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Annual Effective Dose Estimation due to Gross Alpha and Beta Activities in Nigerian Bottled Drinking Water

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Abstract:
Background: *Extremely humid, hot and dry climatic conditions of Nigeria has led to an increasing demand for clear and clean portable water supply across the nation. Additionally, the dehydrating traffic situations commonly witnessed in virtually all the major cities in Nigeria has made consumption of bottled water indispensable component of modern life in Nigeria. It is therefore important that the radiological burden incurred by the Nigerian population from ingestion of bottled water be investigated.*
Materials and Method: *Twenty one brands of commercial bottled water regularly consumed in Nigeria were obtained from standard supermarkets and investigated for their gross alpha and gross beta radioactivity. This analysis, as a recommended first step in radio analytical screening, was performed using a gas-free, low background dual phosphor proportional counter.*
Results: *Results of the analysis showed that mean values for gross alpha and gross beta activity concentrations in all the investigated bottled water samples were 15.22±0.93 mBq l^{-1} and 39.69±1.83 mBq l^{-1} respectively. These values were below safety limits recommended by the World Health organization. Computed average annual effective dose equivalent for adults, children and infants (lactating age) in Nigeria due to consumption of commercial bottled water were lower than the recommended safeguard of 0.1 mSv for drinking water.*
Conclusion: *The results does not suggest any radiological threat to the health of consumers. However, intermittent monitoring of commercially consumed bottled water is recommended for water quality compliance from radiation safety perspective.*

Key Words: *Gross alpha; gross beta; bottled water; effective dose equivalent; gas-free proportional counter; Nigeria*

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I. Introduction

Potential health challenges from naturally occurring radioactive materials (NORM) associated with the consumption of portable water has attracted serious attention throughout the world. Many countries have developed their respective safety guidelines, while others have adopted the guidelines provided by the world health organization [1] for drinking water quality. Routine monitoring and assessment of radioactivity contents of portable drinking water is a significant indices in public health studies because it helps to ensure drinking water quality and alsoin determining the level of exposure of human populace to radiation via ingestion of water[2, 3]. The first preliminary procedure recommended by the world health organization (WHO) for assessing the radiological content of portable water is the determination of gross alpha and gross beta radioactivity [1]. It is a simple analytical procedure which according to Bunotto and Bueno[4], is of greater importance as it offers useful parameters for preliminary screening of portable water supply sources. This importance, according to Ogundare and Adekoya [5],may be due to high LET of alpha particles which enables them deposit high amount of energy within short distances. According to UNSCEAR[6], about 8% of the total human radiation exposure from both external and internal radiation sources can be attributed to food and water consumption. To ensure exposure level of below 0.1 $mSvy^{-1}$ from the ingestion of water, therefore, WHO recommended safety limit of 0.5Bq $l^{-1}$for gross alpha and 1.0 $Bql^{-1}$for gross beta radioactivity in drinking water [1].

Extremely humid, hot and dry climatic conditions of Nigeria has led to an increasing demand for clear and clean portable water supply across the nation. The challenge is more severe in urban cities where continuous population growth as a result of urban migration is putting increasing pressure on their already slim and weak

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water supply systems. Additionally, the dehydrating traffic situations commonly witnessed in virtually all the major cities in Nigeria has made consumption of bottled water indispensable component of modern life in Nigeria. Bottled water producing companies are on the increase in Nigeria to meet the growing demand for clean and safe drinking water. According to Asaduzzaman et al [7] and Fatima et al [8],most of these companies process and package water with little regard for the safety guidelines provided by the world health organization and the International Bottled Water Association [9]. Major water supply sources for these companies are the locally drilled wells and community tap water together with natural flowing springs and groundwater from deep sited aquifers [10]. These water sources contain traces of radioactive nuclides which occur naturally or as a result of anthropogenic activities. Alpha and beta emitters from the decay series of thorium and uranium together with other available radio isotopes such as ^{40}K are major sources of radiological contamination of portable water sources [10-12].

Bottled water has not just become an indispensable component of human diet in Nigeria, it is also used efficiently in the preparation of liquid milk for lactating children. The incorporation of radio isotopes into the human body via direct ingestion of water or indirectly as a component of human food chain is a principal source of internalexposure[11]. Once ingested, the radionuclides are absorbed via the blood stream and deposited on specific sensitive body tissues thereby causing tissue damage. It is therefore paramount that the quality of commercially consumed bottled water in Nigeria is not compromised with respect to the health and wellbeing of the consumers. Sufficient data must thus be provided that will assist regulatory agencies in the establishment of radiation safety guidelines for the production and consumption of bottled water [13].

Several extensive investigations have been conducted worldwide on the quality and safety of portable water with respect to its radioactivity content[8, 12, 14-21]. Very little information is however available in literature about the radioactivity content of commercially consumed bottled water in Nigeria. This study therefore, focuses on the estimation of gross alpha and gross beta radioactivity of commercially consumed bottled water in Nigeria and to estimate the corresponding annual effective dose to adults, children and infants (lactation age)from its consumption.

II. Materials And Method

Twenty one (21) brands of commercial bottled water were purchased for analysis from various public supermarkets across Nigeria. The bottled water brands chosen represents the highest selling and most consumed brands on daily basis by the Nigerian population. The samples were acidified immediately after purchase with extra pure HNO_3 to reduce the pH to 2 and prevent as much as possible, the change in state of the ions present and the clinging of radioactive elements to the walls of the containing vessels [22]. All the acidified samples were corked tightly and transferred to the laboratory at the Centre for Energy Research and Training (CERT), Ahmadu Bello University, Zaria, Nigeria for analysis.

At the laboratory, the samples were evaporated slowly at 60^0 C for about 14 hours to 50 ml using hotplate. This was then transferred to a cleanly washed petri-dish and placed under infra-red light for further evaporation to obtain completely dry sample residue. The dry sample residue was again washed with distilled water after which 0.077 g of sample was transferred into an already weighed counting planchette (ISO-Standard) using rubber policeman. Few drops of Vinyl acetate which act as binder were added to the sample to bind it to the planchette. This was finally stored for about 28 days in a desiccator for it to equilibrate and made ready for counting.

Sample counting for gross alpha and beta activities was done in a gas-free, low background Protean MPC-2000-DP (serial number: 01872140) proportional counter. The counter is a dual phosphor scintillator detector which is supplied with an aluminium window, coupled to a photomultiplier tube and encased in a light tight enclosure. The detector which was accurately calibrated for alpha and beta energies using plutonim-239 (alpha source) and strontium-90 (beta source) has alpha detector efficiency of 87.95% and beta detector efficiency of 42.06%, with alpha and beta background count rate of 0.77 cpm and 0.70 cpm respectively. Detector background was obtained by counting a clean, empty planchette under same conditions as that of the samples. For alpha counting, the detector was set at α-only mode and for beta counting, at β-mode. Alpha and beta activity concentrations measured in Bql^{-1} were calculated from the formula[23, 24]:

$$(\alpha/\beta)\ activity = \frac{count\ \ rate\ \ (\alpha/\beta) - background\ \ (\alpha/\beta)}{detector\ \ efficiency\ \times sample\ \ efficiency\ \times sample\ \ volume} \tag{1}$$

Assessment of the annual effective dose equivalent:

Annual effective dose incurred by any individual due to radionuclide ingestion from consumption of bottled water was calculated using the equation[8, 15]:

$$AED\ (\mu Sv\ y^{-1}) = C_w \times IR_w \times IDF \tag{2}$$

where AED is the annual effective dose, C_w gross alpha/gross beta activities in mBq l^{-1}, IR_w is the water intake per person per year and IDF the dose conversion factor for the radionuclides of interest. Radionuclides assumed to have contributed to alpha and beta radioactivity in the investigated bottled water, together with their respective IDFs are listed in Table 1. In assessing the annual effective doses for the three sub populations, it was assumed that adults, children and infants respectively consume 730, 350 and 250 litres of water yearly, indicating that an adult consumes at least 2 litres of water daily.

Table 1: Annual effective dose conversion factors (IDF) used in this study [1]

Radionuclides	IDF (mSv Bq^{-1})	
	Gross alpha	Gross beta
U-238	4.5 ± 10^{-5}	
U-234	4.9 ± 10^{-5}	
Th-230	2.1 ± 10^{-4}	
Ra-226	2.8 ± 10^{-4}	
Po-210	1.2 ± 10^{-3}	
Th-232	2.3 ± 10^{-4}	
Pb-210		6.9 ± 10^{-4}
Ra-228		6.9 ± 10^{-4}

III. Results and Discussion

Measured gross alpha and gross beta radioactivity in the investigated commercial bottled water consumed in Nigeriaare shown in Table 2. Results showed that alpha activity recorded a mean value of 15.22±0.93 $mBql^{-1}$, with Mr. V showing the highest alpha activity of 74.27±2.25 mBq l^{-1}. Alpha activity was however below detection limit in four water samples namely Aquadana (TW 9), Fedcam (TW 11), Swan (TW 13) and Visleri (TW 18).

Table 2: Gross alpha and gross beta activity concentrations in Nigerian bottled water

		Activity concentration (mBq l^{-1})	
Water sample name	**Sample ID**	**Gross alpha**	**Gross beta**
Nestle pure life	TW 1	0.59±0.05	8.23±0.85
Eva	TW 2	11.22±0.74	8.67±0.94
Bigi	TW 3	2.13±0.62	4.46±0.86
C'est born	TW 4	2.76±0.65	9.61±0.92
Mr. V	TW 5	74.27±2.25	170.84±3.15
Habees	TW 6	10.92±0.80	33.6±1.17
Goje	TW 7	35.87±1.26	62.5±1.56
Golden age	TW 8	7.35±0.97	21.69±1.23
Aquadana	TW 9	bdl	24.26±11.14
Tudunwada	TW 10	18.09±1.42	151.34±2.08
Fedcam	TW 11	bdl	75.23±2.08
Faro	TW 12	7.7±2.28	128.88±2.10
Swan	TW 13	bdl	12.75±1.19
Sona	TW 14	0.68±0.04	9.57±0.63
Hi merit	TW 15	17.11±0.63	13.94±0.99
Leah Smart	TW 16	2.82±0.77	8.26±0.96
Glova	TW 17	14.95±0.77	27.58±1.39
Visleri	TW 18	bdl	17.92±0.94
Peace	TW 19	11.75±0.91	3.69±1.55
DJE	TW 20	26.58±0.93	9.26±1.45
Larisa	TW 21	13.89±0.75	31.22±1.32
Min		**bdl**	**3.69±1.55**
Max		**74.27±2.25**	**170.84±3.15**
Mean		**15.22±0.93**	**39.69±1.83**

Gross beta activity ranged from 3.69±1.55 mBq l^{-1} for Peace (TW 19) bottled water to 170.84±3.15 mBq l^{-1} for Mr. V (TW 5), with overall average beta activity value of 39.69±1.83 mBq l^{-1}. WHO guidelines for drinking water quality [1] recommends practical gross alpha screening level of 0.5 mBq l^{-1} and gross beta screening limit of 1.0 mBq $l^{-1}$for portable water. Below these values therefore, no risk is envisaged. Although gross alpha activity showed lower values compared to gross beta activity in the investigated bottled water brands, their values were below the respective recommended screening levels by WHO.

Gross alpha activity showed very weak linear correlation (R^2 = 0.0246) with gross beta radioactivity in the investigated bottled water samples as seen in Fig 1. This suggests that alpha activity and beta activity in the bottled drinking water are from different radionuclide sources.

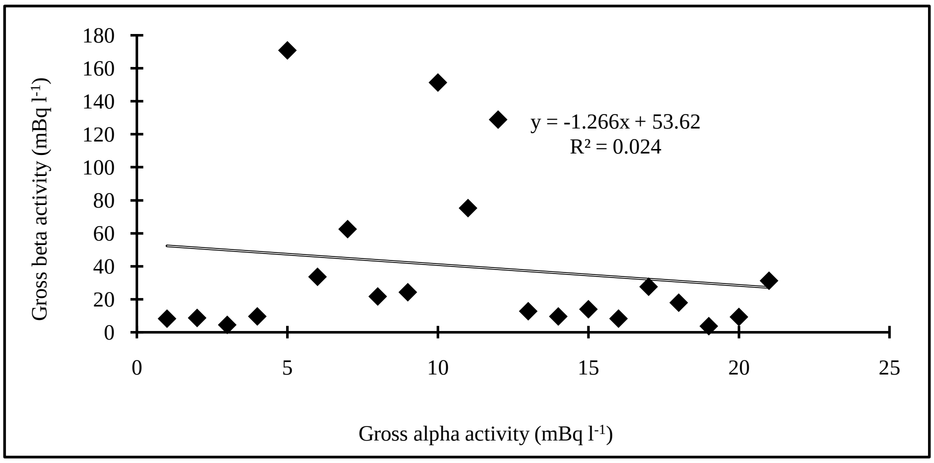

Fig. 1: Gross alpha and gross beta activity correlation forNigerianbottled water brands

Annual effective equivalent dose intake for babies at sucking age (less than 1 year), children (aged 2 to 7 years) and adults (aged above 17 years) due to gross alpha and gross beta radioactivity in Nigerian bottled water were computed using Equation 1 and the results presented in Tables 3 and 4. The highest contribution to annual effective dose equivalent incurred by the population groups due to gross alpha activity in the investigated bottled water samples comes from ^{210}Po and occur in the order adult>children>sucking babies as seen in Table 3.

Similarly, annual effective dose equivalent from gross beta activity increases in the same fashion as adults>children>sucking babies (Table 4). Total effective dose equivalent incurred per year by sucking babies, children and adults from gross alpha and beta activities in the analysed bottled water brands are shown in Figs. 2 and 3.

Table 3: Annual Effective Doses (μSv y^{-1}) of Alpha emitters in Nigerian bottled water brands

	U-238			U-234			Th-230			Ra-226			Po-210			Th-232		
Water sample	**Suck age**	**Children**	**adult**	**suck age**	**Children**	**adult**	**suck age**	**Children**	**adult**	**suck age**	**Children**	**adult**	**suck age**	**Children**	**adult**	**suck age**	**Children**	**adult**
Nestle pure	0.07	0.09	0.02	0.01	0.01	0.02	0.03	0.04	0.09	0.04	0.06	0.12	0.18	0.25	0.52	0.03	0.05	0.10
Eva	1.26	1.77	0.37	0.14	0.19	0.40	0.59	0.82	1.72	0.79	1.10	2.29	3.37	4.71	9.83	0.65	0.90	1.88
Bigi	0.24	0.34	0.07	0.03	0.04	0.08	0.11	0.16	0.33	0.15	0.21	0.44	0.64	0.89	1.87	0.12	0.17	0.36
C'est born	0.31	0.43	0.09	0.03	0.05	0.10	0.14	0.20	0.42	0.19	0.27	0.56	0.83	1.16	2.42	0.16	0.22	0.46
Mr. V	8.36	11.70	2.44	0.91	1.27	2.66	3.90	5.46	11.39	5.20	7.28	15.18	22.28	31.19	65.06	4.27	5.98	12.47
Habees	1.23	1.72	0.36	0.13	0.19	0.39	0.57	0.80	1.67	0.76	1.07	2.23	3.28	4.59	9.57	0.63	0.88	1.83
Goje	4.04	5.65	1.18	0.44	0.62	1.28	1.88	2.64	5.50	2.51	3.52	7.33	10.76	15.07	31.42	2.06	2.89	6.02
Golden age	0.83	1.16	0.24	0.09	0.13	0.26	0.39	0.54	1.13	0.51	0.72	1.50	2.21	3.09	6.44	0.42	0.59	1.23
Aquadana	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl
Tudunwada	2.04	2.85	0.59	0.22	0.31	0.65	0.95	1.33	2.77	1.27	1.77	3.70	5.43	7.60	15.85	1.04	1.46	3.04
Fedcam	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl
Faro	0.87	1.21	0.25	0.09	0.13	0.28	0.40	0.57	1.18	0.54	0.75	1.57	2.31	3.23	6.75	0.44	0.62	1.29
Swan	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl
Sona	0.08	0.11	0.02	0.01	0.01	0.02	0.04	0.05	0.10	0.05	0.07	0.14	0.20	0.29	0.60	0.04	0.05	0.11
Hi merit	1.92	2.69	0.56	0.21	0.29	0.61	0.90	1.26	2.62	1.20	1.68	3.50	5.13	7.19	14.99	0.98	1.38	2.87
Leah Smart	0.32	0.44	0.09	0.03	0.05	0.10	0.15	0.21	0.43	0.20	0.28	0.58	0.85	1.18	2.47	0.16	0.23	0.47
Glova	1.68	2.35	0.49	0.18	0.26	0.53	0.78	1.10	2.29	1.05	1.47	3.06	4.49	6.28	13.10	0.86	1.20	2.51
Visleri	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl
Peace	1.32	1.85	0.39	0.14	0.20	0.42	0.62	0.86	1.80	0.82	1.15	2.40	3.53	4.94	10.29	0.68	0.95	1.97
DJE	2.99	4.19	0.87	0.33	0.46	0.95	1.40	1.95	4.07	1.86	2.60	5.43	7.97	11.16	23.28	1.53	2.14	4.46
Larisa	1.56	2.19	0.46	0.17	0.24	0.50	0.73	1.02	2.13	0.97	1.36	2.84	4.17	5.83	12.17	0.80	1.12	2.33
Min	**bdl**	**bdl**	**bdl**	**bdl**	**bdl**	**bdl**	**bdl**	**bdl**	**bdl**	**bdl**	**bdl**	**bdl**	**bdl**	**bdl**	**bdl**	**bdl**	**bdl**	**bdl**
Max	**8.36**	**11.70**	**2.44**	**0.91**	**1.27**	**2.66**	**3.90**	**5.46**	**11.39**	**5.20**	**7.28**	**15.18**	**22.28**	**31.19**	**65.06**	**4.27**	**5.98**	**12.47**
Mean	**1.71**	**2.40**	**0.50**	**0.19**	**0.26**	**0.54**	**0.80**	**1.12**	**2.33**	**1.07**	**1.49**	**3.11**	**4.56**	**6.39**	**13.33**	**0.87**	**1.22**	**2.55**

Table 4: Annual Effective Doses (µSv y^{-1}) of Beta emitters in Nigerian bottled water brands

	Pb-210			Ra-228		
Water sample	**suck age**	**children**	**adult**	**suck age**	**children**	**adult**
Nestle pure	1.42	1.99	4.15	1.42	1.99	4.15
Eva	1.50	2.09	4.37	1.50	2.09	4.37
Bigi	0.77	1.08	2.25	0.77	1.08	2.25
C'est born	1.66	2.32	4.84	1.66	2.32	4.84
Mr. V	29.47	41.26	86.05	29.47	41.26	86.05
Habees	5.80	8.11	16.92	5.80	8.11	16.92
Goje	10.78	15.09	31.48	10.78	15.09	31.48
Golden age	3.74	5.24	10.93	3.74	5.24	10.93
Aquadana	4.18	5.86	12.22	4.18	5.86	12.22
Tudunwada	26.11	36.55	76.23	26.11	36.55	76.23
Fedcam	12.98	18.17	37.89	12.98	18.17	37.89
Faro	22.23	31.12	64.92	22.23	31.12	64.92
Swan	2.20	3.08	6.42	2.20	3.08	6.42
Sona	1.65	2.31	4.82	1.65	2.31	4.82
Hi merit	2.40	3.37	7.02	2.40	3.37	7.02
Leah Smart	1.42	1.99	4.16	1.42	1.99	4.16
Glova	4.76	6.66	13.89	4.76	6.66	13.89
Visleri	3.09	4.33	9.03	3.09	4.33	9.03
Peace	0.64	0.89	1.86	0.64	0.89	1.86
DJE	1.60	2.24	4.66	1.60	2.24	4.66
Larisa	5.39	7.54	15.73	5.39	7.54	15.73
Min	**0.64**	**0.89**	**1.86**	**0.64**	**0.89**	**1.86**
Max	**29.47**	**41.26**	**86.05**	**29.47**	**41.26**	**86.05**
Mean	**6.85**	**9.59**	**19.99**	**6.85**	**9.59**	**19.99**

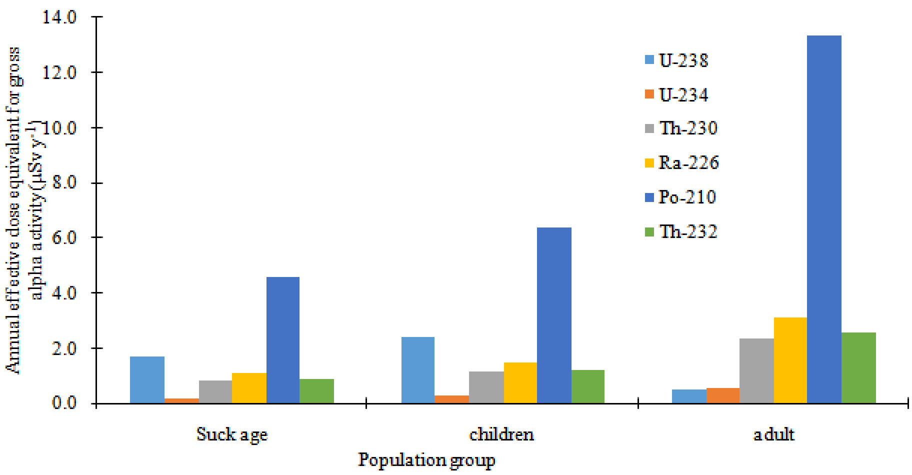

Fig. 2: Annual effective dose equivalent for gross alpha activity in Nigerian bottled water

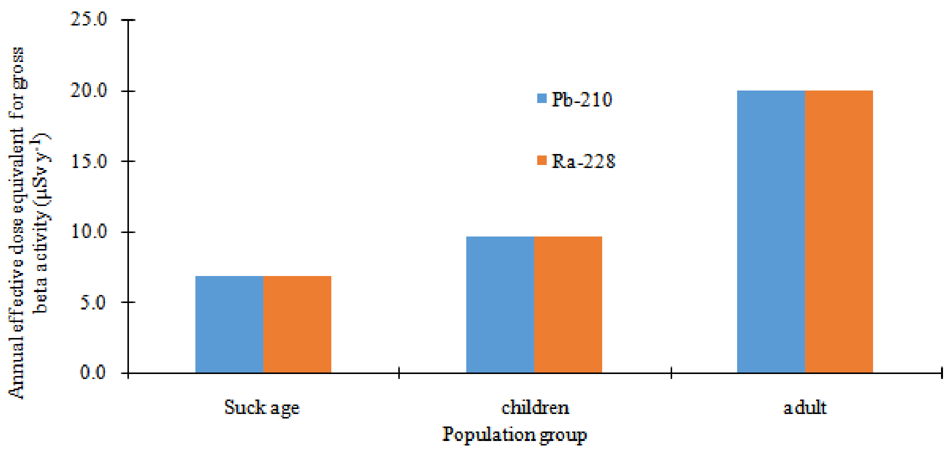

Fig. 3: Annual effective dose equivalent for gross beta activity in Nigerian bottled water

The highest contribution of 13.33 μSv y^{-1} to the overall annual effective dose equivalent due to alpha emitting radionuclides in the studied bottled water samples as seen in Fig.2 comes from ^{210}Po, while ^{234}U recorded the least alpha value of 0.19 μSv y^{-1}. Generally, total annual effective dose equivalent due to alpha and beta emitting radionuclides in this investigation are below the screening level of 0.1 μSv y^{-1} recommended by the world health organization (WHO) for public water consumption. The investigated bottled water are therefore fit for consumption by the adults, children and the suckling from the radiation point of view.

IV. Conclusion

Twenty one brands of frequently consumed commercial bottled water in Nigeria were investigated for their gross alpha and gross beta activities as a preliminary step in assessing their radiological quality.Measured average activities of 15.22±0.93 mBq l^{-1} and 39.69±1.83 mBq l^{-1} for gross alpha and gross beta contents respectively were comparable with results of similar studies reported in literature. These values were also lower than safety limits documented in the World Health organization report for drinking water. Average annual effective dose equivalent computed for the three sub-populations (adults, children and sucking age) from alpha and beta emitters in Nigerian bottled water were below WHO recommended safety limits. Consumption of commercial bottled water does not therefore, pose any radiological risk to the Nigerian population. Although the results of this analysis does not suggest further detailed radiological screening, data presented here could serve as good baseline for the regulatory authorities in setting up safety standards for drinking water quality in Nigeria.

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