SALT 02	0.0067	6.083	6.089
SACH SALT 03	0.0064	5.655	5.661
SACH SALT 04	0.0060	3.499	3.505
SACH SALT 05	0.0061	25.920	25.926
SACH SALT 06	0.0055	2.383	2.389
SACH SALT 07	0.0055	2.161	2.167
SACH SALT 08	0.0056	4.087	4.092
SACH SALT 09	0.0058	17.230	17.236
SACH SALT 10	0.0058	3.018	3.024
Mean	0.0059	7.217	7.223
Standard deviation (σ)	0.000395	7.957	7.957
Standard error (SEM)	0.0001	0.0001	2.5162

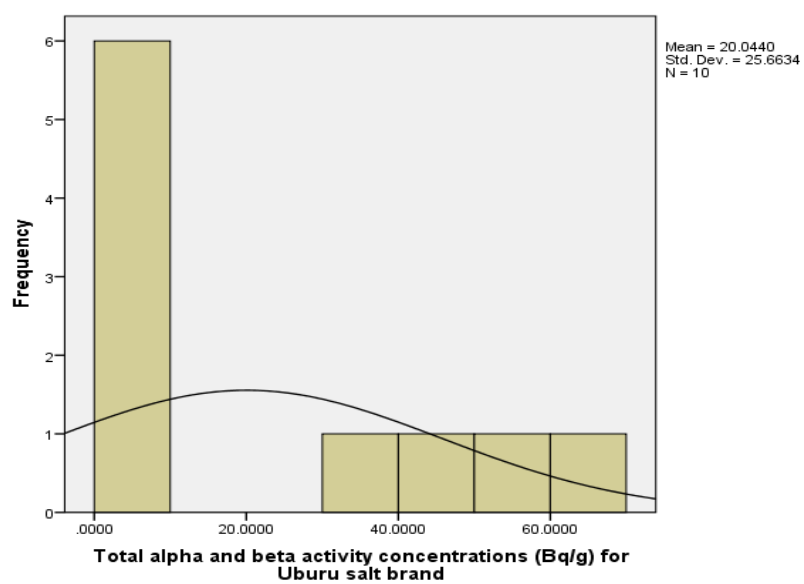

Fig. 4. Frequency distribution histogram for total alpha and beta activity concentrations in Uburu salt brand

Table 4. Summary of the statistical analyses of the results of surveyed samples

Samples	Gross radiation	Mean results	Standard error of mean	Standard deviation	Interval estimates for sample mean at 95% Confidence Interval (CI)
Okposi Okwu salt deposit	Alpha	0.0063	±0.0002	0.0007	0.0058 - 0.0068
	Beta	1.7630	±1.1552	3.6530	-0.8502 - 4.3762
	Total	1.7690	±1.1555	3.6540	-0.8449 - 4.3829
Uburu salt deposit	Alpha	0.0061	±0.0001	0.0004	0.0058 - 0.0063
	Beta	20.0150	±8.1065	25.6350	1.6768 - 38.3532
	Total	22.0440	±8.6261	27.2780	2.5305 - 41.5575
Iodized sachet salt	Alpha	0.0059	±0.0001	0.0004	0.0056 - 0.0062
	Beta	7.2170	±0.0001	0.0004	1.5249 - 12.9091
	Total	7.2230	±2.5162	7.9570	1.53091 - 12.9151

Table 5. Comparison of interval estimates (Range) for sample mean with standard activity limit for general foods consumed

Samples	Range of gross alpha mean (Bq/g)	Range of gross beta mean (Bq/g)	Range of total mean (Gross alpha + Gross beta) (Bq/g)	Standard activity limit for general consumed foods (Bq/g) [13]
Okposi okwu salt	0.0058 - 0.0068	-0.85020 - 4.3762	-0.8449 - 4.3829	0.1
Uburu salt	0.0058 - 0.0064	1.6768 - 38.3532	2.5305 - 41.5575	0.1
Iodized sachet salt	2.5305 - 41.5575	1.5249 - 12.9091	1.5309 - 12.9151	0.1

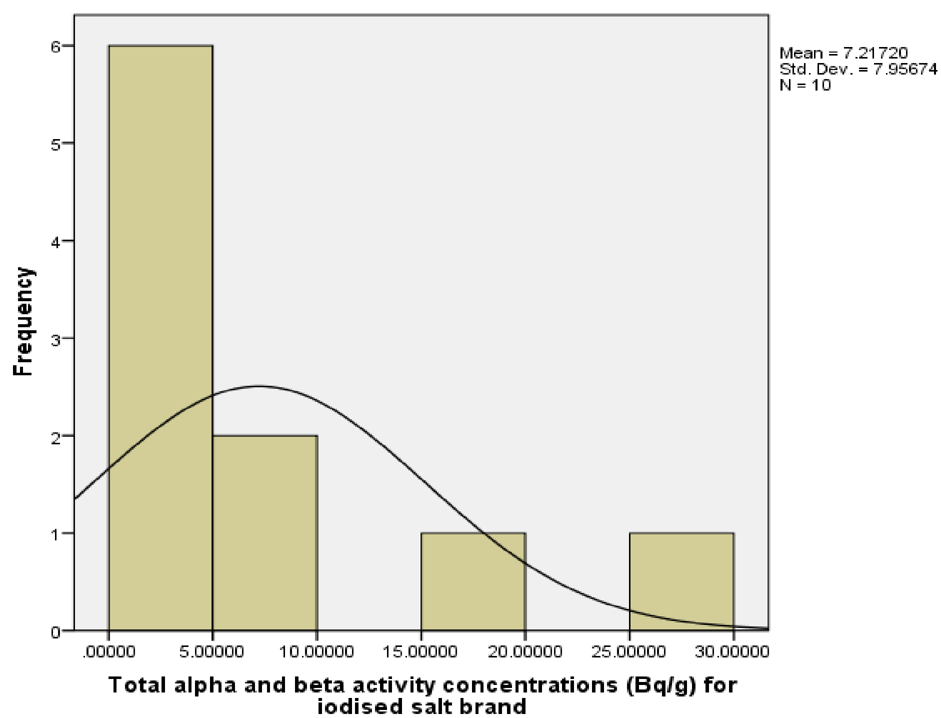

Fig. 5. Frequency distribution histogram for total alpha and beta activity concentrations in iodized edible salt brand

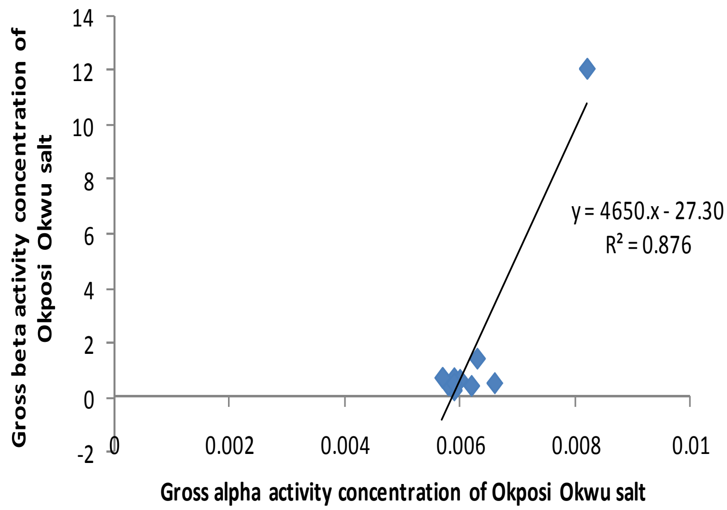

Fig. 6. Correlation of gross alpha and beta activity concentration in Okposi Okwu salt brand

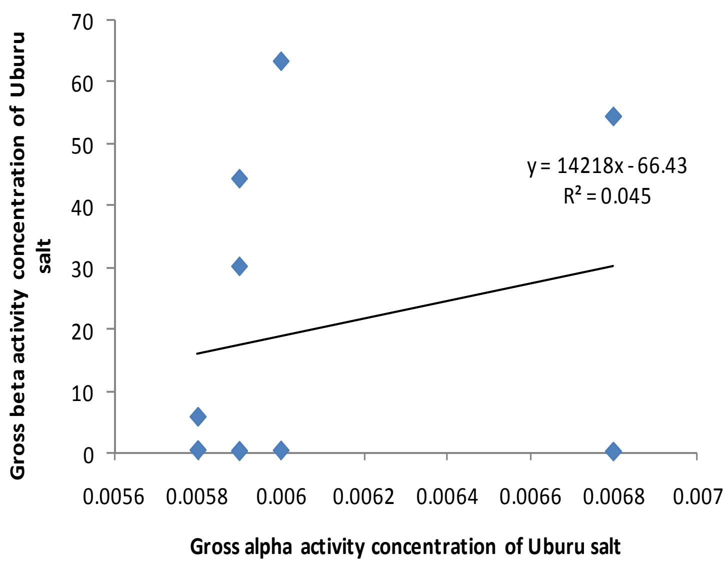

Fig. 7. Correlation of gross alpha and beta activity concentration in Uburu salt brand

3.2.2 Uburu salt

Table 2 shows that the gross alpha activity of locally made salt from Uburu ranged from 0.0058 to 0.0068 $Bq\ g^{-1}$ with a mean of 0.0061±0.0001 Bq/g (and with a range of Sample Mean of 0.0058 - 0.0063 Bq/g computed at 95% CI). The gross beta activity concentrations ranged from from 0.2204 to 63.46 $Bq\ g^{-1}$ with a mean of 20.0150±8.1065 Bq/g (and with a range of Sample Mean of -1.6768 - 38.3532 Bq/g computed at 95% CI). The results of the sum of gross alpha and beta concentration ranged from 0.227 to 63.52 Bq/g with a mean of 22.044±8.6261 Bq/g (and with a range of Sample Mean of 2.5305 - 41.5575 Bq/g computed at 95% CI). The results of the gross beta and, sum of gross alpha and beta activity concentrations are greater than the standard activity limit for general consumed foods which is given as 0.1 Bq/g in Table 5. This implies that high consumption of Uburu salt brand by the populace may have radiological impact on them as a result of the relatively high level of beta radiation.

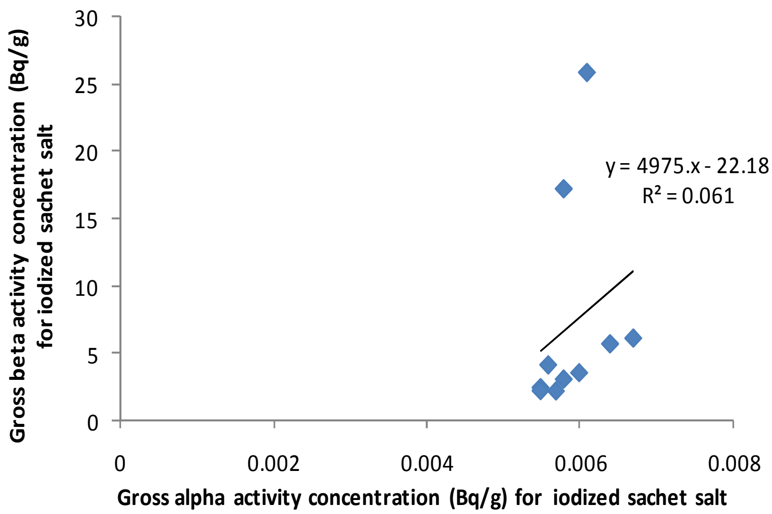

Fig. 8. Correlation of gross alpha and beta activity concentration in iodized sachet salt brand

Fig. 4 shows that the frequency distribution histogram for total alpha and beta activity concentrations from Uburu salt brand is positively skewed with the hump on the left side indicating that few of the samples had high activity concentrations and majority of the samples had low activity concentrations.

From Fig. 7, the linear regression plot of gross beta versus alpha activity concentrations of Okposi Okwu salt brand gave a low R-square value of 0.045. This R^2 value implies a weak positive correlation between alpha and beta activities and is an indication that the concentrations of gross alpha and gross beta activities are not linearly related, rather the distribution is scattered.

3.2.3 Iodized sachet salt

From Table 3, it is observed that the gross alpha activity of iodized sachet salt sold at both Okposi Okwu and Uburu area ranged from 0.0055 to 0.0067 $Bq\ g^{-1}$ with a mean of 0.0059±0.0001 Bq/g (and with a range of Sample Mean of 0.0056 to 0.0062 Bq/g computed at 95 % CI). The gross beta activity concentration ranged from 2.136 to 25.92 $Bq\ g^{-1}$ with a mean of 7.217±0.0001 Bq/g (and with a range of Sample Mean of 1.5249 to 12.9091Bq/g computed at 95% CI). The results of the sum of gross alpha and beta concentration ranged from 2.142 to 25.926 Bq/g with a mean of 7.223±2.5162 Bq/g (and with a range of Sample Mean of 1.53091 to 12.9151Bq/g computed at 95% CI). The results of the gross beta and, sum of gross alpha and beta activity concentrations are greater than the standard activity limit for general consumed foods which is given as 0.1 Bq/g in Table 5. This implies that high consumption of iodized salt brand by the populace may have radiological impact on them as a result of the relatively high level of beta radiation.

Fig. 5 shows that the frequency distribution histogram for total alpha and beta activity concentrations from iodized salt brand is positively skewed with the hump on the left side indicating that few of the samples had high activity concentrations and majority of the samples had low activity concentrations.

From Fig. 8, the linear regression plot of gross beta versus alpha activity concentrations of Okposi Okwu salt brand gave a low R-square value of 0.061. This R^2 value implies a weak positive correlation between alpha and beta activities and is an indication that the concentrations of gross alpha and gross beta activities are not linearly related, rather the distribution is scattered.

3.2.4 General discussion

It was observed from Tables 4 that the mean values of gross alpha activity concentrations for the three brands were very close which indicates that the sources may possibly contain homogeneous alpha emitting natural radionuclides. For all the three brands of salt, the mean gross beta activity concentrations were higher than the gross alpha activity concentrations which suggest that there are more beta emitting radionuclides than alpha emitters. This could be as a result of the presence of lead- zinc minerals in the surveyed areas [3]. Recall that ^{210}Pb a beta radiation emitter is a radioisotope of lead and its presence may have contributed immensely to the relatively high concentration of gross beta activity. The sedimentary rocks, aquifer parameters, lithology and associated complex tectonic features are likely the significant contributors to radioactivity in the environment. During salt water and bedrock interaction at the fracture system, some beta emitting radionuclides may become more soluble at certain pH conditions thus enhancing beta activity concentration. Some other geophysical and geochemical characteristics controlled by the bedrock geology may be responsible for higher beta activity concentration relative to alpha activity in the locally processed salts. Correspondingly, higher mean gross beta activity relative to alpha activity was recorded in NPK fertilizers used in Nigeria [9]; and in soil samples from different locations of Beamer and Shard, Bangladesh [4]. The trend of the mean of gross alpha activity concentration of the three brands in this study shows that Okposi Okwu salt > Uburu salt > industrial sachet salt while that of gross beta activity shows that Uburu salt > industrial sachet salt **>** Okposi Okwu salt. The mean of sum of gross alpha and beta activity for the three brands also follows the trend for the mean of gross beta activity concentration of the present study.

4. CONCLUSION

Gross alpha and beta activity concentrations have been determined in three brands of salt consumed in Ohaozara LGA and neighboring LGAs within Ebonyi State, Nigeria in order to assess the potential ingestion risk to the population. The results showed that the mean alpha activities were exceptionally lower than the beta activity results for the three salt brands. Beta activity concentrations for Uburu salt and iodized sachet salt were respectively about 13.37 and 4.09 times higher than that of Okposi Okwu salt which reveals that there were more beta emitting radionuclides in Uburu salt and iodized sachet salt than Okposi salt. The results of the gross beta and, sum of gross alpha and beta activity concentrations are greater than the standard activity limit set for general consumed foods which is given as 0.1 Bq/g [13]. High consumption of Okposi Okwu salt brand by the populace may have radiological impact on them as a result of the relatively high level of beta radiation. It is suggested that as a means of radiological protection. These salt brands should be screened for radioactivity concentration before consumption. There is presently no safe regulatory limits for gross alpha and beta activity concentration of salt in Nigeria; therefore the data and information from this work could be used as a baseline for future references and also serve as useful information for NAFDAC and radiation measurement and protection agencies. There is need to investigate the surface and ground water sources within the vicinity of the salt lakes for radionuclide contamination.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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