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Analysis of activity concentrations due to natural radionuclides in the fish of Kainji lake

Adamu R.*[1], Zakari Y. I.[2], Ahmed A. Y.[3], Abubakar. S.[1] and Vatsa A. M.[4]

[1]Federal College of Freshwater Fisheries Technology, New Bussa,
[2]Department of Physics, Ahmadu Bello University Zaria, Nigeria
[3]Center for Energy Research and Training, Ahmadu Bello University, Zaria
[4]National Biotechnology Development Agency, Abuja, Nigeria

ABSTRACT

A study is conducted for natural radioactivity of some fish samples from Kainji Lake, situated between latitudes 9^o 50' - 10^o 57' North and longitudes 4^o 25' - 4^o 45' East, New Bussa, Niger state, Nigeria, using gamma spectroscopy method with NaI(TI) detector. Radioactivity a phenomenon that leads to production of radiations, and radiation is known to trigger or induce cancer. The fish are analyzed to estimate the radioactivity (activity) concentrations due to natural radionuclides (Radium 222(^{226}Ra), Thorium 232 (^{232}Th) and Potassium 40 (^{40}K)). The obtained result show that the activity concentration for (^{226}Ra), in all the fish samples collected ranges from 16.06±0.44 Bqkg^{-1} to 67.39±12.34 Bqkg^{-1} with an average value of 37.22±4.31 Bqkg^{-1}. That of ^{232}Th, ranges from 42.66±0.81 Bqkg^{-1} to 200.6±10.66 Bqkg^{-1} and the average value stands at 94.82±3.82 Bqkg^{-1}. The activity concentration for ^{40}K, ranges between 243.3±1.56 Bqkg^{-1} to 384.98±11.97 Bqkg^{-1} and the average is 618.2±26.81 Bqkg^{-1}. This indicated that average daily intake due to natural activity from the fish is valued at 0.999 Bq/day, 2.545Bq/day and 10.31 Bq/day for ^{226}Ra, ^{232}Th and ^{40}K respectively. This shows a promising result, since the activity concentration values for most of the fish are within the acceptable limits. However location Upstream02 (9^{o}51'.285"N, 4^{o}35'.533"E) and Upstream07 (9^{o}51'.285"N, 4^{o}35'.533"E) fish, became outliers with significant values of 113.10μSvy^{-1} and 121.68μSvy^{-1} effective Dose. This could be attributed to variation in geological formations in the lake as while as the feeding habits of these fish. The work shows that consumers of fish from Kainji Lake have no risk of radioactivity ingestion, even though no amount of radiation is assumed to be totally safe.

Key words: Radioactivity, Dose, Radionuclides

INTRODUCTION

Naturally abundant radionuclides (^{226}Ra, ^{232}Th and ^{40}K) in the environment, and releases from fertilizers, agrochemicals, research and medical facilities form the bulk of radionuclides in ground and surface water, [16]. Therefore presence of radioactivity in contaminated environment can be attributed to naturally occurring and artificially induced sources. Naturally occurring radioactivity are due to bedrock formations which are weathered, resulting in mineral leaching that leads to contamination, [8]. Artificial radioactivity is due to human activities, 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. All this contamination may have health effect; that poses great danger to human and other living organism in the biosphere. Study of natural radioactivity is usually done in order to gain information about the present levels of harmful pollutants that are discharged to the environment itself or in the living creatures [12]. Radionuclides lead to production radiations, whereas radiation is known to trigger or induce cancer in living tissue.

MATERIALS AND METHODS

Samples Collection

The study on the lake fish for natural radioactivity was based on the accepted guideline permissible and adopted by the International Commission on Radiological Protection (ICRP), the National Committee on Radiation Protection and Measurements (NCRP). Samples of fish were collected upstream and downstream randomly from 10 reference points for the analysis. This was done using line hook and gills net at these location. The fishes are packaged into polyethylene bags, labelled and placed into ice container. The exact location of the each sample was taken using global positioning system (GPS). The samples were transported to central laboratory unit of National Institute for Freshwater Fisheries Research, New Bussa, in Niger state for preliminary preparation. The fishes were dissected, gills removed, washed and oven dried at 70^0C. They carefully packed into polyethylene bags and transported to the Centre for Energy Research and Training, Zaria for further preparation, Gamma spectroscopy count and analysis in accordance with standard methods.

Samples Preparation for Gamma spectrometry

The collected samples of fish were grounded to fine powder and packed into fill labelled cylindrical plastic containers of height 7cm by 6cm diameter. This satisfies the selection of optimal sample container height [4]. Each container accommodated approximately 300g of fine grounded and sieved fish powder. They were carefully sealed (using Vaseline, candle wax and masking tape) to prevent radon escape and store for a minimum of 30 days. This was to allow the radium attain equilibrium with its daughters, [10].

Samples activity Acquisition and Analysis in gamma spectrometry

Gamma ray spectrometry technique was employed in the spectral collection of the prepared samples using the higher energy region of the γ-lines. The 1764KeV γ-line of ^{214}Bi for U was used in assessment of the activity concentration of ^{226}Ra while 2614.5KeV γ-line of ^{208}Tl was used for ^{232}Th. The single 1460KeV γ-line of ^{40}K was used in evaluation of ^{40}K.The prepared samples were mounted on the detector surface and each was counted for 29,000 seconds in reproducible sample-detector geometry. The configuration and geometry was maintained throughout the analysis. A computer program from ORTEC was used for data acquisitions and analysis of gamma spectra.

Activity concentration

The activity concentrations in the samples were obtained using the equation 1 [9] and [6]:

$$C(Bqkg^{-1}) = kC_n \qquad 1$$

where $k = \frac{1}{\varepsilon P_\gamma M_s}$, C is the activity concentration of the radionuclide in the sample given in $Bqkg^{-1}$, C_n is the count rate under the corresponding peak, ε is the detector efficiency at the specific γ-ray energy, P_γ is the absolute transition probability of the specific γ-ray, and M_s is the mass of the sample (*kg).* The below detection limit (BDL) of a measuring system describes its operating capability without the influence of the samples. The BDL given in $Bqkg^{-1}$ which is required to estimate the minimum detectable activity in samples was obtained using equation (2), [6]:

$$DL(Bqkg^{-1}) = 4.65\,\frac{\sqrt{C_b}}{t_b}k \qquad 2$$

where C_b is the net background count in the corresponding peak, $t_b$is the background counting time (s) and k is the factor that converts counts per second (cps) to activity concentration ($Bqkg^{-1}$) as given in equation (1)

All the obtained raw data were converted to convectional units using conversion factors of $8.632x10^{-4}$, $8.768x10^{-4}$ and 6.43110^{-4} for ^{40}K, ^{226}Ra and ^{232}Th respectively to determine their activity concentrations. With the counting time of 29,000 seconds for each sample, the environmental γ-ray background of the laboratory site was determined using an empty container under identical measured conditions. This then gave the below detectable limit (BDL) limits to be 310.99 $BqKg^{-1}$ for ^{40}K, 16.21 $BqKg^{-1}$ for ^{226}Ra and 123.16 $BqKg^{-1}$ ^{232}Th respectively. This was subtracted from the measured γ-ray spectrum of each sample.

Effective dose from radionuclides in fish food and daily diet

By using the following equation, effective dose from radionuclides in food and daily diet was calculated [11] and [6]:

$$D\ (\mu Svy^{-1}) = D_f \times U \times (C_d \times h) \qquad 3$$

where, D is effective dose (μSvy^{-1}), D_f is the dose coefficient ($\mu SvBq^{-1}$) which is 0.19, 0.072 and 0.006 for ^{226}Ra, ^{232}Th and ^{40}K respectively. U is the amount of food consumed in 1 yr (kg $year^{-1}$), C_d is the radionuclide content of dried food $Bqkg^{-1}$, h is the ratio of dried to fresh foods. Nigeria, as a country has a low annual per capita fish consumption rate of 9.8 kg/year, [15]. Likewise the ratio of dried to fresh fish consumption is estimated at 30:70 going by the level of import in tonnage and local supply of fishes in Nigeria.

Internal hazard index (H_{in})

The internal hazard index (H_{in}) gives the internal exposure to carcinogenic radon in the fish samples and is given by equation (4), [2]:

$$H_{in} = \frac{C_{Ra}}{185} + \frac{C_{Th}}{259} + \frac{C_K}{4810} \qquad 4$$

The value of this index should be less than 1 $mSvy^{-1}$ in order for the radiation hazard to have negligible hazardous effects to the respiratory organs of the public [2].

RESULTS AND DISCUSSION

Activity concentration in fish samples

The gamma ray spectrometric analysis for the collected fish samples were presented in table 1. The obtained result show that the activity concentration for ^{226}Ra, in all the samples collected ranges from 16.06±0.44$Bqkg^{-1}$ to 67.39±12.34$Bqkg^{-1}$ with an average value of 37.22±4.31$Bqkg^{-1}$. That of ^{232}Th, ranges from 42.66±0.81 $Bqkg^{-1}$ to 200.6±10.66 $Bqkg^{-1}$ and the average value stands at 94.82±3.82 $Bqkg^{-1}$. The activity concentration for ^{40}K, ranges between 243.3±1.56 $Bqkg^{-1}$ to 618.2±26.81 $Bqkg^{-1}$ and the average is 384.98±11.97 $Bqkg^{-1}$. In all the fish samples analyzed, ^{40}K is observed to be higher compared to those of ^{232}Th and ^{226}Ra respectively, and this could be attributed to runoff from fertilizer application on farms within.

Average daily intake of radionuclide from fish samples in (Bq/day)

The average daily intake of these radionuclides for an individual consumption of these fishes, are 0.999Bq/day, 2.545Bq/day and 10.310Bq/day for ^{226}Ra, ^{232}Th and ^{40}K respectively. This is high compared to daily intakes from country like India with a higher per capital consumption of fish diet (20kg/yr), which stands at 0.13Bq/day for ^{226}Ra, 0.07Bq/day for ^{232}Th and 4.87Bq/day ^{40}K, [13] and Syria as reported in [1]

Effective dose rate and internal hazard index for fish samples

The annual effective dose to be received from the consumption of the fishes was calculated using equation (4). Since the annual per capital consumption rate for fish in Nigeria is currently put at 9.8Kg/year. As presented in table 4.4, the effective dose rate for ^{226}Ra, ranges between 12.86μSvy^{-1} to 53.96μSvy^{-1} with an average value of 29.802μSvy^{-1}. For ^{232}Th, the value ranges from 12.94μSvy^{-1} to 60.86μSvy^{-1} with an average value is 28.77μSvy^{-1}. ^{40}K, has lower value when compared to the two other radionuclides, with value ranges from 6.15μSvy^{-1}, to 15.63μSvy^{-1}, with an average value of 9.73μSvy^{-1}. All of these values obtained were lower than the world-wide average annual effective dose which is that stand approximately at 70 μSvy^{-1} [14].

The internal hazard index from the consumption of these fishes varies from 0.35 to 1.16 with an average value of 0.65. Internal hazard risk associated with radionuclide has to be less than 1.0 for radionuclide exposure to be considered safe, [5]. Therefore, two fishes samples collected both at upstream (Upstream 02 and 07), has indicated an internal radiation hazard index above 1.0. These fishes exceeded the recommended safe value as shown also in table 2.

Table 1: Total Activity Concentration per Fish Sample

S/No	Sample ID	Sampling Location Longitude	Latitude	Activity in $Bqkg^{-1}$ Ra-226	Activity in $Bqkg^{-1}$ Th-232	Activity in $Bqkg^{-1}$ K-40	Total Activity in Sample $Bqkg^{-1}$
1	Upstm01	9°51'.485"N	4°35'.473"E	26.53±0.32	57.03±1.30	306.3±8.80	389.86±10.41
2	Upstm02	9°51'.285"N	4°35'.533"E	46.46±4.51	200.6±4.70	593.4±4.84	840.46±4.07
3	Upstm03	9°51'.722"N	4°34'.424"E	32.08±4.00	70.48±0.47	286.7±7.90	389.26±12.34
4	Upstm04	9°54'.102"N	4°33'.942"E	42.5±1.64	56.36±0.24	499.1±9.81	597.96±11.68
5	Upstm05	NIL		47.5±5.11	164.3±5.14	365.6±5.61	577.4±5.86
6	Upstm06	NIL		18.78±0.49	42.66±0.81	414.4±3.83	475.84±5.27
7	Upstm07	9°57'.638"N	4°32'.415"E	67.39±12.4	171.7±10.4	618.2±6.81	857.29±4.29
8	Dstream01	9°51'.337"N	4°37'.054"E	29.8±0.60	42.75±0.59	245.7±2.68	318.25±3.17
9	Dstream02	9°51'.369"N	4°36'.952"E	45.1±2.68	79.91±2.64	277.1±7.35	402.11±12.68
10	Dstream03	9°51'.797"N	4°36'.849"E	16.06±0.44	62.45±1.18	243.3±1.56	321.81±3.17
	Average			37.22±4.31	94.82±3.82	384.98±1.7	517.024±0.04
	Max			67.39±12.3	200.6±10.6	618.2±2.81	857.29±4.29
	Min			16.06±0.44	42.66±0.81	243.3±1.56	318.25±3.17

Table 2: Effective dose rate and internal hazard index in Fish sample

S/No	Sample ID	Sampling Location Longitude Latitude	Effective Dose rate in μSvy^{-1} ^{226}Ra	Effective Dose rate in μSvy^{-1} ^{232}Th	Effective Dose rate μSvy^{-1} ^{40}K	Total Effective Dose rate μSvy^{-1}	Internal hazard index H_{in}
1	Upstm01	9°51'.485"N 4°35'.473"E	21.24	17.30	7.74	46.29	0.43
2	Upstm02	9°51'.285"N 4°35'.533"E	37.20	60.86	15.00	113.10	1.15
3	Upstm03	9°51'.722"N 4°34'.424"E	25.69	21.38	7.25	54.32	0.51
4	Upstm04	9°54'.102"N 4°33'.942"E	34.03	17.10	12.62	63.75	0.55
5	Upstm05	NIL	38.03	49.85	9.24	97.13	0.97
6	Upstm06	NIL	15.04	12.94	10.48	38.46	0.35
7	Upstm07	9°57'.638"N 4°32'.415"E	53.96	52.10	15.63	121.68	1.16
8	Dstream01	9°51'.337"N 4°37'.054"E	23.86	12.97	6.21	43.04	0.38
9	Dstream02	9°51'.369"N 4°36'.952"E	36.11	24.25	7.01	67.36	0.61
10	Dstream03	9°51'.797"N 4°36'.849"E	12.86	18.95	6.15	37.96	0.38
	verage		29.802	28.77	9.73	68.31	0.65
	Max		53.96	60.86	15.63	121.68	1.16
	Min		12.86	12.94	6.15	37.96	0.35

CONCLUSION

Fish which is one of the major sources of protein diet to the people living around the lake had shown a promising result. The values obtained were within the acceptable limit. The average daily intakes that may result from the obtained activity in this study were 0.999Bq/day, 2.545Bq/day and 10.310Bq/day for ^{226}Ra, ^{232}Th and ^{40}K respectively. However location Upstream02 (9°51'.285"N, 4°35'.533"E) and Upstream07 (9°51'.285"N, 4°35'.533"E), fish became outliers with significant values of 113.10μSvy^{-1} and 121.68μSvy^{-1} effective dose. They show a higher internal hazards index (H_{in}) values of 1.15 and 1.16, compared to the other fish in this study. This could be attributed to feeding habit of these fish and geological formations of the locations where they are found.

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