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Gross alpha and beta survey of Lake Kainji Water, Nigeria

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Abstract
A water radioactivity study of the upstream and downstream of Kainji Lake was conducted. Gross alpha and beta survey method was used in the study to estimate the radioactivity concentration due to natural radionuclides. 8-channels, multi-channel analyzer, a proportional counter detector is used for the study. The Gross alpha and beta activity concentration analyzed in the water shows that the alpha activity ranges from $1.0x10^{-5}$Bq/cm^3 to 0.7Bq/cm^3 with an average value indication of 0.0702Bq/cm^3, whereas the beta activity concentration indicated BDL for all the sites with exception of upstream 01, location (9^o 51'.485" and 4^o 35'.473"E) which has 0.0022Bq/cm^3. All the values for the selected water samples were lower than the permissible limit for drinking water consumption, 1.0 and 0.1 Bq/L respectively.

Key words: Contamination, decay, downstream, radioactivity, upstream

Introduction

Water is the most essential material that remains critical in fisheries development, and sustainability of life on earth planet. This has brought about the demand for clean water free from contaminations to continuously increase in line with world population growth. Unlike other natural resources or raw materials, ground and surface water is present throughout the world with different distribution pattern used in drinking, aquaculture, irrigation, power generation, recreation etc. This has made ground and surface water with their produce (fish, plant, snail etc.) an area of concern against the hazardous environmental effects. Radioactivity in environment comes from both natural background and man-made sources. Naturally occurring radioactivity are due to bedrock formations which are weathered, resulting in mineral leaching that leads to contamination (Sanchez *et al*., 1995). Artificial radioactivity is due to human activities, contaminations are mainly as a result of agriculture, medicine, research as well as other activities like mining and milling of mineral ore which exposes the earth surface. Most of these activities which can increase to certain degree the environmental radioactivity of an area are commonly found in Kainji lake area to certain proportion.

Many radionuclides are known to decay by alpha, beta and other form of emission which happen to pose hazard when ingested and once found in water can have serious effect on the biological system, through emission of radiation at various energies which will have molecular interaction with the cellular composition of organism, (Bolsover *et al.*, 2004). Alpha-radiation, for instance was recognized to be the most hazardous type of radiation when incorporated in the human body. This is due to the high mass and linear energy transfer (LET) of α-particles (Knoll, 1989). Thus, all radiobiological damage effects begin with the consequence of radiation interactions with the atoms forming the cells.

Due to these reasons, there is an urgent need for the proper monitoring and protection of this largest man-made lake in Nigeria, which is serving as the major source of water to the entire populace living around the Kainji area. Since the Lake is an essential part of livelihood for the people living in the area, its quality assurance is also very crucial for their wellbeing and that of their fisheries recourses.

Material and Method

Study Area

Lake Kainji is situated between latitudes 9^{o} 50' - 10^{o} 57' North and longitudes 4^{o} 25' - 4^{o} 45' East. The Lake was impounded on 2nd August 1968 and it is 136.8 km in length and 24.1 km maximum width. Its surface area has been variously quoted as approximately 1,300 km^2. At full volume, the water is at the altitude 142 m and at low volume the water is at the 133 m level, (Abiodun, 2003). The Lake, which is surrounded by many fishing communities; resulted from the damming of the River Niger is the largest artificial Lake in Nigeria and is well known for fishing, irrigation and recreational activities. Apart from hydropower generation it received thousands of visitors and tourist yearly due to the fact that it is situated within the Nigeria's first game reserve.

Site selection

Ten locations were selected from the already established study stations on the lake, with seven points from the upstream and three points downstream of the lake for the study.

Samples Collection

The study on the lake for natural radioactivity was based on the accepted guideline permissible and adopted by the International Commission on Radiological Protection (ICRP, 1991), the National Committee on Radiation Protection and Measurements (NCRP), (EPA, 2000; IAEA, 1996).

The water samples were carefully collected into 2 litres bottles at a depth of approximately 0.6m to 0.8m from the locations both upstream and downstream of lake. They were then treated immediately with 2 drops of nitric acid to reduce PH and minimize precipitation and absorption on container wall. The samples were then sealed, labelled and the exact position of sampling was noted using GPRS device, before transporting to laboratory at National Institute for Freshwater Fisheries (NIFFR) for storage. Thereafter all samples were transported to Center for Energy Research and Training (CERT), Ahmadu Bello University, Zaria for the analysis.

Samples Preparation for gross alpha and beta analysis

To obtain sediments, 500.0cm^3 volume of the water samples collection were first evaporated using 1000ml beakers and electrical hot plates at lower temperature. Thereafter the reduced volume of water was transferred into crucibles for surface evaporation using UV light to obtain all sediments. The sediments were transferred to Planchet and weighted in order to obtain all the necessary parameters for the use of Multi channel proportional counter for gross alpha and beta assessments. Here the water sample proved to contain much dissolved solids than its counterparts obtained elsewhere in Katsina state.

Counting for gross alpha and beta activity

The counting equipment was standardized and automated. The procedure involves entering the present time, number of cycles and the counting operational voltage. Likewise the counter characteristics (channel efficiency and background count rate), volume of sample used and sample efficiency were entered. The sample efficiency was taken as;

$$Sample\ Efficiency = \frac{M_T}{0.1A} \times 100\% \quad (1)$$

where M_T is the mass of the residue in the Planchet from the samples preparation and 0.1A (mg) is the expected mass of the expected mass of the residue in the Planchet.

Gross Alpha counting

In the gross alpha counting, the operational high voltage was set at 1600V and the samples were counted for 3 cycles of 3600s per cycle. The displayed result were presented as raw count; count rate (count/min), activity and standard deviation. The data were acquired for alpha mode only and the alpha count rate as well as the alpha activity was calculated using the formula; (ISO, 1991),

$$Rate\ \alpha\ (count/\sec) = \frac{Raw\ \alpha\ count \times 60}{Count\ time\ (sec)} \quad (2)$$

$$Activity\ \alpha = \frac{Raw\ \alpha \times Bgd\ \alpha \times \alpha\ unit\ coefficient}{Channel\ \alpha\ efficiency \times Sample\ efficiency \times Sample\ Vol.} \quad (3)$$

where unit coefficient is the multiplication coefficient making it possible to obtain the result expressed in units used for the operation (*p*ci/l, efficiency in %).

Gross Beta Counting

The operational high voltage for the gross beta counting was set at 1700V and samples were also counted for 3 cycles of 3600s in beta mode only. The count rate and activity were calculated using the formula; (ISO, 1991),

$$Rate\ \beta\ (count/\sec) = \frac{Raw\ \beta\ count \times 60}{Count\ time\ (sec)} \quad (4)$$

$$Activity\ \beta = \frac{Raw\ \beta \times Bgd\ \beta \times \beta\ unit\ coefficient}{Channel\ \beta\ efficiency \times Sample\ efficiency \times Sample\ Vol.} \quad (5)$$

Data Presentation as 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, (ISO, 1991);

$$C = \frac{(R_b - R_o) \times a_s \times m \times 1.02}{(R_s - R_o) \times 1000 \times V} \quad (6)$$

Where R_s is the observed sample count rate (s^{-1}), R_o is the background count rate (s^{-1}), $R_b$is the observed standard count rate (s^{-1}), a_b 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;

$$C = \frac{(R_b - R_o) \times 14.4 \times m \times 1.02}{(R_s - R_o) \times 1000 \times V} \quad (7)$$

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). The activity concentration C is converted to Bq/cm^3.

Result and Discussion

Alpha and Beta activity concentration in the collected water samples

Gross alpha and beta activity concentration analysis for the collected water samples is presented in table 1. The alpha activity ranges from 1.0 x10^{-5}Bq/cm^3 to 0.7Bq/cm^3 with an average value indication of 0.0702Bq/cm^3, whereas the beta activity concentration indicated BDL for all the sites with exception of Upstream 01, location (9^o 51'.485"N and 4^{o}35'.473"E), which is 0.0022Bq/cm^3. All the values as presented for the selected water samples studied were very far lower than the permissible limit for drinking water consumption, 1.0 and 0.1 Bq/L respectively.

Radioactivity in lakes is usually expected to be higher than those of flowing waters, because a significant part of the radioactive substance brought in by other tributary rivers accumulates in it, (Szabo *et.al*., 1998).

Although Kainji Lake has many tributary rivers empty into the lake at various locations upstream, this study has shown a very less activity concentration for the lakes water body. This could be attributed to the continuous mass flow of the lake water due to its primary activity of hydro-power generation downstream that constantly replenished and aerate mass volume of this lake in time.

Table 1: Alpha and Beta Activity Concentration in Water Sample collected

S/No	Sample ID	Sampling Location Longitude	Latitude	Alpha Activity In $Bqcm^{-3}$	Beta Activity In $Bqcm^{-3}$
1	Upstream01	9°51'.485"N	4°35'.473"E	0.00018	0.0022
2	Upstream02	9°51'.285"N	4°35'.533"E	0.00037	BDL
3	Upstream03	9°51'.722"N	4°34'.424"E	1.20E-05	BDL
4	Upstream04	9°54'.102"N	4°33'.942"E	1.00E-05	BDL
5	Upstream05	NIL		0.0002	BDL
6	Upstream06	NIL		2.20E-05	BDL
7	Upstream07	9°57'.638"N	4°32'.415"E	3.20E-05	BDL
8	Downstream01	9°51'.337"N	4°37'.054"E	3.70E-05	BDL
9	Downstream02	9°51'.369"N	4°36'.952"E	0.00084	BDL
10	Downstream03	9°51'.797"N	4°36'.849"E	0.7	BDL
			Average	0.07017	BDL
			Max	0.7	0.0022
			Min	0.00001	BDL

Conclusion

The water samples indicate very low alpha activity concentration with an average of $0.07017 Bq/cm^3$ for all location, whereas the beta activity in almost all location proved to be below detectable limit. This could be attributed to the fact that activity in surface water are not easy to be detected when compared to underground water (well or borehole). Though activity measured in lakes is usually higher than that of flowing waters, because a significant part of the radioactive substance brought in by other contributory rivers accumulates in it, (Szabo, *et.al*, 1998). The Kainji lake water is in constant rapid flow due to continuous operational activities for power generation and this constantly replenished the lake water as while as aerating it. This has makes the lake water less radioactive and suitable for domestic, industrial and fisheries activities with respect to surface water radio-ecological contaminants.

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