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Analysis Of Gross Alpha/Beta Activity Concentrations In Different Brands Of Sachet Drinking Water Produced In Ashanti Region Of Ghana

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***Abstract*—Activity concentrations of gross alpha, gross beta, in twenty brands of sachet water produced in the Ashanti Region of Ghana were measured. The analysis was carried out in the Alpha Spectrometry Laboratory at Radiation Protection Center of Ghana Atomic Energy Commission using gross alpha/beta counter system to screen for radiological contaminant of interest in the water samples. The investigation revealed values from of 1.13 ± 0.02 to 3.74 ± 0.02 mBq/L with an average concentration of 2.12 ± 0.02 mBq/L for gross alpha activity concentrations. The Beta activity concentration values ranged from 7.12 ± 0.03 to 22.11 ± 0.01 mBq/L with average activity of 13.60 ± 0.02 mBq/L. The concentration values of gross - alpha and gross -beta for all the sachet water samples were below the Ghana Standard Authority and World Health Organization recommended guideline levels set for drinking water quality which is 0.1Bq/L and 1.0Bq/L, and 0.5Bq/L and 1.0Bq/L respectively. The results obtained indicated that the inhabitants in the Ashanti Region were not exposed to any significant radiological health hazard associated with drinking sachet water. This research will provide some useful data (base –line radiometric values) to be used by the regulatory authority to evaluate possible changes in the future.**

Keywords—Activity Concentrations; Sachet water; Ghana Standard Authority; Ashanti Region and World Health Organization.

1.1 INTRODUCTION

According to WHO/UNICEF (2017), a population of one hundred and fifty nine million worldwide drinks water directly from surface water sources and this has been one of the causes of several waterborne diseases reported in the world. Scarcity of water in most part of the world is of serious concern including even developing countries, and with the current population growth and climate change trends, it is supposed that the problem of water scarcity will escalate in the coming decades (Hanjra & Qureshi, 2010).

All organisms including humans needs water for their survival, hence the need for adequate safe water cannot be overemphasized (Oki & Kanae, 2006). According to de Fraiture *et al*. (2007), the 2025 predictions for scarcity of water by the International Water Management Institute (IWMI) were reached in 2000. Water shortage is even more prominent in countries which cannot afford to develop new water sources due to the high cost involved in such projects (Hanjra & Qureshi, 2010). Most people depend on commercial sachet and bottled drinking water vendors to provide them with safe drinking water (Stoler *et al*., 2012) this is due to the problem of water shortage and the lack of safe drinking water in many sub-Saharan African countries, Despite the increasingly high cost, sachet water has gained popularity in both urban and even some rural communities due to its easy accessibility and supposed safety.

However, studies have largely focused on the physiochemical, heavy metal and microbial quality of the water (Obiri-Danso *et al*., 2003; Addo *et al*., 2009; Olaoye & Onilude, 2009), with little emphasis on radionuclides, although these have also been detected in sachet water meant for human consumption by a few other studies (Tchokossa *et al*., 1999, Hakam *et al*., 2001). Hazards resulting from radionuclides are typically small compared with those from microorganisms and chemicals that may be present in the sachet drinking-water (Gorchev & Ozolins, 2011).Unfortunately, regulatory bodies have also focused on physicochemical and microbial properties in sachet water to the neglect of the radiological properties (Ajayi & Adesida, 2009).

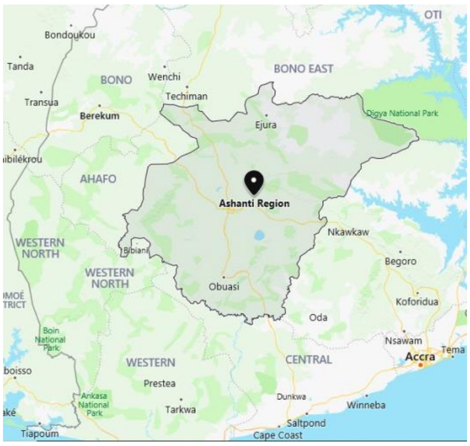
In addition, with the growing global cancer burden, it has become more imperative to investigate all probable sources of radionuclide exposure to humans, one of which is drinking water (Ashraf, 2003; Kanavos, 2006). Human activities such as the wrongful disposal of radioactive material from economic, medical and technological processes result in the contamination of water bodies and underground deposits of water and consequently. Hence the significance of determining the levels of radioactivity in sachet water is necessary to prevent consumers from over exposure to radionuclides and educate the public on radiological effects due to radiation exposure.

It is reported in Ghana, that more than three million people do not have access to safe drinking water (Water Aid, 2017) due to pollution of our water sources and the poor water delivery system (Gaisie & Gyau-Boakye, 2007). Consequently, patronage of sachet drinking water is very high. According to Stoler *et al*. (2012), from 2009 to 2010 the consumption of sachet water had increased to 50% in Accra and it has been growing in recent times. At present, water quality parameters in line with gross alpha/beta radioactivity are not being assessed (FDA, 2017), even though, the Ghana Standard Authority has established a recommended guideline limit values for drinking water (Ministry of Water Resources, Works and Housing, 2015). The major sources of sachet water are from borehole and few are from weija dam. This research is of significance due to inadequate knowledge on radioactivity levels in sachet water and related radiation dose to consumers in Ghana. The data obtained through this research would provide significant baseline information for ensuring public safety from radiation exposure.

METHODOLOGY

2.1 Study Area

Ashanti Region is located in the middle belt of Ghana, it regional capital is Kumasi. It lies between longitudes 0.15ºW and 2.25ºW, and latitudes 5.50ºN and 7.46ºN. The region is divided into 27 districts. It has a land cover area of about 24,389 km^2 (9,417 sq. mi) The factors considered in the selection of the study area were the time frame of the research, proximity of the sampling sites to the Alpha spectrometry laboratory of the Ghana Atomic Energy Commission (GAEC), Accra and equipment and resources availability. The map of the study area is shown below



i: Map of Ashanti Region in Ghana

2.2 Collection of Drinking Water Samples

Twenty different brands of commercially sold sachet drinking water produced in Ashanti region were selected for gross alpha/beta activity concentrations through a questionnaire survey. 1.5 L of each water sample was collected from the company production line between 8:00 am and 9:00 am into a clean two-liter (2 L) polyethylene gallon. 1M of 60% nitric acid was added to each sample to prevent the radionuclides from adhering to the gallon. The gallon was then tightly sealed, labeled and transported to the Alpha spectrometry laboratory of GAEC for analysis.

2.3 Physical Parameters Analysis

Temperature, pH, total dissolved solids and conductivity, of each sample were measured using the HI98129 potable Water Quality Test Kit from Hanna Instruments. The pH was probe was calibrated with pH 4 buffer, pH 7 buffer and pH 10 buffer solution to check for the neutral, basicity and acidity of the water contents. Distilled water was used to rinse the probe before recording the reading.

2.4 Samples Preparation for Gross Alpha and Beta Concentrations

One liter (1L) of each sample was filtered on a filtration system set up and transferred into a one liter (1L) beaker. Two millimeter (2 ml) of HNO_3 was added to all the samples to maintain and to liberate dissolved metals and dissolved organic particles. It was left to stay overnight. sample, 300 ml each sample (filtrate) was measured into Pyrex glassware, evaporated to near dryness on a hot plate in a fume chamber at a temperature of 60ºC-70ºC for three – four hours until a volume of 10-20 ml was obtained. The remaining filtrate was transferred unto 47 mm stainless-steel planchets at a temperature of 10ºC-20ºC. The samples were evaporated to dryness and placed in desiccator to prevent them from absorbing moisture and allow them cool down to room temperature before counting. Sample residues were dried to constant weight, re-weighed to investigate the residue weight using a weighing balance (Krieger, 1995).

2.5 Calibration of the Alpha/Beta Counter System

Americium-241 and strontium -90 standard sources were used to calibrate the system .It was counted 10mins to investigate the efficiency for alpha and beta. The counting efficiencies of beta and alpha were 29.40 %± 2.18% and 70.49% ± 4.39%, respectively. Americium – 241 has higher alpha particle energy (5.49MeV) than those emitted by naturally-occurring Uranium. It is therefore the prescribed radionuclide for gross alpha calibration. Strontium – 90 in equilibrium with its daughter Yttrium – 90 is the correct radionuclide for gross beta calibration. The operating voltage of the system was set at 1500 V.

2.6 Measurement of Gross Alpha/Beta Activity Concentration

The residues were counted for 200 minutes with regards to the procedure selected during the calibration of the instrument to investigate alpha/ beta concentrations within the permissible limits as recommended by WHO (2004). All the samples were counted thrice and the results were recorded.

Calculation of Gross Alpha/Beta.

$$\text{Activity} = \frac{\text{Sample Count} - \text{Background Count}}{\text{Efficiency} * \text{Mass}}$$

2.7 Data Analyses

Data were entered in Microsoft Excel and screened for errors. The data was expressed as mean ± S.D. Differences between the gross mean of the alpha, and beta concentrations of the twenty brands of sachet drinking water. WHO and GSA guideline recommended limits were analyzed using one-sample t-test, P ≤ 0.05 to investigate the statistical significance results. All analyses were investigated using R (R Core Team, 2015).

3. RESULTS

TABLE 3.1: LABELING INFORMATION ON SELECTED SACHET WATER BRANDS

Label Requirement	**Labeling information on selected sachet water brands**	
	Number of brands	**Percentage (%)**
Mineral Information	4	34.5
FDA	9	53.9
Batch Number	2	7.8
Manufacturing Date	0	0.0
Expiring Date	0	0.0
Contact Information	20	100.0

TABLE 3.2: PHYSICAL PROPERTIES OF SELECTED SACHET DRINKING WATER BRANDS

Sample ID	**Physical properties of selected sachet drinking water brands**			
	Temperature (°C)	**Hydrogen Potential**	**Total Dissolve Solids (ppm)**	**Conductivity(μs/cm)**
ASDW 1	27.2	7.05	11	22
ASDW 2	27.7	7.03	12	24
ASDW 3	27.3	7.04	10	20
ASDW 4	27.0	7.01	03	07
ASDW 5	27.5	7.11	08	16
ASDW 6	28.3	7.08	16	28
ASDW 7	28.1	8.03	13	26
ASDW 8	27.6	8.01	14	32
ASDW 9	27.8	8.04	07	14
ASDW 10	27.9	8.02	06	12
ASDW 11	28.0	7.05	05	10
ASDW 12	28.2	8.05	13	26
ASDW 13	28.4	7.14	05	06
ASDW 14	28.4	8.00	04	08
ASDW 15	28.5	7.01	09	18
ASDW 16	27.1	6.08	07	14
ASDW 17	28.2	7.02	09	18
ASDW 18	27.9	6.09	05	10
ASDW 19	27.4	7.03	06	12
ASDW 20	27.1	8.01	02	08

TABLE 3.3: GROSS ALPHA AND GROSS BETA CONCENTRATIONS FOR ALL SELECTED SACHET BRANDS

Sample ID	Gross Alpha concentration **mBq/L**	Gross Beta concentration **mBq/L**
$ASDW_1$	1.13 ± 0.02	7.12 ± 0.03
$ASDW_2$	1.22 ± 0.03	9.05 ± 0.02
$ASDW_3$	1.74 ± 0.02	21.08 ± 0.01
$ASDW_4$	2.26 ± 0.04	10.24 ± 0.02
$ASDW_5$	1.18 ± 0.02	15.13 ± 0.01
$ASDW_6$	1.56 ± 0.01	12.04 ± 0.01
$ASDW_7$	2.46 ± 0.02	8.17 ± 0.02
$ASDW_8$	3.16 ± 0.02	23.11 ± 0.01
$ASDW_9$	1.84 ± 0.01	18.08 ± 0.01
$ASDW_{10}$	2.91 ± 0.02	14.05 ± 0.02
$ASDW_{11}$	1.33 ± 0.02	9.17 ± 0.02
$ASDW_{12}$	2.05 ± 0.03	25.14 ± 0.01
$ASDW_{13}$	1.63 ± 0.01	19.12 ± 0.02
$ASDW_{14}$	3.05 ± 0.02	17.16 ± 0.01
$ASDW_{15}$	2.72 ± 0.02	11.02 ± 0.02
$ASDW_{16}$	3.74 ± 0.02	7.14 ± 0.03
$ASDW_{17}$	3.42 ± 0.01	13.02 ± 0.01
$ASDW_{18}$	2.14 ± 0.02	15.08 ± 0.02
$ASDW_{19}$	1.37 ± 0.02	20.03 ± 0.01
ASDW20	1.53± 0.01	14.01± 0.02
Average	2.12± 0.02	13.60± 0.02
GSA Recommended Limit	100	1000
WHO Recommended Limit	500	1000

WHO Recommended Limit 500 1000

4 DISCUSSIONS

4.1 Level of Patronage of the Selected Sachet Water Brands

A total of 600 respondents were used. Out of the twenty sachet drinking water brands reported, SDW 13 recorded the highest level of patronage (42%) followed by SDW 11 (30%), SDW 3 (22%) and SDW 7 (15%). SDW 14 recorded the lowest level of patronage in Ashanti region with only 2 respondents followed by SDW 8, 12 and 6 respectively. Most of these highly patronized brands were brands produced by larger corporations which advertise on a larger scale. This is in agreement with a study conducted by Rose *et al*. (2012) which reported that advertisement influenced consumer use of products in Ghana.

4.2 Product Labeling Requirement

Sachet drinking water in Ashanti region are required to be labeled with manufacturing date, expiry date, FDA code, batch number, mineral content, batch number, contact information of the manufacturer and batch number. Out of the twenty brands selected, four of the brands had the mineral content on the label, 45.7% (9 brands) had FDA codes. Two brands had batch numbers, all the brands had the contact information of the manufacturers, Also all the twenty brands had no manufacturing and expiring date on them. [Table 3.1] Results of the present study also showed that some of the sachet drinking water brands on the market are not certified and even among those that are certified, many do not meet all the labeling requirements of the FDA. Yidana *et al.* (2014) also reported that a significant number of producers of sachet water in the Tamale metropolis of Ghana were not certified. These results agree with studies conducted by Nwosu & Ogueke (2004), Olaoye & Onilude (2009) and Gyang *et al*. (2004) in Nigeria, all of which reported that most of the sachet water on the Nigerian market were not certified and did not meet the labeling requirement. Regulatory bodies must therefore intensify their monitoring on sachet water in the market and also educate the public on the consequences of patronizing these uncertified products.

4.3 Physical Properties of the Selected Brands

The physical property of selected drinking water brands is shown in table 3.1. The temperature ranged from 27.0 **°C** – 28.5 **°C**. The lowest temperature value was found with ASWD $_4$ and the highest value was found with $ASWD_{15}$. The pH value of the samples ranged from 6.08 – 8.05.$ASWD_{16}$ recorded the lowest pH value $_{\text{whileASWD12}}$ recorded the highest pH value. In this research there was a strong negative relationship between temperature and pH. The pH decreases with increasing temperature (WHO, 2008). Temperature also affects the pH of water. The lowest TDS value was recorded in $ASWD_{20}$ and the highest value was recorded in $ASWD_{6.}$ Also the highest conductivity value was found with $ASWD_8$ and the lowest value was found with $ASWD_{13}$.(WHO, 2008) proposed that TDS levels greater than 1200 mg/L will be objectionable to consumers. GSA recommended TDS level in drinking water is 1000 mg/L. From this study, all TDS values were below the WHO and GSA proposed level. Al –Amir (2012) reported that alpha counts decreased sharply by reaching certain levels of TDS due to easy absorption of radiation in high density media. Egorov *et al.* (2005) investigated TDS on alpha efficiencies, for samples containing ^{230}Th, ^{244}Cm and ^{241}Am. The strong positive correlation between TDS and conductivity values supports the widely-held view that these two parameters are directly related.

4.4 Gross Alpha/Beta Activity Concentrations of Selected Brands

Table 3.3 represents gross alpha/beta activity concentrations in twenty selected sachet drinking water samples produced in Ashanti region of Ghana. The alpha activity concentrations ranged from 1.13±0.02 - 3.74±0.02 mBq/L, with an average concentration value of 2.12±0.02 mBq/L. ASDW1 yielded the lowest alpha concentration value and ASDW16 yielded the highest value. Beta activity concentration also ranged from 7.12±0.02 - 22.11±0.01mBq/L with ASDW13 recording the lowest value and ASDW8 recording the highest concentration value. The average beta activity concentration was 13.60±0.02 mBq/L. The results investigated that gross beta concentrations were higher than the gross alpha concentrations. This can be attributed to the fact that radionuclides that decay by emitting beta particles have shorter half-lives than those that decay by emitting alpha particles. Also beta particles are more soluble in water than alpha particles. This finding is supported by a study conducted in 2012 by Al-Amir *et al* in Amman, Jordan. However, gross alpha/beta activity concentrations in this research did not exceeded WHO and GSA limits which are 0.5 and 1.0 Bq/L, 0.1Bq/L and 1.0Bq/L. The results from this study are lower than the values from different count. In Central Italy, Desideri *et al*. (2007) obtained concentrations up to 128.18 and 258.59 mBq/L for alpha and beta activity. Kleinschmidt (2004) also obtained concentrations up to 1400 and 1150 mBq/L for alpha and beta. Karamanis *et al*. (2007) measured gross alpha / beta concentrations in water in Greece and obtained results ranging from 8-94 and 71-350 mBq/L respectively.

5. CONCLUSION

Activity concentrations for gross alpha/beta analysis were conducted in twenty different brands of sachet water samples produced in the Ashanti region of Ghana using an automatic Alpha/Beta counter (Canberra, iMatic $_{TM}$) system. The investigation revealed a recorded value of concentrations for gross alpha / gross beta. It ranged from 1.13 ± 0.02 to 3.74 ± 0.02 mBq/L and 7.12 ± 0.03 to 22.11 ± 0.01 mBq/L with average values of 2.12±0.02 mBq/L and 13.60±0.02 mBq/L. Gross beta concentrations were higher in all the sachet samples. Both gross alpha and gross beta concentrations were below the recommended guideline limits set by Ghana Standard Authority and World Health Organization which is 0.5 Bq/L, 1.0 Bq/L, 0.1 Bq/L and 1.0 Bq/L respectively. From the research it was concluded that all the selected sachet drinking water have no significant hazard to the public and is radiologically safe.

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