Analysis of Gross Alpha and Gross Beta Radioactivity in Sachet Water Hawked in Birnin Kebbi, Kebbi State

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Abstract— **Natural radionuclides generally represent the main source of radiation exposure to the public. In the environment, they either arise from the direct release of Radon from ground into ambient air or through dissolution of U-and Th-series members into water. As a consequence the control of natural radionuclides in water for human consumption has become a major goal worldwide during the recent decade. Limitations were set and the need for simple and rapid procedures for their implementation becomes necessary. The simple random sampling procedure was employed to collect a total of 14 samples of sachet water in Birnin kebbi and the samples were analyzed for radioactivity content using Eurisys system-eight-channels-gas –filled proportional counters with the aim of improving the health of the people living in Nigeria particularly those who are living in Birnin Kebbi. The obtained results showed that the range of alpha activity in the sampled area is (0.006 to 0.79) Bq/L, with a geometric mean of 0.057 Bq/L and the range of beta activity was from (0.804 to 28.638) Bq/L, with a geometric mean of 3.535 Bq/L. The calculated average yearly effective dose equivalent for Gross alpha and Gross beta are 0.0149mSv/yr and 0.9238mSv/yr respectively. The effective dose limit given by WHO is 0.1mSv/yr. while water from some brand meet the recommendations of WHO, especially with regard to alpha activity quite a reasonable number does not meet the standard particularly when beta activity is considered. There is therefore need for further screening of radioactivity concentration, especially the beta activity, before the sachet water hawked in Birnin Kebbi continued to be used for drinking and domestic purposes.**

Keywords- Gross alpha, activity, Gross beta, activity contaminant limit, Effective dose, geometric mean.

I. INTRODUCTION

Water is necessity to man and his environment; it existed long before man came into existence. Man uses water for domestic and industrial supply, crop irrigation, transport, recreation, sport, commercial fisheries, power generation and waste management [1] [2][3]. Water pollution is the contamination of the water bodies such as lakes, rivers, ocean and underground water by human or natural activities which can be harmful to organisms and plants which live or uses the water [4]. Human activities and natural phenomena are constantly polluting the sources of water and affect water quality [5]. Water, whether surface or underground can be polluted by contamination with: Petroleum and refinery wastes, Mining wastes, Fertilizer and, Radioactive substances (natural and human made).

Natural water is always not completely free of radioactive isotope due to the presence of alpha and beta emitters from the natural decay series of uranium, thorium, Actinium and other isotopes such as ^{40}K [6]. Surface water and especially the groundwater play a role in the migration and redistribution of these radionuclides in the earth crust as ascertained in [3].

Naturally occurring radionuclides are present in the food we eat, the air we breathe, and the water we drink and have resulted in the health hazard among the general public [7]. The unavoidable consequence of the presence in the earth crust, air food and water, of these naturally occurring radionuclides, is the exposure of man.

In developed countries, radioactivity measurement is always part of their water quality determination. So many countries are now adopting the guideline activities recommended by the World Health Organization [8] of concentration for drinking water quality. However in country like Nigeria, no any work has been done in Birnin Kebbi of Kebbi sate with regard to radioactivity measurement. This work is going to be a major contribution in providing information about the level of radioactivity and their possible health hazards in the area under study.

To give an approximate idea of the amount of radionuclide in water, the gross alpha and gross beta activities are measured. Gross alpha activity is defined as the total activity of the alpha emitters (including ^{226}Ra) once radon has been eliminated. Gross beta radioactivity is the activity of beta emitters excluding ^{3}H, ^{14}C and other beta emitters [6]. Limit values for gross alpha and beta radioactivity concentrations for existing or new water supplies as set by WHO (2006) are 0.5Bq/l and 1.0Bq/l respectively. these guidelines, according to Rangel et al (2001) ensure an exposure lower than 0.1mSv/yr, assuming a water consumption rate of 2l/d. these recommendations apply to routine operational conditions of water supply systems and do not differentiate between natural and man-made radionuclides.

Due to the many advantages of the detection of gross alpha and beta in water, several quantification methods have been developed. The generally accepted method in several countries is based on ISO methods whose efficiency is dependent on the water residue mass [9]. The method involves evaporating water to dryness and counting the residue deposited on a planchet/disk through a gas proportional counter [10]. The ISO method adopted in this work is ISO9696, and ISO9697 [11] water quality measurement for gross alpha and beta activity in non-saline water.

There is an increasing demand for potable drinking water to satisfy the need of the uncontrolled increasing population in Birnin Kebbi city. Lack of adequate and sufficient sources of potable water in the city, led to tremendous increase in the daily consumption of sachet drinking water hawked all around the city. The quality of water therefore must be as important as the quantity, where the chemical physical, bacteriological and indeed radiological characteristics determine, to a great extent, their suitability to municipal, industrial, agricultural and domestic water demands [12]. With this increase in sachet water consumption, however, the regulations of the quality of this kind of water with regards to the limits of radioactive content is not specific. Due to the importance of drinking water for human life and the increased consumption of the sachet waters, their quality must be carefully and systematically controlled [7] and investigated so as to guarantee a low level of radioactivity.

In Birnin kebbi many sachet water production industries supplied to the market, 14 and the selection was done at random. Since the base-line radioactivity in potable water in Birnin kebbi is not known, the gross alpha and beta radioactivity were investigated in this representative sachet water with the aim of testing their radiological quality and to attempt to confirm the radiological burden on the populace. This result will also form a baseline data for radionuclide activity for the sachet water.

II. MATERIALS AND METHOD

Sample Collection and Preparation

Five (5) sachets of water were collected from each sample point (sachet water production factory). One of the sachets was used to thoroughly wash the sample container (2l polyethylene bottle) to minimize contamination. The remaining four were mixed together to give a true representation of the water samples from each sample point. The volume of water collected was such that an air space of about 1%of container capacity was created for thermal expansion (Onoja, 2004). Both the pH and the conductivity of the samples were taken in situ. To maintain the homogeneity of the samples, minimize precipitation and absorption of radionuclides to the walls of the container, all the samples were each immediately acidified with three drops of concentrated HNO_3 [5, 13, 14]. The sample containers were then labeled, tightly covered and taken to the laboratory for analysis.

Sample preparation and analysis was done at the Center for Energy Research and Training (CERT) Ahmadu Bello University, Zaria, Kaduna State. The preserved water samples were evaporated to a small volume using a Binatone regulated temperature hot plate and then transferred quantitatively to a 7.1cm^2 counting planchet whose weight has already been determined. Sample residue is dried to constant weight using the infrared radiation lamp and reweighed to determine the dry residue weight. The dry sample was then counted for alpha and beta radioactivity. The sample frequency, volume of sample used, alpha activity and beta activity were all obtained following the procedures earlier reported by [2] and [7]. The counting was done with an eight-channel-gas filled proportional counter which was first automated by entering the pre-set time, counting voltage and number of counting cycles, along with the counter characteristics (efficiency and background), volume of sample used and sampling efficiency. The mode of counting was selected arbitrarily.

The sample efficiency, background measurements and plateau test were carried out using standard methods [10].

$$Sample\ efficiecy = \frac{W_{B+S} - W_B}{0.077}\ x\ 100\% \quad (1)$$

Where: $\mathbf{W_B}$ is the weight of empty planchet,

$\mathbf{W_{B+S}}$ is the weight of planchet plus sample after evaporation,

0.077 A (mg) is the expected mass of the residue in the planchet.

Gross Alpha and Beta Counting

The gross alpha and beta counting equipment used in this work is a Eurisys System Low Background Multiple (eight) Channel Alpha and Beta detector. The equipment is a gas flow proportional counter with 450µg/cm^3 and thick window of diameter 60mm. It allows simultaneous counting on eight 300mm or 55mm diameter samples. Alpha (α) and beta (β) activity measurement on compound sources can be selective, sequential or simultaneous. The procedure involves entering the present time, number of cycles and the operational voltage. Also the count characteristics (channel efficiency, and background count rate), volume of sample used and sample efficiency were entered.

The selective counting was adopted for gross alpha measurement. High voltage of 1650V was used, and samples were counted for 5 cycles of 2700 sec per cycle. The alpha count and alpha activity were calculated using the formula (ISO, 1992).

$$The\ alpha\ count\ rate\ (\alpha) = \frac{Raw\ (\alpha) count}{count\ time}$$

$$The\ alpha\ activity\ (\alpha) = \frac{Rate\ (\alpha) - Bgd\ (\alpha)}{Sample\ efficiency\ x\ chanel\ efficiency\ x\ volume} \quad (2)$$

The selective counting was adopted for gross beta measurement. High voltage of 1700V was used, and samples were counted for 5 cycles of 2700 sec per cycle. The beta count rate and beta activity were calculated using the formula (ISO, 1992).

$$The\ beta\ count\ rate\ (\beta) = \frac{Raw\ (\beta) count}{count\ time}$$

$$The\ beta\ activity\ (\beta) = \frac{Rate\ (\beta) - Bgd\ (\beta)}{Sample\ efficiency\ x\ chanel\ efficiency\ x\ volume} \quad (3)$$

Data Presentation

The alpha activity is expressed as activity concentration C in Becquerel per liter (Bq/L) using the formula (ISO, 1992):

$$C = \frac{R_b - R_o\ x\ a_s\ x\ m\ x\ 1.02}{R_b - R_o x 1000\ x\ V} \quad (4)$$

R_b is observed sample count rate (S^{-1}), Rs is observed standard count rate (S^{-1}), R_0 is background count rate (S^{-1}), V is volume of sample in liters, m is mass in milligrams of ignited residue from volume V. It is important that the factor 1.02 be included in the final equation to correct for the 20 ml of the nitric acid added to the sample as a stabilizer.

The beta activity is expressed as activity concentration C in Becquerel per liter (Bq/L) using the formula (ISO, 1992):

$$C = \frac{R_b - R_o}{R_s - R_o}\ x\ \frac{14.4m}{1000V}\ x\ 1.02 \quad (5)$$

$\mathbf{R_b}$ is observed sample count rate (S^{-1}), $\mathbf{R_s}$ is observed standard count rate (S^{-1}), $\mathbf{R_o}$ is background count rate (S^{-1}), **V**is volume of sample in liters, **m** is mass in milligrams of ignited residue from volume V; $\frac{14.4}{1000}$ represent the specific activity of ^{40}K in KCl. The factor 1.020 was included in the final equation to correct for the 20 ml of the Nitric acid added to the sample as a stabilizer.

III. Data Presentation

A. Alpha activity

The alpha activity is expressed as activity concentration C in Becquerel per liter (Bq/L). The activity concentration is calculated using the formula ISO [10].

$$C = \frac{R_b - R_o\ x\ a_s\ x\ m\ x\ 1.02}{R_b - R_o x 1000\ x\ V} \quad (6)$$

R_b is observed sample count rate (S^{-1}), Rs is observed standard count rate (S^{-1}), R_0 is background count rate (S^{-1}), V is volume of sample in liters, m is mass in milligrams of ignited residue from volume V. It is important that the factor 1.02 be included in the final equation to correct for the 20ml of the nitric acid added to the sample as a stabilizer.

IV. Result and Discussion

The set of conditions for the counting technique are given in table 1. The results for the gross alpha radioactivity concentrations for the water samples are reported in table 2.

Table 1: Alpha and beta background values and channel efficiency

Sample Code	Brand	pH	Conductivity (µS/cm)
SW1	Mijinyawa	7.45	$1.74x10^2$
SW2	Lammude	7.42	$0.73x10^2$
SW3	Jama'a	7.44	$1.96x10^2$
SW4	Sha-Haske	7.44	$2.22x10^2$
SW5	Emirate	7.05	$0.67x10^2$
SW6	Jaji	7.23	$0.67x10^2$
SW7	Kings	7.23	$1.78x10^2$
SW8	Diza	6.90	$0.93x10^2$
SW9	Shekara	6.80	$1.56x10^2$
SW10	De-Lily	6.93	$0.68x10^2$
SW11	Abi	6.85	$0.49x10^2$
SW12	Al-Khairi	6.97	$0.76x10^2$
SW13	Daras	6.90	$0.70x10^2$
SW14	M. Gwandu	6.83	$0.78x10^2$

*Zero Detection in channels 3 and 7 are due to fault of the channels

Table 2: pH and conductivity of the sachet water samples

Channel No	Alpha background Values (cpm)	Beta background Values (cpm)	Channel Efficiency Alpha (%)	Beta(%)
1	0.084	1.050	34.84	46.47
2	0.130	0.496	33.85	35.39
3	0.000	0.000	0.000	0.00
4	0.091	0.573	35.64	38.79
5	0.036	0.459	38.20	40.66
6	0.057	0.359	31.97	42.94
7	0.000	0.000	0.000	0.00
8	0.074	0.412	36.17	34.88

Table 3: Alpha and beta Activity Concentration Obtained.

S/N	**Sample code**	**Brand**	**α – Activity (BqL^{-1})**	**β – Activity (BqL^{-1})**
1	BK01	Mijinyawa	0.030 ± 0.020	18.060 ± 1.510
2	BK02	Lammude	0.006 ± 0.010	0.804 ± 0.440
3	BK03	Jama'a	0.710 ± 0.210	1.510 ± 0.320
4	BK04	Sha-Haske	0.024 ± 0.010	1.796 ± 0.750
5	BK05	Emirate	0.023 ± 0.010	2.477 ± 0.470
6	BK06	Jaji	0.025 ± 0.010	2.315 ± 0.780
7	BK07	Kings	0.380 ± 0.070	4.420 ± 0.230
8	BK08	Diza	0.052 ± 0.020	28.638 ± 2.000
9	BK09	Shekara	0.013 ± 0.010	2.967 ± 0.490
10	BK10	De-Lily	0.790 ± 0.090	2.080 ± 0.140
11	BK11	Abi	0.059 ± 0.010	6.471 ± 0.590
12	BK12	Al-Khairi	0.017 ± 0.010	3.213 ± 0.630
13	BK13	Daras	0.024 ± 0.010	3.866 ± 0.900
14	BK14	M. Gandu	0.480 ± 0.070	3.350 ± 0.210

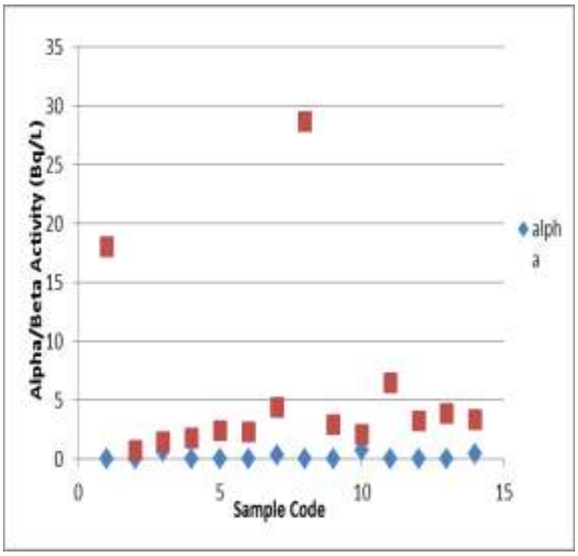

Figure 1: Graphs of Measured Alpha and Beta Activities

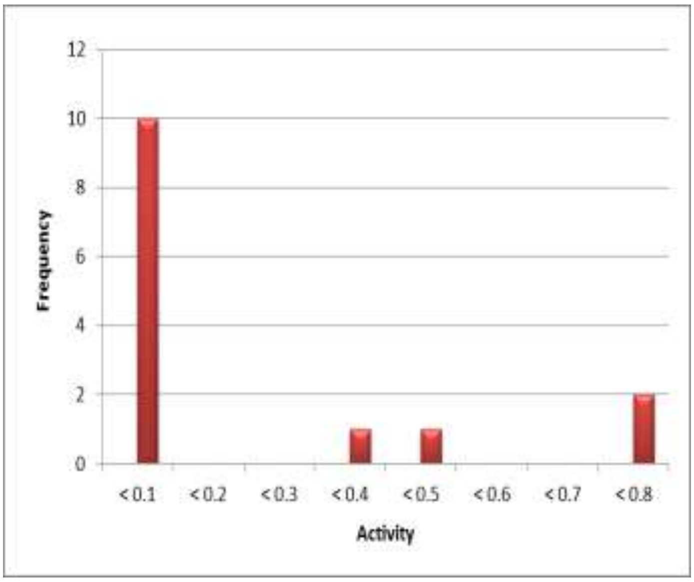

Figure 2: Histogram of Distribution of Alpha Activity in sachet water in Birnin Kebbi

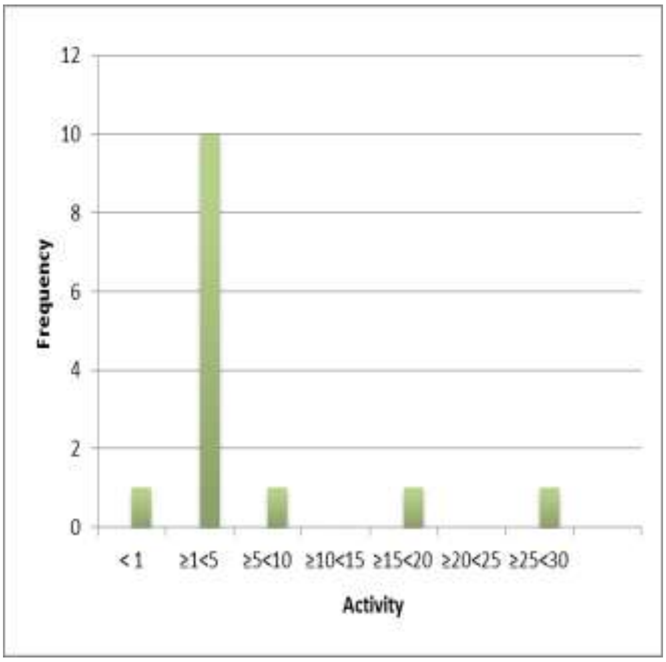

Figure 3: Histogram of Distribution Area of Beta Activity in sachet water in Birnin Kebbi Area

The variations in the conductivity values for all the samples as seen in table 1 may be related to the origin of the source of the water and the pretreatment processes undergone by the water for purification. The pH values for the samples as observed in table 1 range between 6.83 – 7.45 which are weakly acidic and falls within the range acceptable for potable water.

Gross alpha and beta activities in water from Birnin Kebbi sachet water were measured. The range of alpha activity was found to be from (0.006 to 0.79) Bq/L, with a geometric mean of 0.057 Bq/L and the range of beta activity was from (0.804 to 28.638) Bq/L, with a geometric mean of 3.535 Bq/L which give the average yearly effective dose equivalent for Gross alpha and Gross beta as 0.0149mSv/yr and 0.9238mSv/yr respectively

Figure 1 is the distribution of alpha and beta activity and shows almost no elevated alpha activities and few elevated beta activities. This may be due to the geological constituents of the surveyed area due to the fact that most of the sampled sachet water factories are using underground water. It can be seen in figure 2, that the distribution of alpha activity is skewed towards the left. This indicates that most of the sampled water has low alpha activity. Similarly, figure 3 shows similar pattern for the distribution of beta activities which is also skewed to the left; indicating that most of the sampled water has low beta activity. However the highest pocket of beta activity from the histogram is that of 1-5 level of activity, and this shows that most of the areas have beta activity above the level set by USEPA and WHO

From the result obtained for different brand of sachet water in Birnin Kebbi, 85.71% of the alpha activity and 7.1% of the beta activity were below the contaminant limit of 0.5 and 1.0Bq/L respectively, as set out by WHO (2006), while 14.29% of the alpha activity and 92.9% of the beta activity were above the contaminant limit.

It may be concluded that while water from some brand meet the recommendations of WHO, especially with regard to alpha activity quite a reasonable number does not meet the standard particularly when beta activity is considered. There is therefore need for further screening of radioactivity concentration, especially the beta activity, before the sachet water hawked in Birnin Kebbi continued to be used for drinking and domestic purposes.

V. CONCLUSION

It may be concluded that while few samples of water from some bore holes and wells in Usmanu Danfodiyo University permanent site meet the recommendations of WHO [10], quite a reasonable number does not meet the WHO standard. It however, may not pose any serious health side-effects to the public users in the campus. There is therefore need for further screening for radioactivity before the water from bore holes and wells are used for domestic, industrial, agricultural and research purposes.

REFERENCES

[1] Sa'idu, A. (2010); Survey of Gross Alpha and Beta Radioactivity in borehole and Well water from Sokoto.(Unpublished M.Sc. thesis) university of jos.

[2] Saidu A, Baba-Kutigi, A. N. and Buda, S; (2012) Determination Of Gross Alpha Radioactivity In Underground Water in Usmanu Danfodiyo University Permanent Site, Sokoto. *International Journal of Science and Advance Technology* (ISSN 2221 -8386) 2: (1) 1 – 4.

[3] Kolo M. T, Baba-Kutigi A. N, Olarinoye I. O, Sharifat I. (2009) "Survey of Gross Alpha and gross Beta radioactivity in Sachet Water Hawked in Minna, Niger State." *Journal of Science, Education and Technology 2(1): 404 – 413.*

[4] Onoja, R.A. (2004). Survey of Gross Alpha and Beta Radioactivity in Wells from Zaria. (Unpublished M.Sc. thesis) A.B.U.Zaria.

[5] Rangel J.I.D, del Rio H.L, Rod Liguez B. L, Solache M. (2001). Gross alpha and Gross beta radioactivity in drinking water from Zacatecas and Guadalupe cities, Mexico *Journal of Radioanalytical and Nuclear Chemistry, Vol. 247, No. 2, 425-428.*

[6] Avwiry G.O and Agbalagba E.O (2007). "Survey of Gross Alpha and Beta Radionuclide Activity in Okpare-Creek Delta State Nigeria" *J. of Applied Sciences. 7 (22): 3542-3546.*

[7] WHO (2006). Guidance for Drinking Water Quality. 3rd Edition. Chapter 9 (Radiological Aspect). Pp197-209.

[8] Akpa, T.C. (2004); Characteristics of the Gross Alpha/Beta Counter in the Centre for Energy Research and Training from Zaria, *Nigerian Journal of Physics Vol. 16 No. 1*

[9] International Organization for Standardization (ISO), (1992); Water Quality Measurement of Gross Beta Activity in Non-Saline Water, Thick Source Method, ISO (9697-1992 revised). Geneva, Switzerland.

[10] International Organization for Standardization (ISO), (1992); Water Quality Measurement of Gross Alpha Activity in Non-Saline Water, Thick Source Method, ISO (9696-1992revised). Geneva, Switzerland.

[11] Othman, I. and Yassine, T. (1995). Natural Radioactivity in the Syrian Environment. Science Total Environ. pp170, 119-124.

[12] Tajudeen, H.V. (2006). Survey of Radioactivity in Wells and Bore holes from Gwammaja Area of Kano City. (unpublished M.Sc. Thesis), A.B.U.Zaria.

[13] Habila Nuhu (2008). Survey of Gross Alpha and Beta Radioactivity in Jos City.(Unpublished M.sc thesis) University of Jos, Nigeria.

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