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Measurement of radioactivity in water of Zobe Dam Dutsinma, Katsina State, Northern Nigeria

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ABSTRACT

The gross alpha and beta radioactivity of water samples were measured using proportional gas counter. The result show that the gross alpha and beta radioactivity in water samples is higher than the maximum contaminant levels of 0.1 and 1.0 Bq/L set by World Health Organization (WHO). The range of the measured alpha activity was found to be between BDL to 9.547±0.37 Bq/L with mean of 6.18±0.30 Bq/L. Also the beta activity was measured between BDL to12.119±0.46 Bq/L with mean of 8.332±0.44 Bq/L . Due to the high results obtained from the gross alpha and beta measurement, therefore there is need for further screening for radioactivity from the water because continues drinking may pose serious health side effects to the public users.

Key words: Gross Alpha, Gross Beta, water and Gas Flow Proportion Counter

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INTRODUCTION

Water quality is an important parameter of environmental studies. Radioactivity present in surface water is mainly due the present of radioactive elements in the earth's crust. The earth crust contains small amounts of Uranium, thorium and radium, as well as radioactive isotope of potassium. Human activities (mining, milling and processing of uranium ores and mineral sands, manufacture of fertilizers, burning of fossils fuels, metal refining, farming, etc.) have raised natural radioactivity concentrations in the environment. These Radioactive materials can reach surface continental waters by different pathways from each of the processes or activities. Rivers and Dam water can be contaminated by surface runoff of rainwater transporting leached radionuclides from cities, mine waste, soil weathering and agricultural areas [8].

Furthermore, another form of water pollution is as a result of certain rock types containing radioactive elements referred to as Naturally Occurring Radioactive Materials (NORM). When these rocks are disintegrated through natural processes, radionuclides are seep to the soil and are carried to the rivers by rain and floods [9].

Radioactivity in drinking water is one of the major ways in which radionuclides from the environment gets into the human body, which might consequently lead to radiation-induced disorder [10].

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 [1] of concentration for drinking water quality. However in country like Nigeria, no any work has been done in Zobe Dam, Dutsinma of Katsina State, 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 [2].

In order to guarantee an exposure lower than $0.1 mSvy^{-1}$,WHO recommends the guideline values for drinking water 0.1 *Bq/L* for alpha activity and 1.0 *Bq/L* for gross beta activity. If the gross alpha activity exceeds 0.1 *Bq/L* or the gross beta activity exceeds 1.0 *Bq/L*, analysis for specific radionuclides is required [12].

The aim of this work is to determine the gross alpha and gross beta radioactivity in water samples collected from four different locations of Zobe Dam and provides a base line data which can be used to evaluate possible future changes.

MATERIALS AND METHODS

Area of Study and Location

The Zobe Dam is located between latitude 12^0 20' 34.62'' N to 12^0 23' 27.48'' N and between longitude 7^0 27' 57.12'' E to $7^0$34' 47.68'' E, in Dutsinma Local Government Area of Katsina State. The reservoir formed by the Dam cover 4500 hectares of rocky land and during the rainy season stores 177 million cubic metres of water which is released downstream for irrigation and town water supplies. The Zobe Dam has only two tributaries; these include river Karaduwa and river Gada in which river Gada drains to river Karaduwa. The Dam is constructed in river Karaduwa and the Dam over Karaduwa is about 2.7 kilometres long and flowing north westward to the Sokoto Basin. Along the river course, there are no large cities, no mining cites, no nuclear enterprises such as chemical and phosphate industries. Farmers' lives in the area generally rear animals, raise crops and some vegetables. Therefore, agrochemical such as fertilizers and pesticides, herbicides are the main contaminant of the Dam reservoir. Fishing is another major activity in the area.

Sample Collection Procedures

Water sample were collected from Garhi A, Garhi B, Makera and Tabobi. Garhi A, Garhi B and Makera are the areas where farming, domestic/live stocks activities and fishing are very high. While Tabobi is the control area in which the activities mentioned are very less. The sample collection method was achieved as described below.

Sample Collection and preparation

Fifteen (15) water samples were collected. Four (4) samples each were collected in an area where farming, domestic/livestock activities and fishing is very high and three (3) from the control area where farming, domestic/livestock activities and fishing is very less. The stratified random sampling was used in each of the four regions. The point of collection of each sample were given a unique code and noted with its GPS coordinate taken with a handheld GPS device. Samples were collected in 2 liter plastic bottles with tight covers. The sampling bottles were carefully washed in the laboratory and rinsed three times with the sample water to be sure that sample collected are representative of the bulk. The water was collected near the bank of the Dam where there is less dilution of the washout from the surrounding environment. The samples at the time of collection were acidified with about 20*ml* of nitric acid per litre to reduce the pH to 2. This is to minimize precipitation of the radionuclide present in the sample water and also to prevent the absorption of radioactivity by the walls of the sample container. The sample containers were then labeled, tightly covered with a space of about 1% 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 $7.1 cm^2$ 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 [12]. 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 [6].

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

Where: W_B is the weight of the empty planchet, W_{B+S} is the weight of planchet plus sample after evaporation, and 0.077(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 450$\mu g/cm^3$ 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 [3].

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 [6].

$$The\ alpha\ count\ rate\ (\alpha)\ (count/s) = \frac{Raw\ \alpha\ count\ \text{x}\ 60}{Count\ time\ (sec)} \quad (2)$$

$$The\ alpha\ activity\ (\alpha) = \frac{Rate\ (\alpha) - Bgd\ (\alpha)}{Channel\ \alpha\ efficiency\ \text{x}\ Sampl\ efficiency\ \text{x}\ Sample\ vol.} \quad (3)$$

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 [6].

$$The\ beta\ count\ rate\ (\beta)\ (count/s) = \frac{Raw\ \beta\ count\ \text{x}\ 60}{Count\ time\ (sec)} \quad (4)$$

$$The\ beta\ activity\ (\beta) = \frac{Rate\ (\beta) - Bgd\ (\beta)}{Channel\ \beta\ efficiency\ \text{x}\ Sample\ efficiency\ \text{x}\ Sample\ Vol.} \quad (5)$$

Data Presentation of Alpha and Beta Activity

Alpha Activity

The alpha activity in the prepared water sample is expressed as activity concentration C in Becquerel per litre (Bq/L). The activity concentration is calculated using the formula, [6].

$$C = \frac{(R_b - R_0)\ \text{x}\ \ a_s\ \text{x m x}\ 1.02}{(R_S - R_0)\ \text{x}\ 1000\ V} \quad (6)$$

Where: R_s is the observed sample count rate (s^{-1}), R_0 is the background count rate (s^{-1}), R_b is the observed standard count rate (s^{-1}), a_s is the specific activity of alpha standard, V is the volume of the evaporated in litre and m is the mass in mg of the residue from volume V and the factor 1.02 is included to correct for 2ml of nitric acid added per litre as a stabilizer.

Beta Activity

The gross beta activity is expressed as activity concentration C in *Bq/L* and calculated as;

$$C = \frac{(R_b - R_0) \text{ x } 14.4 \text{ x m x } 1.02}{(R_S - R_0) \text{ x } 1000\ V} \quad (7)$$

Where the value $\frac{14.4}{1000}$ represent the specific activity of ^{40}K in Kcl, all other terms expressed have their usual meaning as in equation (6).

RESULTS AND DISCUSSION

Concentration of Gross Alpha Activity

The measured activity concentrations of gross alpha in water samples of four different locations in Zobe Dam are gathered in Table 1. The observed gross alpha activity found in water samples vary from BDL to 9.547±0.37 *Bq/L* with average 6.187±0.37 *Bq/L*. The highest gross alpha activity in the water was found in Zone (A) and the lowest gross alpha activity in water samples was found in Zone (B). The gross alpha activity in water sample is primarily comprised uranium decay products such as ^{226}Ra and ^{40}K. WHO recommends the parameter of gross alpha activity concentration to be 0.1 *Bq/L*. If the gross alpha activity does not exceed 0.1 *Bq/L*, it can be assumed that the annual total indicative dose is less than 0.1 *mSv* per year. The results obtained show that the measured activity concentrations of gross alpha in all water samples are higher than 0.1 *Bq/L* which is the limit recommended by WHO.

Table 1: Alpha and Beta Activity Concentration for Water Samples measured in this work

Alpha and Beta Activity Concentrations in Bq/L					
Sample Locations	**Sample Codes**	**Sample ID**	**Alpha Activity**	**Beta Activity**	**Coordinates**
GARHI A	Zone A	WA1	11.397±0.38	10.997±.048	N12^0 22.784' E007^0 27.987'
		WA2	7.618±0.28	6.966±0.36	N12^0 22.787' E007^0 27.905'
		WA3	1.087±0.31	BDL	N12^0 22.642' E007^0 27.926'
		WA4	7.223±0.28	6.896±0.36	N12^0 22.613 E007^0 27.925
GARHI B	Zone B	WB1	7.458±0.32	BDL	N12^0 21.173' E007^0 30.250'
		WB2	7.475±0.33	9.872±0.41	N12^0 21.210' E007^0 30.256'
		WB3	0.595±0.26	BDL	N12^0 21.216' E007^0 30.289'
		WB4	1.713±0.62	2.837±0.77	N12^0 21.261' E007^0 30.139'
MAKERA	Zone C	WC1	0.826±0.23	BDL	N12^0 22.480' E007^0 27.885'
		WC2	9.547±0.37	12.119±0.46	N12^0 22.496' E007^0 22.896'
		WC3	BDL	BDL	N12^0 22.517' E007^0 27.904'
		WC4	8.940±0.33	6.511±0.43	N12^0 22.433' E007^0 27.873'
TABOBI	Zone D	WD1	BDL	BDL	N12^0 23.121' E007^0 30.715'
		WD2	9.067±0.33	11.721±0.45	N12^0 23.51' E007^0 30.737'
		WD3	5.276±0.22	7.025±0.27	N12^0 23.299' E007^0 30.656'
		MEAN	6.187±0.37	8.332±0.44	
		MAX	9.547±0.37	12.119±0.46	
		MIN	BDL	BDL	

Concentration of Gross Beta Activity

The measured activity concentrations of gross beta in water samples of four different locations in Zobe Dam are shown in Table 1. The observed gross beta activity found in water samples vary from BDL to 12.119±0.46 *Bq/L* with average 8.332±0.44 *Bq/L*. The highest gross beta activity in the water was found in Zone (D) and the lowest gross beta activity in water samples was found in Zone (B). The gross beta activity in water sample is primarily comprised uranium decay products such as ^{228}Ra and ^{40}K. WHO recommends the levels of gross beta activity concentration to be 1.0 *Bq/L*. If the gross beta activity does not exceed 1.0 *Bq/L*, it can be assumed that the annual total indicative dose of adults is less than 0.1 *mSv* per year. The results obtained show that the measured activity concentrations of gross beta in all water samples are higher than 1.0 *Bq/L* which is the limit recommended by WHO. Figure 1 shows that the gross beta activities are higher than the corresponding gross alpha activities for all water samples.

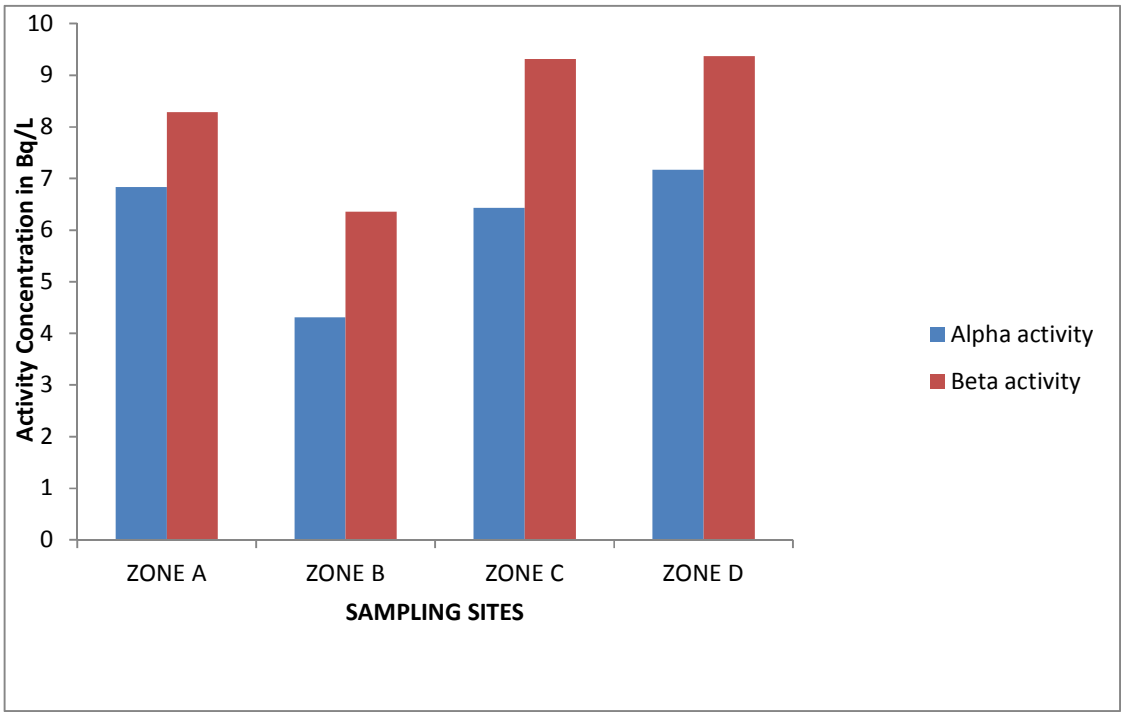

Figure 1: Alpha and Beta activity concentration in all zones

The average value 6.187±0.37 *Bq/L* of alpha activity obtained from this work exceeds the Australia Causeway River water alpha activity by 6.02 *Bq/L* , the average alpha activity also exceed the average alpha activity of river Kaduna (0.1173 *Bq/L*) by 6.0697 *Bq/L* [7]. However, the value is lower than the mean alpha activity value reported earlier for Okpare Creek [2] and is also lower than the alpha activity value of 6.7±0.074 *Bq/L* reported for Opa River irrigation farmland [4].

Comparing the average value 8.332 *Bq/L* of beta activity obtained in this work with: 0.07553 *Bq/L* obtained in Zaria and 1.56 *Bq/L* in Jos by [5] this shows that Gross beta activity measured in all the sampling sites in Zobe Dam are relatively high.

CONCLUSION

Concentrations ranging from BDL to 9.547±0.37 *Bq/L* with an average 6.187±0.37 *Bq/L* and from BDL to 12.119±0.46 *Bq/L* with an average 8.332±0.44 *Bq/L*. were observed for the gross alpha and gross beta activities, respectively. For all water samples the gross beta activities are higher than the corresponding gross alpha activities, the higher value of Gross beta activity could be as a result of the geological formation of the area whose land is highly invaded with phosphorus, a by-product of phosphate that has potassium-40 which is a beta and gamma

emitter whose source is fertilizer used by farmers. Both gross alpha and gross beta activities are respectively higher than 0.1 *Bq/L* and 1.0 *Bq/L* recommended by WHO. Since the gross alpha activity in drinking water is higher than 0.1 *Bq/L* and the gross beta activity exceed 1.0 *Bq/L*, it can be assumed that the annual effective dose is higher than 0.1 *mSv* per year.

Nigeria has no public drinking water standards for radioactivity yet. So, the above results are comparable with the guideline values of WHO for drinking water. It is found that the water in all the sampling sites is not safe for livestock and domestic consumption. Therefore there is need for further screening for radioactivity from the all sampling sites and the whole Dam because continues use of the water for direct drinking from the Dam may pose serious health side effects to the public users.

The obtained data in this study serve as base–line data used to evaluate the possible health impact of the water. This work could help to create a public awareness about the total or gross alpha and beta activities in drinking water and the radiological impact on the dweller's health.

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