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Determination of the Gross Alpha and Beta Activity Concentration in Groundwater from Damaturu

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Abstract: *The major source of potable water in Damaturu is underground water especially boreholes and artesian wells which may contain radioactive substances. The presence of radioactivity in water may pose severe health risk to consumers. In light of this, the gross alpha and beta activity concentration of 15 borehole water samples from Damaturu were analysed using the gasless channel MPC 2000B-DP proportional counter. The highest concentration of alpha activity was recorded for samples from Gwange with* $50.26 \pm 2.78 mBq/L$. *This was also found to have the highest activity concentration* $79.87 \pm 5.26\, mBq/L$ *for beta activity. The lowest alpha activity concentration was obtained in New Abbari with* $0.79 \pm 1.19\, mBq/L$ *and the lowest beta activity concentration was obtained in Waziri Ibrahim* $10.24 \pm 3.05\, mBq/L$. *The mean alpha and beta activity concentrations in the study area are* $15.76 \pm 1.74\, mBq/L$ *and* $35.11 \pm 4.09\, mBq/L$, *respectively. All the samples analysed are below the* $0.5\, Bq/L$ *and* $1.0\, Bq/L$ *screening level set by the WHO (2011) for alpha and beta activity concentration, respectively. The annual gonadal equivalent dose (AGED) and committed effective dose (CED) were calculated for the samples and it was found that all the samples were within the* $1 mSv/yr$ *limit set by the ICRP for members of the public. Therefore, the level of radioactivity in the water samples may not pose a significant health risk. It is recommended that this study be expanded to analyse all potable water sources in the study area using an improved method of analysis.*

Keywords: *Activity concentration, gross alpha, gross beta, MPC 2000B-DP detector, water, CED, AGED*

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1.0 Introduction

Water is essential for the sustenance of life by plant and animals (Ebele, 2006). In developing nations, major sources of water in the rural areas are rain and groundwater. The groundwater sources may include surface groundwater like rivers, oceans, etc. and deep groundwater like wells and boreholes. Research evidences have shown that most ground water are contaminated and the levels of contamination varies within locations (National Research Council, 1977) Commonly investigated water contaminants include physicochemical variables, organoleptic parameters, heavy metals, emergent contaminants and few others. Less attention is paid to possible hazards from radioactive elements, which have higher toxic

impacts than most contaminants (Saleh and Eskander, 2010).

Radioactive radiation consists of numerous particles of various origins and energies such as alpha, beta, neutron, etc. and electromagnetic rays such as gamma radiation with intensity of exposure varying inversely with height above sea level (UNSCEAR, 1993). The radiation may be natural (such as those from the sun) or artificial (such as radiation from radioactive fall-out, nuclear power plants, radiology units of hospitals, mining, etc.) (Martin *et al*., 2019).

However, radioactivity in water is mostly from the natural sources, specifically terrestrial radiation. This is because water, as a universal solvent, dissolves many substances when it flows some of which contains the naturally occurring radioactive materials (NORMs). When human beings ingest such water they are exposed to radiation which can cause somatic effect that result to mutations and genetic effect that damage radiosensitive organs of the body and can even lead to death (Abba *et al*., 2013).

The process of measuring radioactivity in water involves identifying the concentration of individual radionuclides which is time-consuming, expensive and the concentration is low in most cases. Therefore, such detailed analysis is not justified for routine monitoring. A more pragmatic way is to screen the water for total radioactivity from alpha and beta radiations without regard to the individual radionuclides (WHO, 2011).

2.0 Materials and Method

2.1 The Study area

The area under survey is Damaturu, the State Capital of Yobe State with a land area of 2,366 sq. km and a population of 124,500, as per the 2017 estimate (National Population Commission, 2017), most of whom rely on borehole as the source of potable water (Usman, 2019). It is situated between latitude 11.6583^0N to 11.7833^0N and longitude 11.9000^0E to 12.0300^0E (Fig.1) The topography of the town is plain with open valleys having an average depression between 45 to 75 m and separated from the Benue valley by Biu plateau. Damaturu is not drained by any river and the inhabitants depend mainly on underground water which are accessed through drilling of boreholes and artesian wells (Usman, 2019).

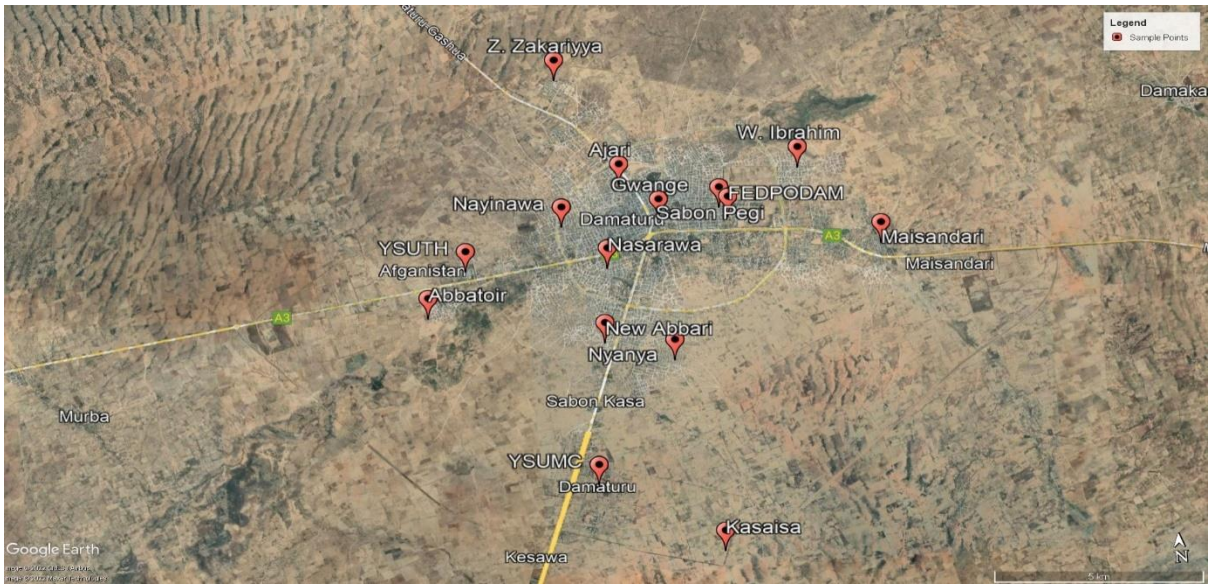

Fig. 1: Map of the study area showing the sampling points

2.2 Sample collection and preparation

Fifteen (15) borehole water samples were collected in a 2L plastic containers using a GPS device to record the geo-coordinates of the sampling points as shown in Figure 1 above. The samples were prepared by evaporating to dryness and analysed for gross alpha and beta activities using the MPC

2000B-DP (PIC) gas free proportional counter at the Health Physics and Radiation Biophysics Section (HPRBS) of the Centre for Energy Research and Training (CERT), Zaria.

The operating voltage for the detector was chosen to be 1300V to protect the photomultiplier tube (Dauda, 2017). The detector was calibrated using ^{239}Pu at 4π steradian for alpha activity and ^{90}Sr at 2π steradian for beta activity with activities ranging from $133.3Bq$ to $185.8Bq$ and $105.1Bq$ to $117.7Bq$ for alpha and beta, respectively (Dauda, 2017). The detection efficiencies for alpha and beta detection are 87.95% and 42.06% respectively. The background was determined by counting clean empty planchets for the same duration the samples were counted. The average background for the alpha and beta activities are $0.40cpm$ and $0.35cpm$, respectively. The minimum detectable activity (MDA) is expressed as (Calin and Radulescu, 2012).:

$$MDA = \frac{2.71 + 4.65\sqrt{R_b}}{t \cdot E_{ff}} \quad (1)$$

where MDA is the minimum detectable activity; t the sample and background count time; R_b is counting rate of the background; E_{ff} is counting efficiency.

2.3 Counting

The equipment used in this work is the MPC 2000B-DP, a gasless single channel manual loading desktop proportional counter with $9\,ft \times 16\,ft$ dimension equipped with ZnS detector. The measurement of alpha and beta activities can be done individually or simultaneously. The detector is automated and the procedure involves entering the pre-set time and selecting the counting mode. The result is displayed as raw counts or count per minute (cpm). For this study, the counting mode was set to count for alpha and beta activity separately for 30 minutes. The counting was done twice due to the probabilistic nature of radioactivity. The alpha and beta activity concentration of the samples were then calculated in Bq/L using the formula:

$$Activity = \frac{Net\ cpm(\alpha,\beta)}{E_{ff}(\alpha,\beta) \times S.E \times S.V} \times \frac{1}{60} \quad (2)$$

where $Net\ cpm = raw\ cpm - R_b$; E_{ff} is the detector efficiency; $S.E$ is the sample efficiency; $S.V$ is the sample volume which is the actual volume of sample water that yielded the required weight of residue counted; the value 1/60 is the time *conversion factor*.

2.4 Annual gonadal equivalent dose (AGED)

The annual gonadal equivalent dose measures the threat to gonads from particular ionising radiation. The AGED for members of the public is calculated using (Seydou & Abdullahi, 2016):

$$AGED = \frac{AEDE}{W_R \times W_T} \quad (3)$$

where $AEDE$ is the annual effective dose equivalent; $W_R(20\ for\ \alpha\ and\ 1\ for\ \beta)$ is radiation weighing factor; $W_T(=0.08\ for\ gonads)$ is the tissue weighing factor. The AGED gives the genetic significance of yearly dose received by the reproductive organs of the population of the study area (Ravisankar *et al*., 2014).

2.5 Committed effective dose (CED)

The committed effective dose (CED) represents the cumulative amount of radiation dose the body will be exposed to due to intake of radioactive material (Ministry of the Environment, 2013). The radioactive materials may reach the gastrointestinal tract and be absorbed into the body thereby irradiating tissues and organs. The CED is calculated using the relation (International Atomic Energy Agency, 2010):

$$E_{avg}(\alpha/\beta) = A(\alpha/\beta) \times DCF(\alpha/\beta) \times 730L/yr$$

(for adult) (4)

$$E_{avg}(\alpha/\beta) = A(\alpha/\beta) \times DCF(\alpha/\beta) \times 183L/yr$$

(for infant) (5)

where $E_{avg}(\alpha/\beta)$ is average committed effective dose per year for α or β; $A(\alpha/\beta)$ is the gross alpha or beta activity concentration

of the sample water; $730\,L/yr$ and $183L/yr$ is the volume of water consumed in a year by adults and infants, respectively, assuming $2\,L/day$ and $0.5\,L/day$ for adults and infants respectively (Environmental Protection Agency, 2005); and according to Avwiri, Osimobi, & Ononugbo (2016) $DCF(\alpha/\beta)$ is the dose conversion factor which is given as $2.8\times10^{-4}\,Sv/Bq$ for ^{226}Ra which is the main contributor to gross alpha activity and $6.9\times10^{-4}\,Sv/Bq$ for ^{210}Pb and ^{226}Ra, the main contributors to gross beta activity (Gortir *et al*., 2011).,.

3.0 Result and Discussion

3.1 Gross alpha and beta concentrationThe potable water samples collected from the boreholes in Damaturu were analysed for gross alpha and beta activity using the MPC 2000B-DP detector. The mean activities obtained were $15.76\pm1.74\,mBq/L$ and $79.87\pm5.26\,mBq/L$ for gross alpha and beta radiations, respectively. Table 1 shows the alpha and beta activity concentrations in the sampled waters. From the Table it is clear that the gross beta activity is generally higher than the gross alpha activity with the exception of New Abbari where the gross beta is below the detection limit (DL) of the detector.

Fig. 2 shows that the gross alpha and beta activity concentrations for all the samples are far lower than $0.5\,Bq/L$ and $1Bq/L$ respectively. These are the recommended levels set by WHO in 2011.

Table 1: Gross alpha and beta activity concentrations of the water samples

S/No.	Sample ID	Alpha Activity (mBq/L)	Beta Activity (mBq/L)	Geo-coordinates
1	Abbatoir	12.63 ± 1.79	15.41 ± 3.36	11.72569^0N, 11.91302^0E
2	Ajari	17.75 ± 2.43	35.63 ± 4.80	11.75643^0N, 11.95682^0E
3	FEDPODAM	23.10 ± 2.20	30.51 ± 4.11	11.74682^0N, 11.9800^0E
4	Gwange	50.26 ± 2.78	79.87 ± 5.26	11.74713^0N, 11.96486^0E
5	Maisandari	*BDL*	28.16 ± 4.09	11.73823^0N, 12.01291^0E
6	Nasarawa	26.68 ± 2.67	67.66 ± 5.47	11.73570^0N, 11.95289^0E
7	Nayinawa	*BDL*	33.24 ± 5.50	11.74654^0N, 11.94359^0E
8	New Abbari	0.79 ± 1.19	*BDL*	11.71713^0N, 11.95108^0E
9	Nyanya	19.59 ± 1.97	22.53 ± 3.27	11.71193^0N, 11.96602^0E
10	W. Ibrahim	*BDL*	10.24 ± 3.05	11.75817^0N, 11.99601^0E
11	Kasaisa	20.25 ± 3.91	54.79 ± 7.96	11.66368^0N, 11.97375^0E
12	Sabon Pegi	12.89 ± 1.65	48.92 ± 3.63	11.74928^0N, 11.97822^0E
13	YSUMC	13.96 ± 1.18	25.55 ± 2.29	11.68187^0N, 11.94736^0E
14	YSUTH	28.28 ± 3.12	62.84 ± 6.28	11.73639^0N, 11.92194^0E
15	Zanna Zakariya	8.26 ± 1.17	12.23 ± 2.24	11.78324^0N, 11.94446^0E
Mean		15.76 ± 1.74	35.11 ± 4.09	
MDA		$3.57\times10^{-3}\,Bq$	$7.21\times10^{-3}\,Bq$	

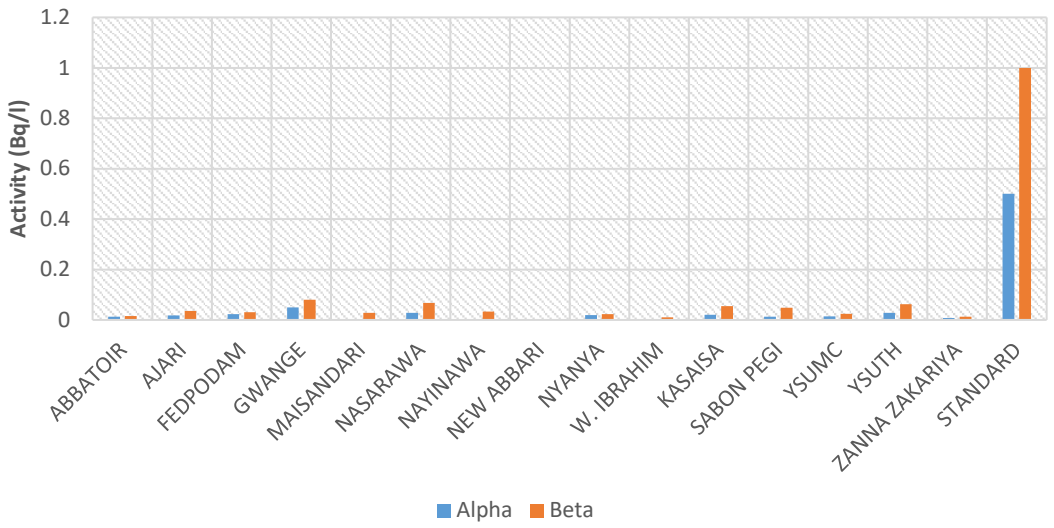

Fig. 2: Comparison of the Alpha and Beta Activity Concentrations with the WHO (2011) Standard.

3.2 Annual gonadal equivalent dose

The AGED due to gross alpha and beta activity is calculated using equation (3) and presented in Table 2.

From the results presented in Table 2, it is evident that the AGED for all the samples were below the $1 mSv/yr$ limit set by ICRP for members of the public (ICRP, 1990).

2.3 Committed effective dose

The CED due to ingestion of the water samples for both adults and infants in the study area is calculated from the gross alpha and beta activity using equations (4) and (5) and presented in Table 3.

Table 2: Annual gonadal equivalent dose for the samples in the study.

S/No.	Sample ID	Alpha AGED (mSv/yr)	Beta AGED (mSv/yr)
1	Abbatoir	8.2575×10^{-7}	2.0150×10^{-5}
2	Ajari	1.1605×10^{-6}	4.6590×10^{-5}
3	FEDPODAM	1.5103×10^{-6}	3.9895×10^{-5}
4	Gwange	3.2860×10^{-6}	1.0444×10^{-4}
5	Maisandari	*BDL*	3.6822×10^{-5}
6	Nasarawa	1.8751×10^{-6}	8.8472×10^{-5}
7	Nayinawa	*BDL*	4.3464×10^{-5}
8	New Abbari	5.1650×10^{-8}	*BDL*
9	Nyanya	1.2808×10^{-6}	2.9460×10^{-5}
10	W. Ibrahim	*BDL*	1.3390×10^{-5}
11	Kasaisa	1.3239×10^{-6}	7.1643×10^{-5}
12	Sabon Pegi	8.4274×10^{-7}	6.3968×10^{-5}
13	YSUMC	9.1270×10^{-7}	3.2101×10^{-5}
14	YSUTH	1.8489×10^{-6}	8.2169×10^{-5}
15	Zanna Zakariya	5.4004×10^{-7}	1.5992×10^{-5}

Table 3: Committed effective dose for adults and infants in the study area

S/No.	Sample ID	Alpha CED (mSv/yr)		Beta CED (mSv/yr)	
		Adult	**Infants**	**Adult**	**Infants**
1	Abbatoir	2.58×10^{-3}	0.65×10^{-3}	7.76×10^{-3}	1.95×10^{-3}
2	Ajari	3.63×10^{-3}	0.91×10^{-3}	17.95×10^{-3}	4.50×10^{-3}
3	FEDPODAM	4.72×10^{-3}	1.18×10^{-3}	15.37×10^{-3}	3.85×10^{-3}
4	Gwange	10.27×10^{-3}	2.58×10^{-3}	40.23×10^{-3}	10.09×10^{-3}
5	Maisandari	*BDL*		14.18×10^{-3}	3.56×10^{-3}
6	Nasarawa	5.86×10^{-3}	1.47×10^{-3}	34.08×10^{-3}	8.54×10^{-3}
7	Nayinawa	*BDL*		16.74×10^{-3}	4.20×10^{-3}
8	New Abbari	0.16×10^{-3}	0.40×10^{-4}	*BDL*	
9	Nyanya	4.0×10^{-3}	1.0×10^{-3}	11.35×10^{-3}	2.84×10^{-3}
10	W. Ibrahim	*BDL*		5.16×10^{-3}	1.29×10^{-3}
11	Kasaisa	4.14×10^{-3}	1.04×10^{-3}	27.6×10^{-3}	6.92×10^{-3}
12	Sabon Pegi	2.63×10^{-3}	0.66×10^{-3}	24.64×10^{-3}	6.18×10^{-3}
13	YSUMC	2.85×10^{-3}	0.72×10^{-3}	12.37×10^{-3}	3.10×10^{-3}
14	YSUTH	5.78×10^{-3}	1.45×10^{-3}	31.65×10^{-3}	7.93×10^{-3}
15	Zanna Zakariya	1.69×10^{-3}	0.42×10^{-3}	6.16×10^{-3}	1.54×10^{-3}
Mean		4.03×10^{-3}	1.01×10^{-3}	18.95×10^{-3}	4.75×10^{-3}

From the results in Table 3, the CED for adults ranges from $10.27\times10^{-3}\,mSv/yr$ to $0.16\times10^{-3}\,mSv/yr$ with a mean value of $4.03\times10^{-3}\,mSv/yr$ for alpha radiation while for beta radiation, CED ranges from $40.23\times10^{-3}\,mSv/yr$ to $5.16\times10^{-3}\,mSv/yr$ with a mean value of $18.95\times10^{-3}\,mSv/yr$. On the other hand, the CED for infants ranges from $2.58\times10^{-3}\,mSv/yr$ to $0.40\times10^{-4}\,mSv/yr$ with a mean value of $1.01\times10^{-3}\,mSv/yr$ for alpha radiation while for beta radiation, the CED ranges from $10.09\times10^{-3}\,mSv/yr$ to $1.29\times10^{-3}\,mSv/yr$ with a mean value of $4.75\times10^{-3}\,mSv/yr$. The highest CED due to alpha activity is recorded at *Gwange* and the lowest value is recorded at *New Abbari*. The highest CED due to beta activity is also recorded at *Gwange* while the lowest value is recorded at *W. Ibrahim*. However, none of the samples exceed the recommended dose level of $1mSv/yr$.

4.0 Conclusion

The gross alpha and beta activity concentration in borehole water sample from Damaturu was measured using the MPC 2000B-DP detector. It was found that the gross alpha and beta activity concentrations were below the screening level recommended

by WHO (2011). The AGED and the CED due to the gross alpha and beta activities were also calculated and were found to be far lower than the limit set by ICRP. This implies that the borehole water from the study area is safe for drinking and domestic use. However, it is recommended that further study and analysis should be carried out to include all boreholes and other sources of water in the study area using an improved method of analysis.

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