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ORIGINAL

# Gross alpha and beta activity concentrations in beers and ground water samples from selected breweries in Nigeria and their potential radiological hazards

# Concentraciones brutas de actividad alfa y beta en cervezas y muestras de aguas subterráneas de cervecerías seleccionadas de Nigeria y sus riesgos radiológicos potenciales

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## ABSTRACT

Background: Ingestion of radionuclides via beer products may predispose consumers to radiological health hazards. This study aimed to determine the gross alpha and beta activity concentrations in beers and ground water samples in selected breweries in Nigeria and their potential radiological hazards.
Materials and Methods: A cross-sectional study was conducted with some selected beer and ground water samples collected from fourteen (14) different sampled brewery locations in Nigeria. Fifteen (15) ml/L of 1 mol/dm3 of concentrated Trioxonitrate (v) acid (HNO3) was added into each keg of ground water sample immediately after collection from each brewery sites to preserve the in situ radionuclides from being adsorbed on the keg wall. No sample preparation was required for beer samples. Further sample preparation and analysis were carried out at Radiation Protection Institute, Ghana Atomic Energy Commission, Accra, Ghana (Test number: N4 and N5). Method 900 of the US Environmental Protection Agency was applied and Canberra iMaticTM Automatic low background gas-

filled counter was employed to determine the mean values of Gα and β RAC in both beer and ground water samples.
Results: Mean values obtained for Gα and β RAC in beer and some ground water samples were apparently safe for consumption across all breweries sites in Nigeria in line with the recommended safe limits (0.1 Bq/L for Gα RAC and 1.0 Bq/L for Gβ RAC for water) by World Health Organization (WHO). Kaduna (Kakuri) and (Kudenda) sites both in Northern Nigeria recorded the highest mean GαRAC (0.0387Bq/L) and Gβ RAC (0.0892±0.123) respectively in beer samples. Port Harcourt (Oginigba) site in southern Nigeria recorded the least mean Gα and β RAC (0.0009Bq/L and 0.0076Bq/L) in beer samples. Gα RAC in water samples from mostof the brewery sites were relatively high. Imo (Awo-omama) site recorded the highest Gα RAC (0.9330Bq/L) while Onitsha site recorded the highest value of Gβ RAC (0.694Bq/L). Port Harcourt (Oginigba) as usual maintained the least Gβ RAC (0.0064Bq/L).
Conclusion: Gα and Gβ RAC from beer samples across all the breweries in Nigeria were within WHO recommendation. However, water samples across most of the brewery sites in Nigeria were higher than the WHO recommendation and therefore may potentially pose radiological health hazards (Stochastic effects) on consumers.

**Keywords:** Gross Alpha/ Beta, Beer, Groundwater, Radionuclide, Radionuclide activity concentration, radiological hazard.

**RESUMEN**

Antecedentes: La ingestión de radionucleidos a través de los productos de la cerveza puede predisponer a los consumidores a riesgos radiológicos para la salud. El objetivo de este estudio era determinar las concentraciones brutas de actividad alfa y beta en cervezas y muestras de aguas subterráneas en cervecerías seleccionadas de Nigeria y sus posibles peligros radiológicos.
Materiales y métodos: Se llevó a cabo un estudio transversal con algunas muestras seleccionadas de cerveza y agua subterránea recogidas en catorce (14) cervecerías de Nigeria. Se añadieron quince (15) ml/L de 1 mol/dm3 de ácido trioxonitrato (v) concentrado (HNO3) a cada barril de muestra de agua subterránea inmediatamente después de su recogida en cada fábrica de cerveza para evitar que los radionucleidos in situ se adsorbieran en la pared del barril. No fue necesario preparar las muestras de cerveza. La preparación posterior de las muestras y los análisis se llevaron a cabo en el Instituto de Protección Radiológica de la Comisión de Energía Atómica de Ghana, Accra (Ghana) (números de prueba: N4 y N5). Se aplicó el método 900 de la Agencia de Protección del Medio Ambiente de EE.UU. y se empleó el contador automático de bajo fondo lleno de gas Canberra iMaticTM para determinar los valores medios de Gα y β RAC tanto en las muestras de cerveza como en las de agua subterránea.
Resultados: Los valores medios obtenidos para Gα y β RAC en la cerveza y en algunas muestras de agua subterránea fueron aparentemente seguros para el consumo en todos los sitios de las cervecerías en Nigeria, en línea con los límites de seguridad recomendados (0,1 Bq/L para Gα RAC y 1,0 Bq/L para Gβ RAC para el agua) por la Organización Mundial de la Salud (OMS). Los sitios de Kaduna (Kakuri) y (Kudenda), ambos en el norte de Nigeria, registraron las medias más altas de GαRAC (0,0387Bq/L) y Gβ RAC (0,0892±0,123) respectivamente en muestras de cerveza. El sitio de Port Harcourt (Oginigba) en el sur de Nigeria registró la menor media de Gα y β RAC (0,0009Bq/L y 0,0076Bq/L) en muestras de cerveza. El Gα RAC en las muestras de agua de la mayoría de las cervecerías fue relativamente alto. El sitio de Imo (Awo-omama) registró el valor más alto de Gα RAC (0.9330Bq/L) mientras que el sitio de Onitsha registró el valor más alto de Gβ RAC (0.694Bq/L). Port Harcourt (Oginigba), como de costumbre, mantuvo el menor Gβ RAC (0,0064Bq/L).

Conclusiones: Gα y Gß RAC de las muestras de cerveza a través de todas las fábricas de cerveza en Nigeria estaban dentro de la recomendación de la OMS. Sin embargo, las muestras de agua en la mayoría de las cervecerías de Nigeria fueron superiores a la recomendación de la OMS y, por lo tanto, pueden suponer riesgos radiológicos para la salud (efectos estocásticos) para los consumidores.

**Palabras clave:** Alfa/Beta bruto, Cerveza, Agua subterránea, Radionucleido, Concentración de actividad de radionucleidos, Riesgo radiológico.

## INTRODUCCIÓN

Man had continuously and ubiquitously been exposed to trace levels of ionizing radiation from cosmic sources, decay products of terrestrial radionuclides and anthropogenic radiation sources (mining activates, fertilizer application in Agriculture and nuclear technologies) since his existence on earth[1]. These processes have significantly influenced the migration of natural occurring radioactive materials (NORMs)/ radionuclides such as Uranium-235, Uranium-238, Thorium-232 and Potassium-40 from earth, water and food into humans body[2,3].The concentration of NORM in our environment differs from one place to another due to geological variations of different environment[4]; with the geochemistry and geophysics of different environments playingpivotal role in the radionuclide transfer from earth and ground water bodies into our food and drinking water [5]. The major pathways through which these NORMs/radionuclides can migrate into the human body include consumption of contaminated food, water, etc; inhalation of radioactive gas such as radon; injection of radiopharmaceuticals and absorption of radionuclides through cracks/wound on the skin surfaces[6].The decay products radionuclides such as alpha and beta particles from ground water with their high linear energy transfer (LET); when ingested and deposited in the body tissue are useful parameters in determining potential internal radiation hazards [7]. Hazardous effects caused by alpha particle is predominantly in the DNA double-strand break which is severe and irreparable[8]. These effects are dependent on the nature of the radioactive contaminant ingested, the level of contamination and the extent of distribution [9].

Brewery factories are locations in some environment that may be contaminated with these radionuclides at different ambient concentration which can be traceable to rocks, soil, ground water source and grains used in brewing beer. Quantitatively, it has been established that beer contains about 90-95% of water by volume and about 5-10% of grains (barley, wheat, maize, rice, sorghum, hops and millet), yeast etc.[10], which are sources of radionuclides.

In Nigeria, beer is the most popular alcoholic drink, with an average consumption of twelve (12) liters per capita per annum [11]. As at 2020 ranking of beer brands in Nigeria, Heineken, Budweiser and Guinness are the top three most consumed brands respectively [11]. Beer intake is culturally tolerated as part of social life of many ethnic groups in Nigeria especially in communities where it was not forbidden by religious practice [12]. Nigeria currently leads the top 10 largest beer consuming countries in Africa by virtue of her population, which technically translates to high volume and liters consumed per year [13]. The country currently has about four mega breweries namely the Nigerian Breweries PLC, Guinness Breweries PLC, International Breweries PLC and Champion brewery which are located in different states with a total production capacity of about 17.72 million hectoliters per annum (hl/a) [13]. A report recently released by a market research group estimated that beer consumption rate in Africa has grown by a five percent Annual Growth Rate between 2015 and 2020 which records the highest growth rate across all continents in the world[13]. Because of the quantity of beer products brewed and consumed at different geographic location of Nigeria, there may be potential variation in activity concentration of in-situ radionuclides and associated potential radiological health hazards.

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There is therefore need to analyze these beer products to determine their gross alpha and beta activity concentration. Results from a research on activity concentration in ground water samples from brewery sites in Nigeria which noted that all the samples were bored right in the brewery revealed that there is high mean values of gross alpha and beta activity concentration from majority of the breweries sampled[14]. Although the results were within the safe reference level of activity concentrations of water for gross alpha activity (0.1 Bq/L)and gross beta activity (1.0 Bq/L) recommended by World Health Organization [15]. Similarly, another study was carried out in Poland by Skwarzec et al[16] to determine the intake of 238U, 234U and 210Po radionuclides in beer samples consumed using alpha-spectrometry with low-level activity silicon detectors. Their results revealed that the mean concentrations activity of 210Po in beer samples were nine times higher than those in drinking water sample. Generally, the mean value of uranium concentration in beer (weighted average) is similar to its activity in bottled mineral water and drinking (public) water. It can be inferred that the study carried out in Poland was basically on determination of presence of radionuclides and gross radioactivity in beer and drinking water products. However, our study laid emphasis on gross alpha and beta activity concentration which are useful in determining radiological health hazard for internal radiation exposure. Also, we used Canberra iMaticTM Automatic low background gas-filled counter because it is readily available in our domain and cost effective when compared with a similar study in Poland that used alpha-spectrometry with low-level activity silicon detectors. Literatures reviewed revealed paucity of data and recommended safe reference value for gross alpha and beta activity concentrations in beer products. Consequently we adopted the same recommended reference value approved for water products by World Health Organization (WHO) since beer contain about 90-95% of water by volume. This study will help to guarantee equasi radiation safety for beer consumers in Nigeria, thus the rationale for this study.

## MATERIALS AND METHODS

Cross-sectional design was adopted and a total of forty-eight (48) beer and ground water samples were collected samples were purposively collected from brewery sites in Nigeria. An ethical approval (MH/AWK/M/132/452) for this study was obtained from the research ethics committee of the Ministry of Health, Anambra state, Nigeria and the participant's consent was obtained using written informed consent form. Instruments used were Laboratory beakers, Petri-dishes, hot plate, infra-radiator lamp, Experimental (Digital) weighing balance, planchet, cotton wool, acetone, vinyl acetate, low background automatic gross alpha/beta count system (Canberra IMaticTM, USA) and Americanium-241 and Strontium-90 standard sources.

Method 900 of the United States Environmental Protection Agency (USEPA) was applied during sample collection as follow: samples of ground water were collected directly into two liter (2) of plastic kegs (polyethylene containers) after washing the containers properly and rinsed with the same water sample to be collected. About 15ml/L of validated 1 mole per cubic decimeter (1mol/dm3) sample of concentrated Trioxonitrate (V) acid (HN03) was added into the collected ground water samples at the point of collection using a syringe, gloves and a face-mask. The addition of concentrated Trioxonitrate (V) acid (HN03) served to preserve the radionuclides present in the water samples by preventing the adsorption of radionuclides from water to the inner walls of the containers[17].The taps was first turned on at its full capacity for about three (3) minutes to purge the plumbing system of any water impurity and radon gas which might have been there for some time. The taps flow rate was subsequently reduced to attain steady turbulence and radon loss before collecting the water into the kegs [17]. Beer samples did not need any preparation as they were in corks. Beer and ground water samples were finally sent to the Radiation Protection Institute (RPI), Ghana Atomic Energy Commission (GAEC), Kwabenya Accra, Ghana, where they were further prepared, analyzed and data generated for gross alpha (α) and gross beta (β) activity concentration in ground water and beer samples.

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The beakers, crucibles (Petri-dishes), planchet and spatula were washed properly during analysis, rinsed with clean water and sterilized using acetone. Then the apparatus were kept and dried inside an oven. A little quantity of ground water sample was used to rinse the beaker twice so as to ensure that there was no cross contamination before evaporation. About one liter (1L) of the ground water samples was filtered on a filtration system set up and transferred into a one liter (1L) beaker. Two millimeter (2 ml) of HNO3 was added to all the samples to maintain and to liberate metals and dissolve organic particles. It was left to stay overnight. For each sample, 300ml of the filtrate was measured into Pyrex glassware and set on electric hot plate in a fume camber with steady temperature below boiling point 600 - 700 for three hours to allow gradual evaporation and to avoid excessive loss of the residue until a volume of 20-30 ml was obtained. The remaining filtrate was transferred into 47mm stainless-steel planchet at 100C – 200C. This process of heating continues until when the volume of the groundwater samples were evaporated to dryness and placed in desiccators to prevent them from absorbing moisture and allow them cool down to room temperature before counting. This process is known as surface drying. Sample residues were dried to constant weight, reweighed to investigate the residue weight using a weighing balance. Having taken the initial weight (of the empty dish), the weight of the residue together with Petri-dish was measured using digital analytical weighing balance. The weight of the total residue obtained from the total volume evaporated was calculated by using the relation:

Wr= W (d+s) - Wd (3.1)

Where: W (d+s) is the weight of the dish with sample's residue,

Wd = the weight of empty dish

Wr = the weight of the total residue.

0.0770g of the residue was transferred to the sterilized planchet and the exact volume that produced this required weight (0.0770g) was calculated by the use of the expression:

0.0770g x Vtr = Wtrx V. (3.2)

Where: Vtris the volume that generated total residue,

Wtris the weight of the total residue obtained

V is the volume that yielded the required residue

For samples with residue obtained greater than or equal to 0.0770g, the sample efficiency was said to be 100%. But for the samples with residue less than 0.0770g, sample efficiency was obtained using the expression below;

$$\text{Sample efficiency} = \frac{\text{weight of residue}}{0.0770\text{g}} \text{X } 100\%. \quad (3.3)\ [17].....3.3$$

The Alpha/Beta activity concentration measurement was done using low background automatic gross alpha/beta count system (Canberra IMaticTM, USA). Americanium-241 and Strontium-90 standard sources were used to calibrate the system; it was counted 10 minutes later to determine the efficiency of alpha and beta Counter system. The counting efficiency of beta and alpha were 31.01 % ± 2,18% and 69.01% ± 4.39%, respectively. Americanium-241 has higher alpha particle energy (5.49MeV) than those emitted by naturally occurring uranium. It was therefore the prescribed radionuclide for gross alpha calibration. Strontium-90 in equilibrium with daughter

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Yttrium-90 was the correct radionuclide for gross beta calibration. Calibration was used to count the background radioactivity of the environment. The gross alpha and beta radioactivity counting modes applicable to the counter, with respective voltages of 1,600 and 1,700 volts were employed to count the prepared beer and ground water samples collected. The counting system was used to count clear empty planchet in all the counting modes to obtain the background radioactivity of the environment which is needed to be used in the subsequent measurements.

For gross alpha counting, the high voltage was set at 1600V and samples was counted for 3 cycles of 2700s (45mins) per cycle. The results were displayed as raw counts and count rate (count/min). The data was generated for alpha mode and the specific activity for alpha in the samples was also calculated using the formula below.

$$\text{Activity } (\alpha)\ (\text{Bq/L}) = \frac{\text{Net count (CPM) } (\alpha)}{\text{DE x 60 x Sample Size (Volume) X Sample Efficiency}} \qquad (3.4)$$

Where D.E is the detector's efficiency and net counts given by:

Net counts = Raw counts (CPM) – Background (CPM). …… (3.5) [18].

The high voltage for gross beta counting was set at 1700V and samples were counted for 3 cycles over a preset period of 2700s in beta mode. The specific activities were calculated using the formula below.

$$\text{Activity } (\beta)\ (\text{Bq/L}) = \frac{\text{Net count (CPM) } (\beta)}{\text{DE x 60 x Sample Size (Volume) X Sample Efficiency}} \qquad (3.6)$$

The parameters remain the same as for equation 3.5[18].

The residue were counted for 200 minutes with regards to the procedure selected during the calibration of the instrument to investigate alpha/beta activity concentration within the permissible

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limit as recommended by WHO[19]. All the samples were counted twice to ensure accuracy and validity and the results were recorded.

Data obtained after sample analysis from Radiation Protection Institute (RPI), Ghana Atomic Energy Commission (GAEC), Kwabenya Accra, Ghana were saved on a computer Microsoft excel spread sheet and categorized into name of sample and brewery locations of sample collection. Statistical analysis was done using descriptive statistics (range, mean standard deviation, frequency, percentage, and tables).Data collation and analysis were carried out using Statistical Package for Social Sciences (IBM, SPSS) version 20.0 (IBM Corp.Armonk NY,2011).

## RESULTS

Gα and β RAC in beer samples across sampled brewery sites in Nigeria.

Results from table 1 revealed that the mean values of Gα RAC of beer products from Kaduna (Kakuri) brewery site recorded the highest mean value of gross alpha activity concentration (0.0387Bq/L) while Kaduna (Kudenda) site had the highest mean value for β RAC (0.2990Bq/L) with both cited in northern part of Nigeria. Port Harcourt (Oginigba) site in southern part of Nigeria recorded the lowest mean value of Gα and β RAC (0.0009Bq/L and 0.0076Bq/L respectively). Table 3 revealed that there was no statistical significant difference between the Gα and β RAC in beer samples in all the sampled sites ($p > 0.05$).

Gα and β RAC in ground water across sampled brewery sites in Nigeria

Result from table 2 revealed that the mean value of Gα RAC in water samples from Imo (Awo-omama) site recorded the highest mean value (0.9330Bq/L), while Port Harcourt (Oginigba) site recorded the lowest mean value of Gα RAC. Anambra (Onitsha) brewery site recorded the highest mean β RAC (0.694Bq/L) while Port Harcourt (Oginigba) site as usual recorded the lowest β RAC (0.0064Bq/L). Table 4 and 5 revealed that there was no statistically significant difference between the mean Gα and β RAC in ground water samples from all the sites sampled.

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Table 1: Gα and ß RAC in beer samples across various brewery sites in Nigeria.

| Brewery sites | Alpha activities in beer(Bq/L) Mean ± SD | Inference (α) | Beta activities in beer(Bq/L) Mean ± SD | Inference (ß) |
|---|---|---|---|---|
| Ogun (Ilesha) | 0.0093±0.000 | Safe | 0.0150±0.000 | Safe |
| Ogun (Ijebu Ode) | 0.0112±0.016 | Safe | 0.0722±0.045 | Safe |
| Kaduna (kudenda) | 0.0226±0.000 | Safe | 0.2990±0.000 | Safe |
| Benin (Ikpoba Hill) | 0.0230±0.000 | Safe | 0.1010±0.000 | Safe |
| Enugu (Ama) | 0.0284±0.004 | Safe | 0.1310±0.017 | Safe |
| Ogun (Sango Ota) | 0.0153±0.024 | Safe | 0.0892±0.123 | Safe |
| Onitsha (Budweiser) | 0.0114±0.008 | Safe | 0.1140±0.140 | Safe |
| Kaduna (Kakuri) | 0.0387±0.038 | Safe | 0.0809±0.050 | Safe |
| Lagos (Oba Akan) | 0.0031±0.003 | Safe | 0.0375±0.041 | Safe |
| Lagos (Iganmu) | 0.0092±0.007 | Safe | 0.1183±0.040 | Safe |
| Port Harcourt (Oginigba) | 0.0009±0.002 | Safe | 0.0076±0.008 | Safe |
| Uyo (Aka Ufot) | 0.0020±0.000 | Safe | 0.0164±0.000 | Safe |
| Imo (Awo-omama) | 0.0047±0.000 | Safe | 0.0720±0.000 | Safe |

Table 2: Gα and ß RAC in ground water samples across the various brewery sites in Nigeria.

| **Breweries sites for water** | **Alpha concentration in water**<br><br>**Mean** | **Inference (α)** | **Beta concentration in water**<br><br>**Mean** | **Inference (β)** |
|---|---|---|---|---|
| Ogun (Ilesha) | 0.5220 | **Not Safe** | 0.0083 | Safe |
| Ogun (Ijebu Ode) | 0.5600 | **Not Safe** | 0.0103 | Safe |
| Kaduna (kudenda) | 0.6750 | **Not Safe** | 0.4200 | Safe |
| Benin (Ikpoba Hill) | 0.1540 | **Not Safe** | 0.6125 | Safe |
| Enugu (Ama) | 0.2045 | **Not Safe** | 0.0535 | Safe |
| Ogun (Sango Ota) | 1.0000 | **Not Safe** | 0.0604 | Safe |
| Onitsha (Budweiser) | 0.0404 | Safe | 0.6945 | Safe |
| Kaduna (Kakuri) | 0.2580 | **Not Safe** | 0.5670 | Safe |
| Lagos Oba Akan) | 0.0030 | Safe | 0.0092 | Safe |
| Lagos (Iganmu) | 0.2230 | **Not Safe** | 0.0500 | Safe |
| Port Harcourt (Oginigba) | 0.0014 | Safe | 0.0064 | Safe |
| Uyo (Aka Ufot) | 0.5010 | **Not Safe** | 0.0164 | Safe |
| Imo (Awo-omama) | 0.9530 | **Not Safe** | 0.0629 | Safe |
| Aba (Ogbo Hill) | 0.0831 | Safe | 0.0916 | Safe |

Table 3: Fisher's exact test comparing the Gα and β RAC in beers samples from brewery sites in Nigeria.

| Fishers Test | F-value | P-value |
|---|---|---|
| Alpha values in beer (site by site) | 627.085 | 1.000 |
| Beta values in beer (site by site) | 651.395 | 1.000 |

Table 4: Fisher's exact test comparing the Gα and β RAC in water samples from brewery sites in Nigeria.

| Fishers Test | F-value | P-value |
|---|---|---|
| Alpha values in water (site by site) | 41.274 | 1.000 |
| Beta values in water (site by site) | 254.397 | 1.000 |

Table 5: Fisher's exact test comparing the Gα and β RAC in beers and water samples across breweries in Nigeria.

| Variable pair | | Mean ± SD | N (%) | $\chi^2$ | P |
|---|---|---|---|---|---|
| **Gross alpha activity concentration:** | | | | | |
| Water and beer | Water | 0.3698 ±0.3699 | 14 (29.2) | 254.397 | 1.000 |
| | Beer | 0.0144 ±0.0194 | 34 (70.8) | | |
| **Gross beta activity concentration:** | | | | | |
| Water and beer | Water | 0.193 ±0.257 | 14 (29.2) | 254.397 | 1.000 |
| | Beer | 0.085 ±0.086 | 34 (70.8) | | |

## DISCUSSION

Results revealed that the Gα and β RAC in all beer samples were within the reference range for portable water as approved by WHO. However, beer samples from Kaduna state (Kakuri) and Kaduna (Kudenda) recorded the highest mean value of Gα and β RAC respectively while the lowest mean values were obtained from Rivers state (Oginigba). This high preponderance in Kaduna state (Kukuri and kudenda) both in northern Nigeria agrees with a study carried out in Kaduna metropolis by Akudo et al[20], which assessed the gross alpha and beta radioactivity in surface and ground water. They found that activity concentration of both gross alpha and beta activities were above the reference value for portable water[20]. This could be as a result of the geology of these areas which are rocky and granitic in texture[21] and because the dwellers of these areas are mainly famers, tillage of rocky soil by Tractors and their habitual use of fertilizer can increase the concentration of radionuclides in these environments where geochemistry and geophysics may help in the migration radionuclides from the rock, soil to food, ground water and crops [5]. It also agrees with a studies conducted in Poland which evaluated the radionuclides of 210-Polonium, 234-Uranium and 238-Uranium in drinking bottle mineral water and intake of 210-Polonium, 234-Uranium, and 238-Uranium in beer samples[16,22]. They reported that geographical variations were the cause of difference inactivity concentrations of the radionuclides in beer and water samples[16,22]. The lowest value of gross alpha activity concentration in beer samples recorded in River state (Oginigba), agrees with a study carried out in River state to determine the natural radionuclides and activity concentration in borehole water samples by Avwiri et al[23], which reported values that are below the recommended limit. This finding could be as a result of geological formation (hydrogeological) of the sampled areas which is predominantly aquifer [9].

Results also reveal that ground water samples from Imo (Awo-omama) site recorded the highest mean value of gross alpha activity concentration, while Port Harcourt (Oginigba) site recorded the lowest mean value of gross alpha activity concentration among all the sampled breweries. Anambra state (Onitsha) brewery recorded the highest mean value of gross beta activity concentration in water. The least mean value of gross beta activity concentration in ground water samples were recorded at River state (Oginigba). This could be as a result of the geological formation and characteristics of rocks, soil, water and mineral deposits in the areas. These high values in Imo (Awo-omama) and Anambra state (Onitsha) breweries agree with a research on activity concentration in ground water samples from brewery sites in Nigeria, which reported that there is high mean values of gross alpha and beta activity concentration from majority of the breweries sampled [18]. This could be as a result of the geological formation and characteristics of rocks, soil, water and mineral deposits in the areas.

Also, the mean gross alpha and beta activity concentrations were higher in ground water samples than in beer samples. This could be as a result of mode of ground water sample preparation which included the addition of concentrated Trioxonitrate (V) acid (HN03) to preserve the radionuclides present in the ground water samples by preventing the adsorption of radionuclides from water to the inner walls of the containers which was done carried out in the case of beer samples [17].

Statistically significant difference in the mean values of gross alpha activity in beer and water samples (p-value=1) were revealed in the study. This implies that different geographical regions have different mean alpha concentration in their beer and water samples. This finding is in agreement with a similar study conducted by Skwarzec et al [16] and Skwarzec et al [22] carried out in Poland to determine the radionuclides of 210-Polonium, 234-Uranium and 238-Uranium in drinking bottled mineral water and intake of 210-Polonium, 234-Uranium and 238- Uranium, radionuclides in beer in Poland and they reported that the concentration of these radionuclides of the different brand of beers vary from one region to another. The polonium isotopes, especially 201Po, which is the main source from alpha emitters of the internal radiation dose received by humans [22, 24], are amongst the more radiotoxic nuclides and their activity concentration in drinking water is very important from radiological point of view [16]. The means of values of gross alpha activity concentration obtained in most ground water samples were higher than

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the safe value of 0.1 Bq/L for gross alpha activity and 1.0 Bq/L for gross beta activity [19]. This shows that it may pose radiological health consequences to the consuming population.
The major limitations of this study was that during sample collection and preparation, fifteen (15) ml/L of 1 mol/dm3 of concentrated Trioxonitrate (v) acid (HNO3) was added into the water samples to preserve the radionuclides present in the water samples from adsorbing to the inner walls of the containers which was not carried out for beer samples because they were already corks. This will definitely reduce mean value of Gα and Gß RAC and could explain why activity concentration in water samples are higher than in beer samples Our study was not aimed at respective brands of beer but was generalized for all sampled products from each sampled brewery sites. Some bottled beer and kegs of ground water samples were cracked and drained aware while transporting them from Nigeria to Ghana as a result of mode of transportation and consequently, reduced the sample size. Some brewery sites turned down our consent to collect ground water and beer samples and that reduced our sample size.

## CONCLUSION

Gα and Gß RAC from beer samples across all the breweries in Nigeria were within WHO recommendation. However, water samples across most of the brewery sites in Nigeria were higher than the WHO recommendation and therefore may potentially pose radiological health hazards (Stochastic effects) on consumers.

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## FINANCING

None.


## CONFLICT OF INTEREST

No conflict of interest.

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