Research article
2024 | Volume 12 | Issue 2 | Pages 65-69

ARTICLE INFO

Received
February 27, 2024
Revised
April 26, 2024
Accepted
April 28, 2024
Published
May 29, 2024

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Keywords
Effective dose
Fish
Radioactivity
Radionuclides
River Kubani

How to Cite
Adigun MO, Sodipo BK. Determination of ^{40}K, ^{238}U and ^{232}Th activity levels in fishes from river Kubanni in Nigeria. Science Letters 2024; 12(2):65-69

Open Access

Determination of ^{40}K, ^{238}U and ^{232}Th Activity Levels in Fishes from River Kubanni in Nigeria

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Abstract

Radionuclides exist naturally in the water, soil and air and human activities can increase the concentration of background radiation and redistribution of radioactive isotopes in the environment. In this study, the radioactivity concentration of three radionuclides (^{40}K, ^{232}Th and ^{238}U) was measured in three fish species, *Oreochromis niloticus* (Tilapia), *Brycinus leuciscus* (Kawara), *Brienomyrus longianails* and *Clarias anguilaris* (catfish) in river Zaria (Kubanni). The results showed that ^{40}K and ^{232}Th concentrations were high in Brienomyrus longianails with mean activities of 357.26 and 92.282 Bq/Kg, respectively. While the concentration of ^{226}Ra was found high in *Clarias anguilaris* (56.129 Bq/Kg). The mean committed dose for both adults and children were 0.00214 and 0.00342 µSv/yr, respectively. The values of three radionuclides obtained in this study are lower than the maximum permissible level of 1.0 mSv/yr recommended by the International Commission on Radiological Protection (ICRP) as the total annual effective dose for the public. The obtained results show that the radiation dose acquired from the consumption of fresh fish from the river Kubanni will have no significant health effect on the populace.

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Introduction

Radionuclides are ubiquitous in varying concentrations in our environment. Radionuclides exist in the environment (water, soil and air) from either natural or artificial sources such as medical or industrial operations [1]. The naturally occurring radionuclides can be due to the mining of geological resources such as gas exploration, oil and minerals and manufacturing of phosphate fertilizer [2]. These activities can increase the concentration of background radiation and redistribution of radioactive isotopes in the environment [3]. Plants and animals in the aquatic environment can absorb radionuclides more than the ambient. This is due to the chemical and physical attributes of their surfaces [4]. Studying and monitoring radioactivity levels allows continuous evaluation of the number of radioactive materials in the environment or exposed to living organisms. Therefore, radiation levels need to be constantly monitored and evaluated for the safety of the environment [5]. The presence of radionuclides in aquatic biota is due to their solubility in water. Radionuclides in the rivers may contribute to the dose level in man through different pathways including consumption of seafood. In Nigeria, fish is the most common seafood and one of the major sources of animal protein. It is of interest to know the levels of radionuclides in freshwater fish. The study area, River Kubanni is dominated by human activities. It receives wastewater from Samaru, Ahmadu Bello University (ABU) Campus and the surrounding settlements. Daily activities such as irrigation, fishing and domestic consumption increase at different rates and sections of the river. An increase in human and industrial activities can cause a rise in the level of radiation in the river. For the basis of monitoring environmental radioactive concentrations in the river and any future change due to anthropogenic factors, this report determines radionuclide dose in common fish species in River Kubanni. The internal radiation dose to the inhabitance due to Fish consumption is estimated using the obtained data.

Materials and Methods

Location

River Kubann (Fig. 1), Zaria, Kaduna State, Nigeria has its course from the Kampagi Hills near Shika and flows 21 km southward into the Galma River (Latitude 11° 230″N–11° 30″N and Longitude 7° 37′30″E–7° 45′0″E). It is located at approximately 670 m above sea level and within the Central High Plains of Northern Nigeria Savannah region.

Samples collection and preparation

Based on the common species in the river, 200 samples of four different species were selected. The selected species are *Oreochromis niloticus* (tilapia), *Brycinus leuciscus* (Kawara), *Brienomyrus longianails* and *Clarias anguilaris* (catfish) and labeled as fish A, B, C and D, respectively. Each species was grouped into three groups and labeled SO_1, SO_2, and SO_3, respectively. Then, the average was determined. The fish were dried at 80°C and ground into fine powder as reported earlier [4]. From the prepared samples, 150 g, was analyzed using the International Atomic Energy Agency standard [6]. The samples were packed with Radon-impermeable cylindrical plastic containers and triple-sealed to prevent the escaping of radon-222. Before gamma spectrometry measurements, the samples were kept for 30 days for a secular radioactive equilibrium of radon and its short-lived progenies. Gamma spectroscopy by Canberra with the assembly of sodium iodide detector doped Therlium, {NaI(TI)} detector, with Ortec's MAESTRO software for Windows Model A65-B32 was used to measure the activity concentration of the samples. The model number of the Gamma spectroscopy is 727 with serial No. 11914167. Each sample was measured for 29000 seconds. The average activity concentrations of ^{40}K, ^{232}Th and ^{238}U were calculated using the gamma energy peak of 1460.0, 2614.5 and 1764.0 Kev, respectively.

Determination of activity concentration

The activity concentration of the samples was determined using equation 1 [7]:

$$C\ (Bq/kg) = \frac{C_n}{C_{fk}} \quad (1)$$

Where C = activity concentration of the radionuclides in the samples, C_n is the counting rate per second and C_{fk} is the calibration factor of the detecting system.

Committed effective dose

The total committed effective dose in adults and children for consumption of fish was calculated by adding the doses for each radionuclide using equation 2 as reported earlier [8].

$$D = \sum[C_R \times A_D \times C_C] \quad (2)$$

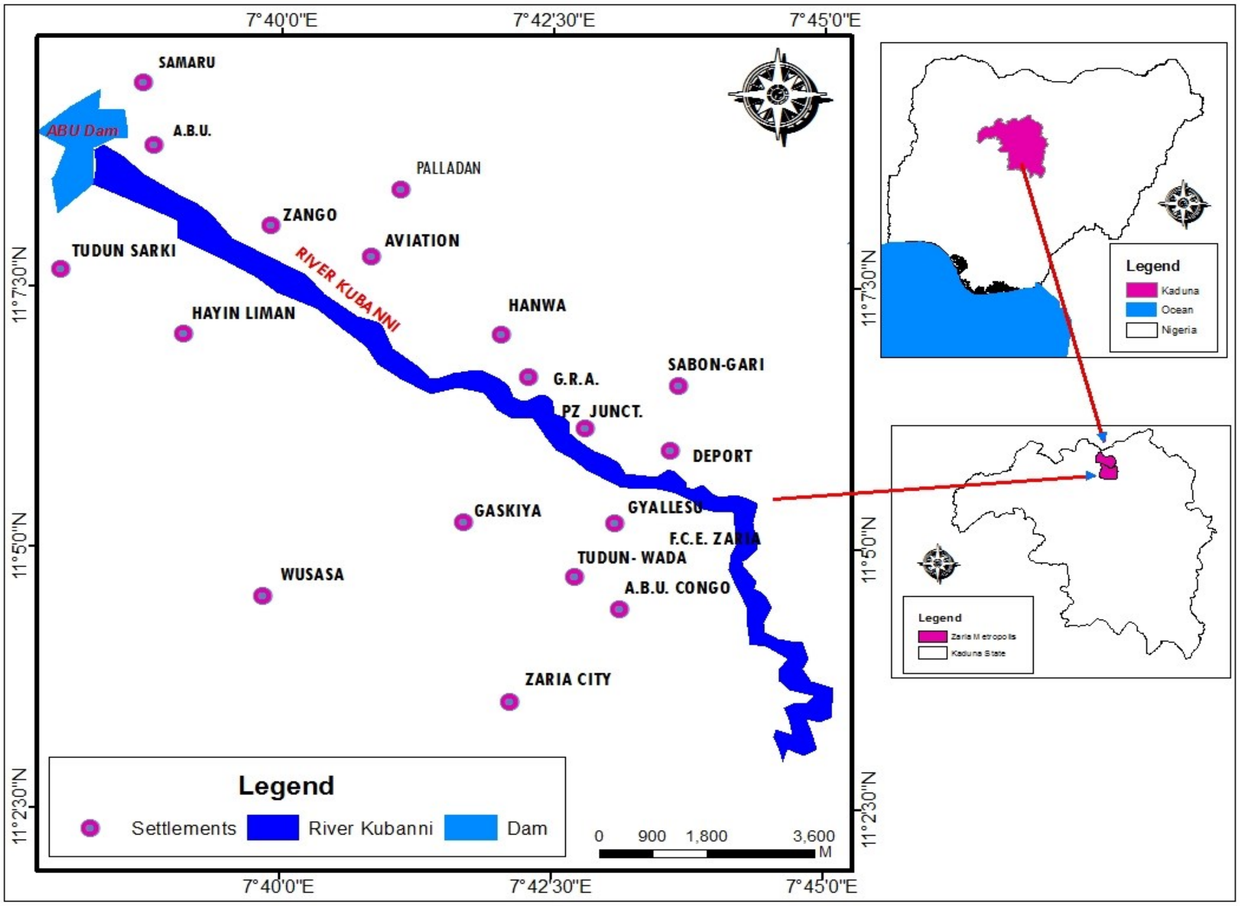

Fig. 1 Map of River Kubanni showing only settlements and dam sites.
Source: GIS Lab, Department of Geography and Environmental Management, A.B.U. Zaria.

Where D (mSv) is the committed effective dose, C_R (Bq kg^{-1}) is the activity concentration of radionuclides in the fish, A_D (kg) is the average daily intake of the fish and C_C is the committed effective dose coefficient of the radionuclides. The dose coefficients for adults used in this work are 2.8×10^{-7} Sv Bg^{-1}, 2.3×10^{-7} Sv Bg^{-1} and $6.2 \times 10-9$ Sv·Bq^{-1} for ^{226}Ra, ^{232}Th, and ^{40}K, respectively. Potassium-40 isotope is homeostatically regulated in the human body and its content in the body is often decided by its physiological characteristics rather than by its consumption [4].

Statistical analysis

The obtained data were expressed as means and their standard deviations were determined. One-way analysis of variance (ANOVA) was used to compare the mean concentrations of the obtained radioisotopes from different samples. Tukey's post hoc multiple comparison test was used to compare the samples. Values of p less than 0.05 were considered significant at a 95% confidence interval. A statistical package for social sciences (IBM SPSS version 26, 2019) was used for the analysis.

Results and Discussion

Activity concentration

The activity concentrations of the radionuclides were found to be 270.1, 46.8 and 82. 8 Bq/Kg, respectively. The concentration of ^{40}K was significantly ($P < 0.05$) high in sample C (357.26 Bq/Kg). There were no significant differences in the concentration of ^{226}Ra and ^{232}Th in all the samples. However, sample D was found with the highest average activity concentration of ^{226}Ra (56.13 Bq/Kg) while ^{232}Th was highest in sample C (92.28 Bq/Kg). The activity concentrations of the radionuclides are presented in Fig. 2. ^{40}K concentration was highest in sample C and lowest in sample D. Although, ^{226}Ra has no significant difference in the analyzed samples. Sample D demonstrated the highest value of ^{226}Ra. The average

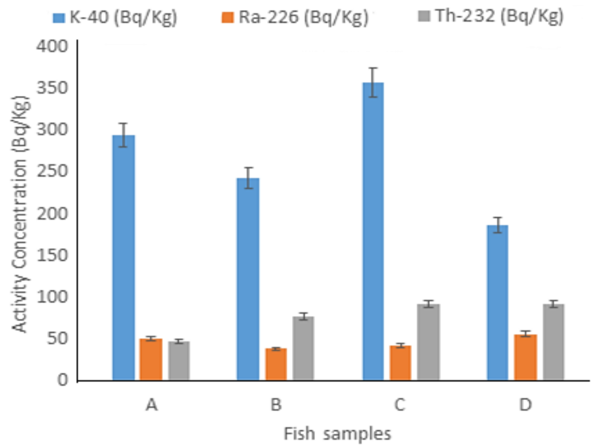

Fig. 2 The average activity concentration of the radionuclides in fish samples. A = *Oreochromis niloticus* (tilapia); B = *Brycinus leuciscus* (Kawara); C = *Brienomyrus longianails*; D = *Clarias anguilaris* (catfish)

activity concentrations for ^{226}Ra and ^{232}Th were above the world average value of 30 and 36 BqKg^{-1}, respectively. This can be related to industrial and agricultural waste contaminants in the river. The sources of the radionuclides may be traceable to refuse dumps, farmlands, public gutters and effluents from research centers and institutions in the catchment area of River Kubanni [9, 10]. These natural radionuclides can be present in water, sediments, fish, rocks and soils [11]. Like Ademola and Ehiedu [4], our results are comparable to the activity concentration of ^{226}Ra and ^{232}Th but lower than the results of some other researchers [5, 12]. The ^{40}K activity values obtained from this study indicate lower concentrations compared to related works within Nigeria [4], in Ondo State [12], in Kainji Dam [13] in Ado-Ekiti and Turkey [14]. However, it is higher compared to that in Niger Delta, India [15, 16], and Malaysia [1]. The significantly higher activity concentration of ^{40}K in the samples can be due to their consumption of feeds high in ^{40}K content. This can be due to high agricultural activities around the river. The use and erosion of fertilizer from the farmlands may increase the presence of ^{40}K in the river.

Committed effective dose

The radiation dose absorbed by the inhabitants of the study area was estimated using the activity concentration obtained. The committed effective doses (CED) were used to calculate for both adults and children. The effective dose to an individual (children or adults) due to consumption of the fish containing radionuclides is calculated based on the metabolic model [5]. The model provides the relevant conversion factors to calculate effective doses from the total activity concentrations of radionuclides measured in food (fish). The model is based on equation 2 which involves the measured activity concentrations of the radionuclides in the fish (Bq·kg^{-1}), the consumption rate of the fish and the dose conversion factor for each radionuclide present in the fish. The information obtained was used to evaluate the potential health risks to the populace. The radionuclides concentration in the environment can influence the amount of CED due to fish intake. The committed doses due to consumption of the fish were calculated for adults and children with 25 and 40 kg per average consumption rate, respectively [15]. The total CEDs calculated for both adults and children are recorded in Table 1. The highest CED values 0.00271 and 0.00433 µSv/Yr, for both adults and children, respectively, were obtained in sample C. However, the lowest values (0.00156 and 0.00250 µSv/Yr) for both adults and children, respectively, were obtained in sample D. The mean total committed dose recorded was 0.00214 µSv/Yr and 0.00342 µSv/Yr for both adults and children, respectively. The mean total committed dose for adults in this study was compared with values recorded by other researchers such as 0.80 mSvy^{-1} for Canada [17], 0.82 mSvy^{-1} for Bangladesh [18], 0.76 mSvy^{-1} for USA [19], 2.30 mSvy^{-1} for Pakistan [20] and 36 mSvy^{-1} for South Africa [21]. The obtained value of this work was significantly lower. The values were lower than 0.29 mSvy^{-1} than the world average value as determined by UNSCEAR [11] and lower than 1.0 mSvy^{-1} by ICRP [8] as the maximum acceptable level for the public. The results demonstrated the radiation dose from the fish consumption from the study area has no significant health effect on the populace.

Table 1 Committed effective dose ingested by children and adult fish.

Sample	Committed effective dose (µSv/Yr)	
	Children	Adult
Fish A	0.00224 ± 0.00050	0.00359 ± 0.00081
Fish B	0.00205 ± 0.00025	0.00328 ± 0.00041
Fish C	0.00271 ± 0.00031	0.00433 ± 0.00051
Fish D	0.00156 ± 0.00015	0.00250 ± 0.00024
Mean	0.00214 ± 0.00020	0.00342 ± 0.00033

A = *Oreochromis niloticus* (tilapia); B = *Brycinus leuciscus* (Kawara); C = *Brienomyrus longianails*; D = *Clarias anguilaris* (catfish)

Conclusion

The activity concentrations of radionuclides were determined in four different fish samples from River Kubanni, Zaria Kaduna using gamma-ray spectrometry techniques. The values of mean activity concentrations were found to be 270.14, 46.86 and 77.24 Bq kg$_{-}^{1}$ for ^{40}K, ^{226}Ra and ^{232}Th, respectively. Sample C demonstrated the highest average activity concentration. ^{40}K and ^{232}Th recorded 357.26 and 92.28 Bq/Kg, respectively. While the highest value of ^{226}Ra 56.13 Bq/K was obtained in D species. The calculated committed effective dose via fish consumption by adults was 0.00214 µSv/Yr. The committed effective dose via fish consumption by children is found to be 0.00342 µSv/Yr. The recorded annual committed effective dose values are lower than the acceptable limit of 1.0 mSv y$_{-}^{1}$. The acquired dose from the consumption of these species from river Kubanni shows no significant radiological health effect.

Conflict of interest

The authors claim no conflicts of interest.

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