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Assessment of commited effective dose from drinking water available to anyigba dwellers, north central Nigeria

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Abstract
The study of the committed effective dose from drinking water available to Anyigba dwellers have been carried out using a background Gasless Alpha-Beta Counting System (Protean Instrument Corporation) – MPC 2000DP. The gross alpha and gross beta activity concentrations of the collected water samples were below the safe limits of 0.5 Bq/l and 1 Bq/l respectively, as recommended by the world health organization (WHO). Also, results of the committed effective dose calculated were all below the reference dose level (RDL) of 0.1mSv/yr. Hence, Anyigba dwellers are radiologically safe as they consume their water from the various sources studied in this research work.

Keywords: drinking water, gross alpha, gross beta, effective dose, anyigba

Introduction

Water is the most abundant liquid on earth. It covers more than 70% of the earth's surface and it remains the most important natural resource to man. It has several domestic and industrial uses and supports the growth of both plants and animals (including humans). Summarily, water sustains the planet and of course the existence of life.

The importance of water to humans especially for our daily domestic needs (like drinking, bathing, cooking, washing, cleaning etc.) can never be overemphasized. Hence, the need to properly monitor and manage our various water sources to eliminate pollution of any kind that may reduce their quality or cause us serious health challenges or even death.

Water bodies including oceans, lakes, lagoons, rivers and underground water usually get contaminated due to natural activities and human actions. It's common sight to find people washing and bathing at the bank of our rivers in Nigeria. Also, processing and disposal of agricultural and industrial waste/sewage, mining waste, electronic waste (e-waste), radioactive waste, petroleum waste etc. are some human activities found around our water bodies. Over 1 billion people have no access to safe drinking water and over fifty percent of them suffer from water related health problems [19]. The United Nations reported that 80% of wastewater resulting from human activities is discharged into rivers or seas without any pollution removal.

The population of Anyigba town has increased drastically due to rural –urban drift largely owing to the establishment of Kogi State University in 1999. Hence, the demand for healthy drinkable water has risen astronomically. In the absence of a well reticulated public water supply system, most people depend on rivers, rain water (during the raining season) and a few commercial (private) boreholes for their daily water needs with little or no regards for the quality and safety of what they consume. Moreover, recent discoveries of high amount of parasitic contamination of drinking water sources in Dekina local government area of Kogi State [10] has necessitated more inquiry into the quality of water consumed by the people, especially the radiological safety of drinking water sources to the populace, as data is scarce in this regard.

Natural contamination of our water bodies is mainly due to the presence of Naturally Occurring Radioactive Materials (NORMs) in the earth crust. Rivers (and other water bodies) flow through rocks that may contain radioactive materials and could be transported into boreholes, wells, and tap water via ruptured pipes [11]

Radionuclides emit dangerous, life-threatening radiation like alpha and beta particles, gamma rays (photons) and neutrons. Naturally Occurring Radioactive Materials (NORMs) are found in our environment including surface and underground water, and human activities on our water bodies tend to enhance/increase their concentration [13]. Evidence abound that radiation exposures (internal and external) have caused cancer, genetic issues and even death [6][13]. Primary alpha emitters in potable water are ^{226}Ra, ^{224}Ra, ^{210}Po and sometimes ^{238}U, ^{234}U, and ^{235}U while beta emitters in potable water are mainly ^{40}K, ^{228}Ra, and, ^{210}Pb [17].

Due to the world's quest for radiological safety of drinking water, this study aims to find the gross alpha and gross beta activities of drinking water available to Anyigba residents and also to investigate their committed effective dose due to one year of consumption. Several countries including the United States, the European Union and the World Health Organization (WHO) have adopted some safety limits and regulations. WHO for instance has given a threshold of 0.5 Bq/L and 1 Bq/L for gross alpha and gross beta activity respectively in drinking water [18]. Gross alpha and beta analysis is among the easiest procedures used to analyze the radiation levels in water and results from this procedure helps to decide whether further radiological analysis is needed or not.

2. Materials and Methods

2.1 Study Area

The study area (see Fig. 1) is Anyigba in Dekina local government area of Kogi state, North Central Nigeria. Anyigba which is home to Kogi State University is located on coordinates 7.4934ºN and 7.1736ºE and the major sources of livelihood of the people are farming and commercial activities. With a total land mass of 420 Km^2, and an average altitude of 385 meters above sea level [8], Anyigba falls within the tropical wet and dry climatic region with an annual rainfall of 1250 mm [1]. The inhabitants are mainly Igala-speaking people and their main sources of drinking water are borehole water, river/stream water, sachet water and rain water.

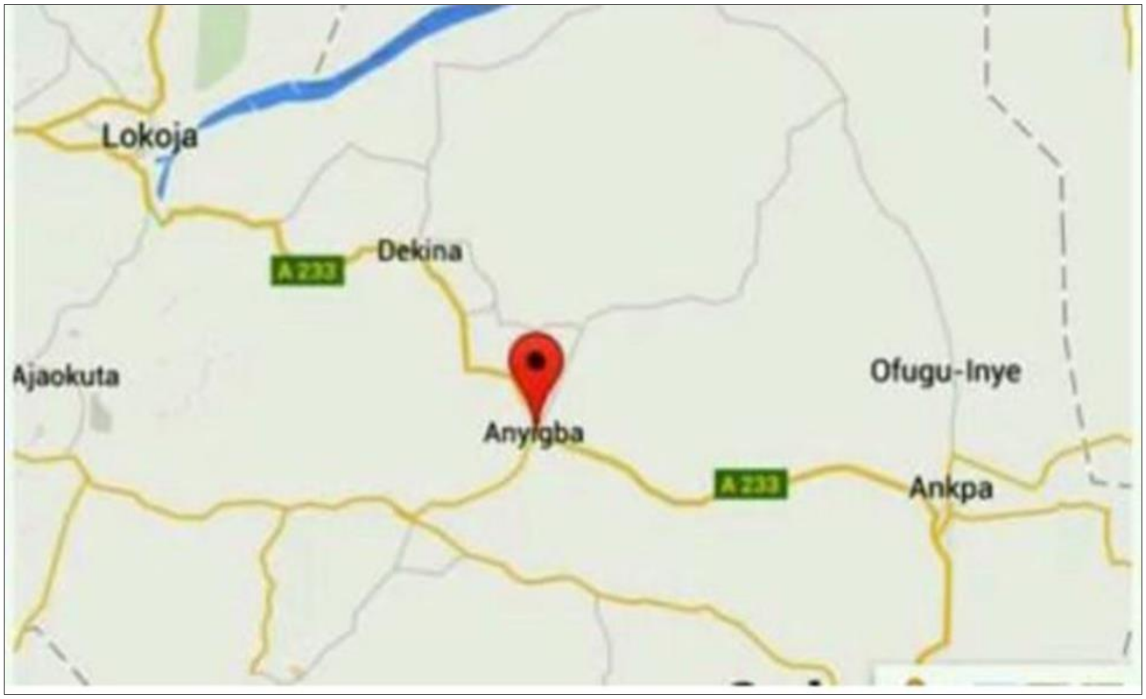

Fig 1: Google map showing Anyigba in Kogi State – Nigeria

2.2 Sample Collection and Preparation

A total of six (6) water samples were randomly collected from the available drinking water sources in Anyigba community. Samples were taken from three borehole sources (Federal water resources near Our Lady of Schools, Kogi State University Water Project and Kogi State water Project at Iji primary school), two river/stream sources (Abu-Uja Ojofu and Ogane-aji) and a sample from a popular sachet water factory (Dikubs Table Water).

A Global Positioning System (GPS) was used to take the coordinates of the sampling points. The water samples to be collected were first used to rinse the 2 litre containers before getting the samples into them. Little space was left at the brim of the containers for thermal expansion.

The grab sampling technique [2] was used to collect the river/stream samples in the early hours of the morning. Before collection of the borehole water samples, the tap was first allowed to run at high pressure to clean the plumbing system [15]. Lastly, one sachet water sample was bought from a famous factory in the area.

All samples collected were well sealed in their containers after acidifying them with nitric acid. The nitric acid helps to control undesired growth of microorganisms and also reduces precipitation and absorption of the sample by the walls of the container [3]. All samples were later conveyed to the low background laboratory of the Center for Energy Research and Training (CERT), Ahmadu Bello University, Zaria.

2.3 Sample Analysis

The water samples were put in an open beaker, and placed on an electric hotplate to undergo a gradual evaporation process. It took about 1800 minutes to complete the process for a 2 litre sample. When the level of the sample in the beaker was about 50 ml, it was transferred into a petri dish. An infrared source was later used on the sample to ensure a complete dryness of the residue.

The samples were subsequently left to cool down, weighed using a laboratory scale and later placed in the low background Gasless Alpha-Beta Counting System (Protean Instrument Corporation) – MPC 2000DP, to determine the alpha and beta activity concentrations. The MPC 2000DP alpha-beta counter uses a solid state silicon (Passivated Implanted Planar Silicon - PIPS) detector to detect alpha and beta particles. Having counted the samples for 200 minutes [3], the alpha and beta efficiencies was gotten to be 87.95% and 42.06% respectively. The background reading of the alpha and beta activity concentration were 0.30 cpm and 0.43 cpm respectively and the detection limit for alpha activity was 0.21 cpm while that of beta activity was 0.22 cpm. The calibration sources used were Sr-90, a beta source and Pu – 239 which is an alpha source.

2.3.1 Gross Alpha and Beta Counting

According to ISO [9], the alpha and beta count rate was calculated by the following formula:

$$\text{Count rate } (\alpha \text{ or } \beta) = \frac{\text{Raw } \alpha \text{ or } \beta \text{ count}}{\text{Count time}} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

According to ISO [9], the alpha activity concentration was calculated by the following formula:

$$\text{Activity } (\alpha \text{ or } \beta) = \frac{\text{Count Rate } (\alpha \text{ or } \beta) - \textit{Background Count } (\alpha \text{ or } \beta)}{\text{Detection Efficiency x Sample Volume x sample Efficiency}} \text{ x } 0.0167 \quad (2)$$

2.3.2 Committed Effective Dose (Total Effective Equivalent Dose)

Ingestion and inhalation of radionuclides are possible ways they reach the internal organs of the body where they cause serious damages especially the alpha and beta particles that have very high ionizing power. The annual alpha and beta effective dose due to intake from the various water sources around Anyigba town found via the mean of the individual annual committed effective doses contributed by the major alpha and beta emitters in the Uranium – 238 and Thorium – 232 series of the naturally occurring radioactive materials (NORMs) [12]. The following formulae were used to find the effective dose over one year of consumption of water [7]:

$$E_{avg} (\alpha \text{ or } \beta) = \sum A_{i(\alpha \text{ or } \beta)} \text{ x DCF}_{i(\alpha \text{ or } \beta)} \text{ X 730 (ADULT)} \quad (3)$$

$$E_{avg} (\alpha \text{ or } \beta) = \sum A_{i(\alpha \text{ or } \beta)} \text{ x DCF}_{i(\alpha \text{ or } \beta)} \text{ X 183 (INFANT)} \ldots \quad (4)$$

Where E_{avg} (α or β) is the average gross annual alpha or beta committed effective dose in drinkable water, $A_{i(\alpha \text{ or } \beta)}$ is the gross alpha or beta activity concentration of individual radionuclide present in the water samples and $DCF_{i(\alpha \text{ or } \beta)}$ is the dose conversion factor in Sv/Bq for ingestion of the individual radionuclide, it was assumed based on USEPA [16] report that an adult consumes a minimum of 2 liters of water per day resulting in an annual consumption rate of 730 liters per year while an infant consumes 1/2 liter of water per day resulting in an annual consumption rate of 183 liters per year. It was also assumed based on the report [4] that more than 50% of the annual dose from intake of water corresponds to radium (gross alpha radium). This assumption was necessary since the proportional counter could not determine the radionuclide elements present in the water samples due to its limited function.Gortir [5] reported that Radium – 226 contributes mainly to gross alpha activities while Lead – 210 and Radium – 228 contribute majorly to beta activities. For calculations, the dose conversion factor of 2.8 x 10^{-4} Sv/Bq is used for Radium – 226 and 6.9 x 10^{-4} Sv/Bq for both Lead – 210 and Radium – 228 [3].

2.3 Statistical Analysis

The analysis was done using Microsoft Excel software.

3. Results and Discussion

Table 1: Activity concentration of water samples around Anyigba Township.

S/N	Sample Codes	Description	Geographical Coordinates		Sample Gross Radioactivity Measurement	
			Longitude	Latitude	Alpha Activity (Bq/L)	Beta Activity (Bq/L)
1	BH2	Borehole KSU	7°28'46.80''N	7°10'47.47''E	0.0265 ± 0.0073	0.0512 ± 0.0106
2	R1	River Abu Uju	7°31'47.99''N	7°11'15.03''E	0.0379 ± 0.0086	0.0495 ± 0.0112
3	BH3	Borehole at Iji	7°30'22.83''N	7°10'18.62''E	0.0278 ± 0.0077	0.0902 ± 0.0128
4	SW	Sachet Water	7°29'32.57''N	7°11'13.30''E	0.0041 ± 0.0033	0.0061 ± 0.0046
5	R2	River Ogane Aji	7°31'45.87''N	7°09'40.50''E	0.0041 ± 0.0057	0.0037 ± 0.0083
6	BH1	Borehole (Federal water) at O.L.S	7°29'42.31''N	7°10'17.85''E	0.0503 ± 0.0099	0.0950 ± 0.0142
				Mean Activity	0.0251 ± 0.0071	0.0493 ± 0.0103

Radioactivity of drinking water sources around Anyigba Township has been carried out. The gross alpha and gross beta activity concentrations in river, borehole and sachet water samples are represented in Table 1 above. The gross alpha activity concentration ranges from 0.0041 ± 0.0033 Bq/l to 0.0503 ± 0.0099 Bq/l with a mean value of 0.0251 ± 0.0071 Bq/l. Also, the gross beta activity concentrations ranges from 0.0037 ± 0.0083 Bq/l to 0.0950 ± 0.0142 Bq/l with a mean value of 0.0493 ± 0.0103 Bq/l. SW recorded the lowest gross alpha activity concentration while BH1 recorded the highest concentration. The lowest gross beta activity concentration was recorded in R2 and the highest activity was recorded in BH1.

All results recorded for gross alpha and gross beta activity concentrations were below the reference dose level (RDL) of 0.5 Bq/l and 1.0 Bq/l respectively as set by world health organization [18]. See figures 2.

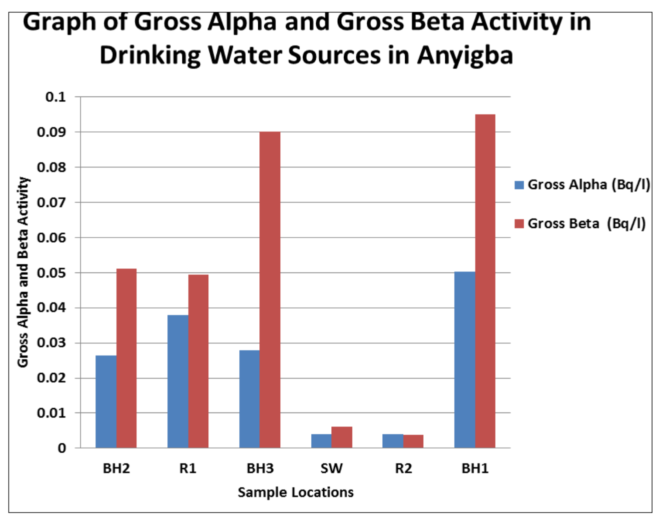

Fig 2: Gross alpha and beta activity of drinking water sources in Anyigba town.

Table 2 below shows the effective dose and the total effective equivalent dose to adults and infants, due to gross alpha and gross beta activity. The effective equivalent dose for adult ranges from 2.7 x 10^{-03} mSv/yr to 5.8 x 10^{-02} mSv/yr with a mean value of 3.00 x 10^{-02} mSv/yr, while that of infants ranges from 9.80 x 10^{-04} mSv/yr to 1.46 x 10^{-02} mSv/yr with a mean of 7.51 x 10^{-03} mSv/yr. The highest values for both adults and infant was recorded in BH1. However, the lowest values for adult and infant was recorded in R2 and SW samples respectively. The study reveals that none of the samples exceeded the recommended reference dose level (RDL) for committed effective dose (for adult and infant) which is 0.1 mSv/yr (See figures 3).

Table 2: Annual Effective Dose and Total Effective Equivalent Dose to Adult and Infant

S/N	Sample	Alpha Particle Eff Dose (mSv/yr)-Adult	Beta Particle Eff Dose (mSv/yr)-Adult	Total Eff Dose (mSv/yr)-Adult	Alpha Particle Eff Dose (mSv/yr)-Infant	Beta Particle Eff Dose (mSv/yr)-Infant	Total Eff Dose (mSv/yr)-Infant
1	BH2	5.417E-03	2.579E-02	3.121E-02	1.358E-03	6.465E-03	7.823E-03
2	R1	7.747E-03	2.493E-02	3.268E-02	1.942E-03	6.250E-03	8.192E-03
3	BH3	5.682E-03	4.543E-02	5.112E-02	1.424E-03	1.139E-02	1.281E-02
4	SW	8.380E-04	3.073E-03	3.911E-03	2.101E-04	7.702E-04	9.803E-04
5	R2	8.380E-04	1.864E-03	2.702E-03	2.101E-04	4.672E-04	6.773E-04
6	BH1	1.028E-02	4.785E-02	5.813E-02	2.577E-03	1.200E-02	1.457E-02

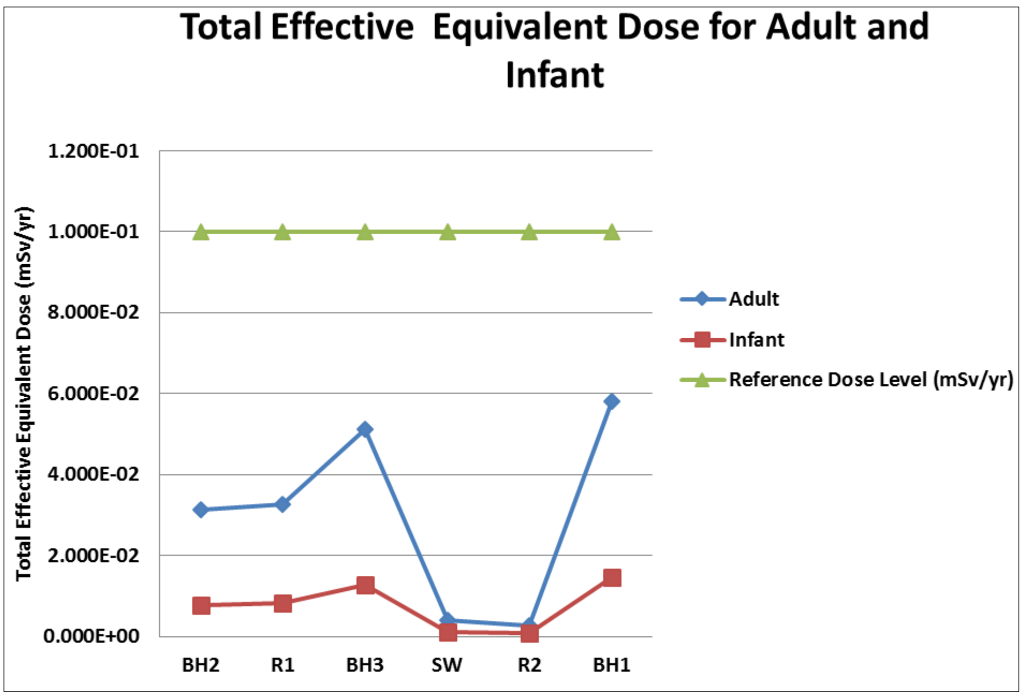

Fig 3: Total Effective Equivalent Dose for Adult and Infant with Reference Dose Level (RDL)

4. Conclusion

The study of the committed effective dose from drinking water available to Anyigba dwellers have been carried out using a background Gasless Alpha-Beta Counting System (Protean Instrument Corporation) – MPC 2000DP. The gross alpha and gross beta activity concentrations recorded were below the safe limits of 0.5 Bq/l and 1 Bq/l respectively, as recommended by the world health organization. Also, results of the committed effective dose calculated were all below the reference dose level (RDL) of 0.1mSv/yr.

Hence, from the samples studied, we conclude that the drinking water sources available to Anyigba community are radiologically safe for consumption. However, regular assessment should be carried out on the water sources to ensure that they remain safe for drinking. Also, investigation should be carried out on the radiological status of rain water widely consumed by the people. This study did not cover that area because it was carried out in the dry season.

5. Conflict of Interest

Declared None

6. References

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