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Gross Alpha and Beta Activity Concentrations in Portable Drinking Water in Ado - Ekiti Metropolis and the Committed Effective Dose

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Abstract: *Portable water consumption has been the fastest growing and the most dynamic sector of all the food and beverage industry. Radionuclides in water is primarily a problem for water supplies which extract water from drilled holes in rocks or from springs flowing through areas with crystalline rocks. The ingested radionuclides accumulate in the human body primarily through the intake of food and water. This study determined the gross alpha- and beta-activity of major portable water sachets produced and sold by some portable water producing companies in Ado – Ekiti, and estimated the committed effective dose. The total gross alpha and beta activity concentrations in the portable drinking water within Ado-Ekiti metropolis in Ekiti state Nigeria ranged from 20 mBq/L to 357.8 mBq/L. The mean effective committed dose values of 0.15 mSv/y for children under 17 years and 0.03 mSv/y for adults obtained are below the recommended reference level of 0.1 mSv/y as suggested by WHO.*

Keywords: *Radioactivity, Portable water, committed effective dose , Gross alpha, Gross beta*

1. Introduction

Portable water consumption has been steadily growing in the world for the past 30 years. It is one of the fastest growing and the most dynamic sector of all the food and beverage industry Radionuclides in water is primarily a problem for water supplies which extract water from drilled holes in rocks or from springs flowing through areas with crystalline rocks, which have somewhat higher uranium concentrations than the average bedrock [1].

Natural radionucalides present in water beyond the recommended level are considered to have potential risks to man from their consumption at a regular rate. This is because of their long environmental half-life, high radiotoxicity and high affinity to biota. Natural radionuclides are classified as radiological toxic agents. The ingested radionuclides accumulate in the human body primarily through the intake of food and water. The contribution of drinking water to the total intake is important when the drinking-water supplies are drawn from ground water supplies, as the radium concentrations vary widely and in excess of 200 $Bq{\cdot}m^{-3}$ are not uncommon [2]. Most of the table water producing companies use groundwater as the sources for purification processess.

When groundwater moves from one place to another, it takes away the soluble radionuclides. Groundwater deposits display a diverse range of quality and chemistry [3]. The quality depends on the mineralogy and reactivity of the drift material and the degree of equilibrium that has been attained between water and rock. Elevated levels of radionuclides in ground water are associated with low-grade radionuclides deposits [4].

The average consumption per person in Nigeria is greater than 50 L/yr in spite of its excessively high price compared to tap water.

Literature reveals that the levels of some water constituents in bottled waters are in violation of action levels for various parameters, especially for some toxic natural radioelements and trace metals [5]. Concern on the total radionuclides content in water intended for human consumption has prompted the World Health Organisation (WHO) and the European Union to establish maximum allowable concentrations for these elements in drinking water supplies. Parameter values in the EC Directive 98/83 have been established for the tritium content and the total indicative dose. The WHO guidelines for drinking water suggest performing an indirect evaluation of committed dose by measuring gross alpha and beta radioactivity and checking compliance to derived limit values; the proposed limit values are 0.1 Bq/L for gross alpha and 1 Bq/L for gross beta-activity [5]. Gross alpha- and beta-activities depend on many factors, such as the time intervals between sample collection, preparation and analysis, the radionuclides used as the calibration standards, the counting efficiency etc. However the contribution of distinct radionuclides to the gross alpha- and beta-activity whould not be considered in this study.

The aim of this study was to determination of gross alpha- and beta-activity of major portable water sachets produced and sold by some portable water producing companies in Ado – Ekiti, and to estimate the committed effective dose.

2. Materials and Methods

Four different portable water sachet producing companies labelled A, B, C and D were found in Ado–Ekiti the capital city of Ekiti State Nigeria as at the time of sample collection. These companies were located at different areas of the city, which forms a sample representative for the city. Twenty different portable water sachets of each of the producing companies on the Ado – Ekiti market were selected for this study. Their capacity ranged between 0.5 and 0.75 L.

AN EURISYS MEASURE IN 20 a low background multiple (eight) channel alpha and beta counter was used for the measurements of the gross alpha and beta in the portable water samples. It is a gas flow proportional counter with 450 $\mu g/cm^3$ thick window of diameter 60 mm. The counting gas is an argon-methane mixture at the ratio of 90% and 10% respectively. The counting system incorporates an anti-coincident guard counters used to eliminate the influence of high energy cosmic radiation that would enter the measuring environment. The background radiation level within the measuring environment was estimated to be less than 1.0 mSv/hr. The chambers are covered with 10 cm thick lead and the inside dimensions are 480 x 280 x 105 mm^3. The system is connected to a micro-processor IN-SYST, a spreadsheet programmed QUARTTRO-PRO and a graphic programmer.

For the alpha activity measurements the standard used is ^{239}Pu α-sources with activity ranging from 133.3 Bq to 185.8 Bq for the eight channels at 2π-stearadians. The radionuclide impurity in each of them varied from 0.74 – 0.82% (Akpa et al, 2004, Fasae, 2013). For the beta activity measurements the standard used are ^{90}Sr β sources of diameter 38 mm and an active film of 12 $mg.cm^{-3}$ thick. For the eight channels, eight sources of activities varied from 105.1-Bq to 117.7Bq at 4π-stearadians. The radionuclide impurity in each of them was less than 0.1%. Cerca and LEA Laboratories in France certified all measurements with certificate No. CT001271/00/1778 – 1783 [6, 7].

The beta and alpha specific activities were calculated using the following expression [6, 7]:

$$Specific\ Activity(\alpha,\beta)\ Bq/kg = \frac{Counting\ Rate\ (\alpha,\beta) - Background\ \ counting\ rate\ (\alpha,\beta)}{Sample\ \ Efficiency \times Channel\ \ Efficiency \times Weight\ of\ \ sample} \tag{1}$$

3. Results and Discussions

3.1. Gross and Beta Activity Concentrations

The gross alpha and Beta activity concentrations in the portable water sachets samples sold in Ado – Ekiti, the capital city of Ekit state Nigeria are presented in Table 1. The activity concentrations of the gross α and β measured in the portable water sachets samples in brand B, which has the lowest values ranged from 2.0 mBq/L to 9.4 mBq/L with a mean value of 5.8 ± 2.9 mBq/L and 11 mBq/L to 19.9 mBq/L with a mean value of 14.7 ± 2.4 mBq/L respectively. The brand C portable water sachets samples has the highest gross α and β activity concentration values which ranged from 130.9 mBq/L to 176.6 mBq/L with a mean value of 151.1 ± 2.9 mBq/L and

201.6 mBq/L to 222.5 mBq/L with a mean value of 206.5 ± 9.5 mBq/L respectively. Fig. 1 also shows the gross alpha and beta activity concentrations in the portable water samples from the different companies within the city.

Table1. *The mean and range of activity concentration of gross alpha and beta (mBq/L) in different brands of portable water samples investigated*

Brand of Portable Water	No of samples	Gross alpha (mBq/L)	Gross beta (mBq/L)	Total gross alpha and beta (mBq/L)
A	20	57.6 ± 7.5 (43.2 – 68.2)	40.8 ± 6.2 (31.0 – 47.7)	98.4
B	20	5.8 ± 2.9 (2.0 – 9.4)	14.7 ± 2.4 (11.0 – 19. 9)	20.5
C	20	151.1 ± 14.4 (130.9 – 174.6)	206.5 ± 9.5 (201.6 – 222.5)	357.6
D	20	53.2 ± 4.1 (52.9 – 55.6)	34.9 ± 0.7 (33.5 – 36.0)	88.1

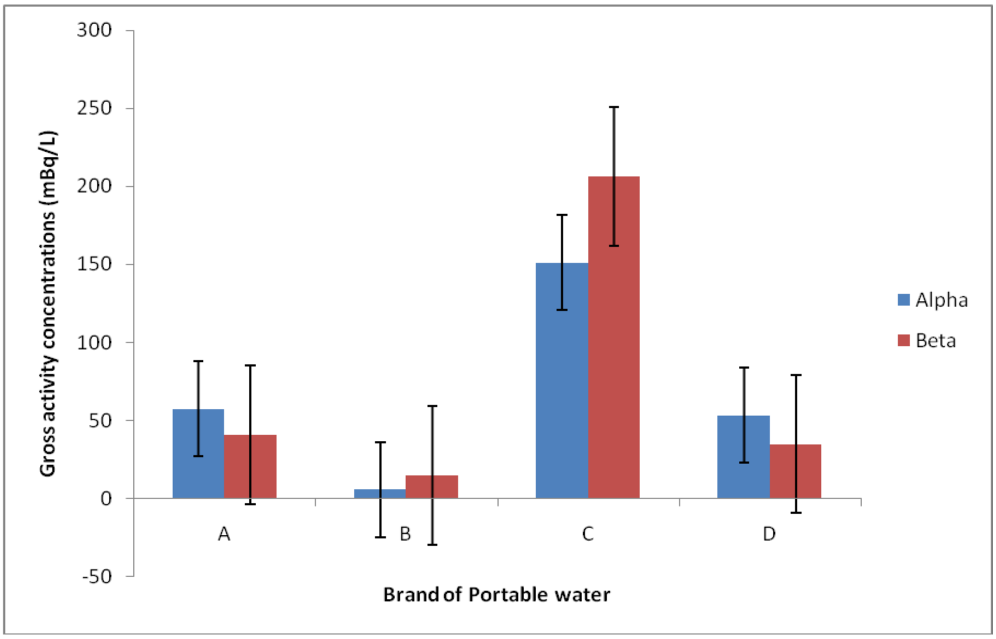

Fig1. *Gross alpha and beta activity concentrations in brands of portable water in Ado- Ekiti*

T- test for equality of means showed that there is significant difference at 5% significant level in the gross alpha and beta activities determined in all the samples showing that the gross alpha and beta activities determined were not the same in the study area. A two way ANOVA at the same significant level further confirmed that the gross alpha and beta activities differ from one another with respect to the locations considered in this study. There is positive correlation between the gross alpha and gross beta activities as shown in Fig. 2, having pearson correlation coefficient of $r = 0.963$.

The portable water producing companies are situated in different areas in the city, this may account for the variations in the gross alpha and beta activity concentrations in the portable water samples in the city. This may also depend on the the mineralogical and geochemical composition of the soil and rock, chemical composition of the water, the degree of weathering of the rock, redox conditions and the residence time of ground water in the soil and bedrock [8]. The dependence of the gamma and beta activity concentrations on the season (summer and winter) was not considered in this study. The portable water with the highest gross alpha and beta activity concentrations are from the company situated at Dallimore area in the city, this agrees with Fasae [7] on dung well water. The determined activity concentration values are lower than the values obtained in dung well water by Fasae [7]. This may be attributed to the depth of the dung/ drilled well and treatment of the portable water before sales for public consumption, where as the dung well water samples did not undergo any treatment processes before gross alpha and beta activity values were determined. The area is covered with more rocks and hills compare to other areas within Ado-Ekiti metropolis. In agreement with similar results, it is evident that mineral ground waters are the most radioactive [5].

It can be seen clearly from Table 1 that all the values of the gross alpha activity concentrations are lower than recommended upper limit value of 500 mBq/L while all the values of the gross beta activity concentrations are lower than recommended upper limit value of 1000 mBq/L. The gross alpha and beta activity concentrations obtained compare well with other values reported in literatures as presented in Table 2.

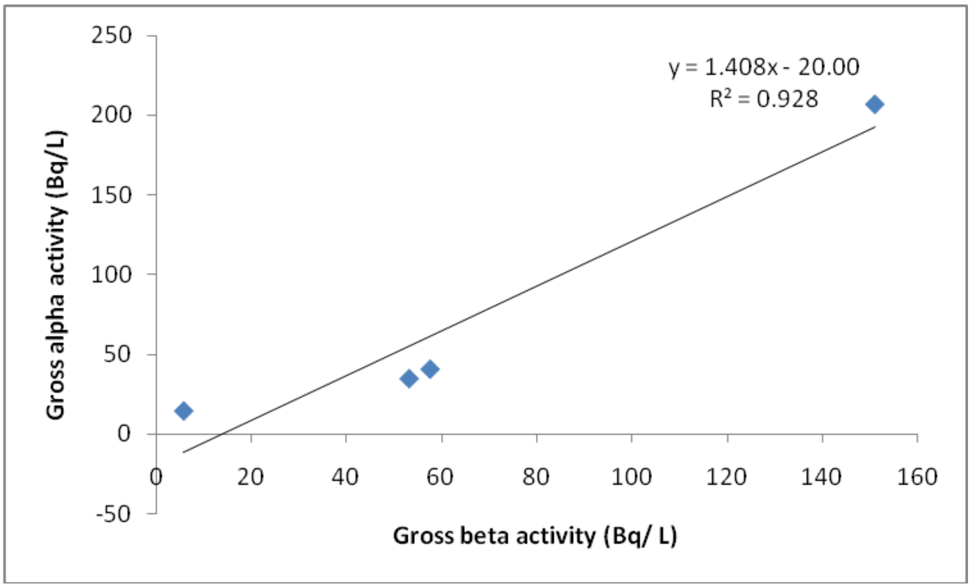

Fig2. *Correlation of gross alpha and beta activities in portable water in the study area*

Table2. *Comparison of the gross α and β concentrations determined in portable drinking water samples with those reported in other countries*

Country	Gross alpha (mBq/L)	Gross beta (mBq/L)	References
Greece	82	283	[5]
Turkey	192	579	[9]
Brasil	1 – 400*	120 – 860*	[10]
Jordan	29 – 3146*	0 – 5014*	[11]
Nigeria	216 – 1299*	64 – 582*	[7]
Nigeria	5.8 – 174*	14.7 – 222.5*	This study

** Range*

3.2. Estimation of Effective Committed Dose

Radionuclide may reach the gastrointestinal tract directly by ingestion or indirectly by transfer from the respiratory tract. From small intestine (S1) the radionuclide can be absorbed to the body fluids. Annual committed effective dose associated with radiation exposure through ingestion of portable water sample was estimated to assess the health risk for adult and children members of the public.

The committed quantities, because of small effective half-lives, are practically realized within one year after intake [12]. In this work, the effective dose over one year was calculated using the following relation.

$$E = I\,AC \times 365 \quad (2)$$

where I is the daily water consumption in l/day, A is the activity/l; C is a dose conversion factor in Sv/Bq. Dose conversion factors used to calculate the internal radiation exposure via ingestion of radionuclide by IAEA [13] were considered.

The committed effective doses due to gross alpha are estimated using equation 2. The dose coefficient for ingestion factors of 1.5×10^{-6} for children and 2.8×10^{-7} for adult. It is assummed that an adult consumes about 2 litres of water daily which corresponds to 730 L/y, while a child is assummed to consume about 200 L/y [14, 15]. The estimated committed effective dose values are presented in Table 3.

Table3. *The annual committed effective dose (mSv/y) calculated for the different brand of the portable water samples*

Portable water brand sample	Total gross α and β (mBq/L)	Annual committed effective dose (mSv/y)	
		Children (17yrs)	Adults
A	98.4	0.108	0.020
B	20.5	0.022	0.004
C	357.6	0.392	0.073
D	88.1	0.096	0.018

The annual committed effective dose calculated values for children under 17 yrs of age ranged from 0.022 mSv/y to 0.0392 mSv/y with a mean value of 0.15 mSv/y while the values ranged from 0.004 mSv/y to 0.073 mSv/y with a mean value of 0.03 mSv/y for Adults. These effective committed dose values are within the dose reference level of 0.1 mSv/y as suggested by WHO [16]. Therefore the consumption of the portable water sachets sold in the city is of minor concern for the public health.

However, portable drinking water producing companies should include other purification processes such as Reverse Osmosis (RO) which takes out all dissolve mineral radionuclides, and any other unrecognized contaminants, this will further reduce the radiological burden to the population.

4. Conclusion

The gross alpha and beta activity concentrations in portable drinking water samples collected from the different areas in Ado-Ekiti metropolis in Ekiti state Nigeria were determined to investigate the radiological burden to the population. The data obtained can be used as a baseline for ascertaining possible changes in radioactivity concentrations in portable drinking water samples in Ekiti state capital in Nigeria. The mean committed effective dose values of 0.15 mSv/y for children under 17 years and 0.03 mSv/y for adults obtained are within the recommended limits.

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