EVALUATION OF NATURAL RADIOACTIVITY IN FISH-FEEDS AND COMMERCIALLY CULTIVATED CATFISHES IN LAPAI-GWARI, NIGER STATE.

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ABSTRACT

This study is focused on the concentration of natural radionuclides in locally produced fish feeds and Catfishes (Clarias gariepinus) obtained from commercial fish ponds from Lapai Gwari in Niger State. Five (5) samples of local fish feed and catfishes were collected from the feed market in Lapai Gwari, Niger State and analyzed for their natural radionuclide contents using NaI (TI) gamma ray detector. The activity concentrations of primordial radionuclides in the samples were determined using the gamma spectrometric technique because of its high efficiency detection with the aim of evaluating the radiological implications attached with the consumption of locally cultivated catfishes in Lapai Gwari. The mean activity concentration in the catfish samples for ^{40}K, ^{226}Ra and ^{232}Th were 41.61, 0.55 and 2.03 Bq/kg respectively; while the mean activity in the fish-feed samples for ^{40}K, ^{226}Ra and ^{232}Th were 30.14, 0.60 and 4.6 Bq/kg respectively. The mean committed effective dose evaluated from the activity concentrations of ^{40}K, ^{226}Ra and ^{232}Th in the catfish samples is 0.0682 μSv/y. The excess lifetime cancer risk was also estimated, having a mean of 0.2387×10^{-6} for the catfishes. The computed mean committed effective dose and excess lifetime cancer risk were found to be lower than the recommended safety limit of 1.0 mSv/y and 2.9×10^{-3} respectively as set by International Commission for Radiological Protection (2007). This shows that the radiation dose incurred from the ingestion of the fresh catfish samples pose no significant health risks to the population from a radiological point of view.

Keywords: *(Natural Radioactivity, Catfish, Fish-feed, Lapai-Gwari, Radionuclides)*

INTRODUCTION

There are three major sources of ionizing radiation: natural radioactivity, cosmic radiation and artificial radioactivity. Natural radionuclides, such as uranium, thorium and their daughters, were formed at Earth's origin (Aswood, 2017). Cosmic radiation originates outside the Earth, Artificial radioactivity has been since the beginning of the atomic era, to which a number of radionuclides have been produced by man and released into the environment (UNSCEAR, 2000). All sources of radionuclides to the environment contribute to the radiation doses on both humans and the wider environment, and therefore should be evaluated. The measurement of radioactivity in the environment is a more recent effort with several studies focused on the distribution of natural radioactivity via exposure. (Khandaker *et al*., 2015). Radioactive elements are widely distributed through the environment, generally in a trace amount in sediment, air, soil and others (Fasae and Isinkaye, 2018). Natural occurring radionuclides are present in every human environment; earth materials, water, air, food and even our body (Alausa, 2012).

Fishes are produced from capture and cultured (aquaculture) fisheries operations. Fish farms are usually established in other to achieve self-sufficiency in fish production and to supplement capture fishery production. According to Gabriel *et al.* (2007), Catfish is consumed because it has high protein, essential amino acids, vitamin, and mineral content. It is undoubtedly one of the important sources of protein in the diet of Nigerians (Ayanwale *et al.*, 2013; Opasola *et al.*, 2019).

This Fishes could be exposed to natural radionuclides in polluted environments. While human and fishes are daily exposed to external radiation from cosmic and terrestrial radiation, radionuclides in the feed may more typically contribute to internal exposure via ingestion. There is a growing concern on the radiation levels in fish feed due to the addition of mined limestone. It is important therefore to investigate the radioactivity levels in fish feeds and fish samples. The data obtained would be used to estimate the resulting internal radiation dose received by the populace as a result of fish consumption. The exposure of human beings to radionuclides is majorly through the pollution of the food chain which is as a result of the direct deposit of radionuclides from intake of contaminated water, leaves of plants or even through contaminated fishes (Avwiri et al., 2007). The fate and cycling of radionuclides in ecosystems have long been a subject of major interest to applied ecologists and health physicists (Gabriel, 2015).

The environment of Lapai-Gwari in Niger State has a lot of commercially cultivated fish ponds and as such requires a systematic investigation on the levels of radionuclide contamination. Human beings through the ingestion of aquatic organisms (catfishes) are at risk due to increase in trace metal concentration in the marine environment (Uluturhan *et al.*, 2007). As a result of the effects of these radionuclides in the biota, the determination of the levels of radionuclides contamination have received considerable attention in different countries around the world. Such interest is aimed at minimizing the potential hazard effect such as cancer and ensuring safety towards human health (Alauddin, 2017).

MATERIAL AND METHODS

Study Area

The surburb of Lapai-gwari has its major source of water through irrigation and boreholes as Fish Farming is the major occupation of those living there. The geographical location (geolocation) of Minna is on the north and east hemisphere. Lapai-gwari as a village under minna, occupies the central portion of the Nigerian basement complex. Minna as an area comprises of meta-sedimentary and meta-igneous rocks which have undergone polyphase deformation and metamorphism. These rocks have been intruded by granitic rocks of Pan-African age. Many fish ponds were found to be in Lapai-gwari located within Latitude 9^0 31' 24.86" N and Longitude 6^0 29' 59.68" E (as shown in Figure 1).

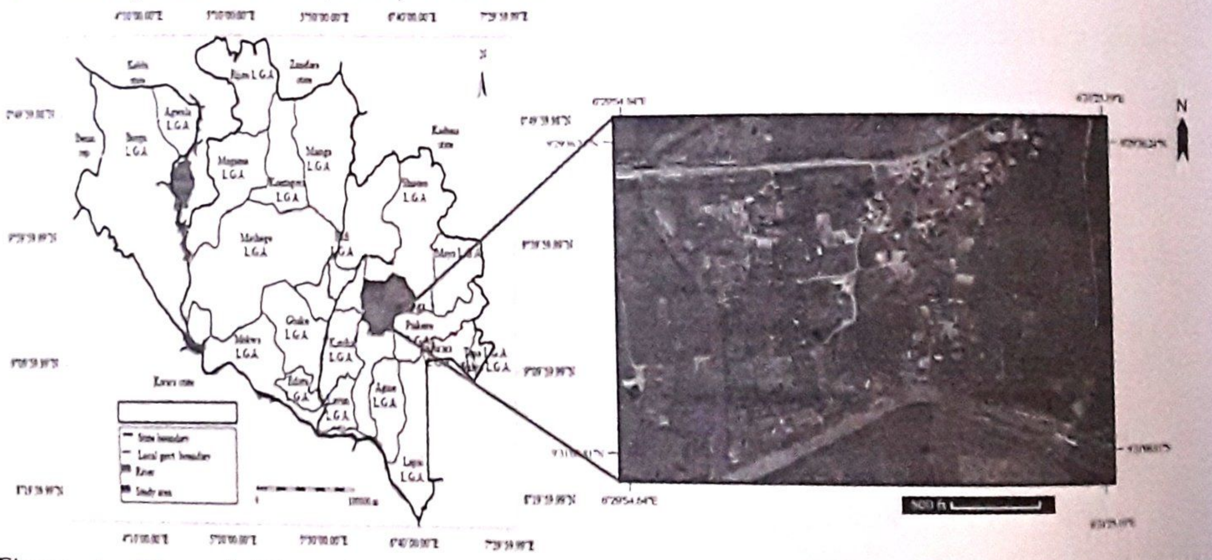

Figure 1: Map of Niger State showing Chanchaga area (Abd'Razack and Muhamad, 2013; https://thegpscoordinates.net/nigeria/minna).

Sample Collections and Preparation

Ten samples each of the local fish feed and catfishes samples (20 in total) were collected from the feed market and fish ponds in Lapai-Gwari area, Niger State. About 5 Kg of locally produced fish feeds were bought from the feed mills within the study area where the locally made feeds were produced. Similarly, the same species of catfish (*Clarias Gariepinus*) were bought directly from a fish farmer whose pond was been harvested. Five (5) pieces of catfish were bought having varying weights between 2 Kg-2.5 Kg. The catfishes were taken to the laboratory and were washed with distilled water. The fish feeds and the fish samples were dried at 80 °C in an oven until there was no detectable change in mass of the samples. The dried samples were thoroughly crushed, grounded and pulverized to fine powder (Ademola & Ehiedu, 2010). The powder was sieved through a 2 mm sieve. Due to the limited space of the detector shield, only 100 g of the fish feed and fish samples (dry-weight) were used for analysis. The samples after weighing, were transferred to radon-impermeable cylindrical plastic container of uniform size (60 mm height by 65 mm diameter) and sealed for a period of 4 weeks. This was done to allow for radon and its short-lived progenies to reach secular radioactive equilibrium prior to gamma spectroscopy.

Figure 2: The sealed catfish and feed samples

Radioactivity Measurement

The gamma ray spectrometry system consisting of 3x3 inch NaI(Tl) detector by Scintillation Technologies USA located at Ladoke Akintola University of Science and Technology (LAUTECH) Ogbomosho, Nigeria was used for the measurement. The detector is housed in a 6cm thick lead shield so as to reduce the background radiation levels. The inside of the detector was lined with cadmium and copper sheets, which help to absorb the emitted x-rays from lead which may contain radioactive impurities due to antimony impurities. The detector assemblage was coupled to a computer based multichannel analyzer (MCA) with ACCUSPEC computer program used for data acquisition and analysis of gamma spectra. The efficiency and energy calibration of the detector were done over energy range using ^{137}Cs and ^{60}Co standard isotopic sources over energy range of 200keV to 3MeV, being the energy range of radionuclides to be determined. Prior to the sample measurement, an empty container of the same dimension was counted for 10 hours (36000 seconds) so as to determine the background gamma-ray distribution count. The data analysis routine subtracted a linear net background distribution from the corresponding net peaks for a particular radionuclide in the spectra of the samples. The activity concentration of ^{226}Ra was evaluated from 1764keV gamma line of ^{214}Bi, while 2614keV gamma line of ^{208}Tl was used to evaluate the activity concentration of ^{232}Th. ^{40}K was determined by measuring the 1460.0 keV gamma rays emitted during the decay. Each sample was counted for 10 hours. From the net area of a certain peak, the activity concentrations in the sample were obtained using Equation 1 (Khandaker et al., 2015):

$$A = \frac{C_n}{E_\gamma \times P_\gamma \times t \times m} \quad (Bq\ kg^{-1}) \qquad (1)$$

where A is the activity concentration of a particular nuclide in Bq/Kg, C_n is the net count (background subtracted) in the corresponding photo peak, E_γ is the absolute efficiency at photo peak energy and P_γ is the gamma-ray emission probability corresponding to the photo-peak energy, t is the counting time and m is mass of the sample (dry-weight of 100 g each). When this method was employed, the sample containers were of the same geometry as the standard as well as the same counting time. The minimum detectable activity for ^{40}K is 4.39 Bq/Kg, ^{226}Ra is 0.16 Bq/Kg and ^{232}Th is 0.60 Bq/Kg.

RESULT AND DISCUSSION

Activity Concentration

The activity concentrations of the primordial radionuclides (^{40}K, ^{226}Ra and ^{232}Th) in the Catfish and fish feed samples are presented in Tables 1 and 2 respectively. ^{40}K exhibited the highest activity concentrations in all the samples while ^{226}Ra had the least mean activity concentrations. The mean concentration of ^{40}K obtained in the Catfish samples was 41.61 Bq/kg, while the mean values for ^{232}Th and ^{226}Ra were 2.03 and 0.55 Bq/kg respectively. The mean values for ^{226}Ra, ^{232}Th and ^{40}K were below the world safety limit of 30, 35 and 400Bq/kg (USEPA, 2000).

Table 2 revealed the activity concentrations of the primordial radionuclides (^{40}K, ^{226}Ra and ^{232}Th) in the fish feed samples. ^{40}K had the highest activity concentrations in all the samples while ^{226}Ra had the least mean activity concentrations. The mean concentration obtained in the fish feed samples for ^{40}K, ^{226}Ra and ^{232}Th are 30.14, 0.60 and 4.6 Bq/kg respectively. These mean values for ^{226}Ra, ^{232}Th and ^{40}K were below the world safety limit of 30, 35 and 400Bq/kg respectively. Ademola & Ehiedu (2010) determined the mean activity concentrations in an oil exploration area of Ondo State, Nigeria, of which each species of fish samples collected from fresh water varied from 462 ± 80 to 792 ± 107 Bq/kg for ^{40}K, 21.4 ± 3.8 to 38.6 ± 11.6 Bq/kg for ^{226}Ra and 40.7 ± 25.9 to 84.4 ± 2.3 Bq/kg for ^{232}Th. For the fish samples collected from marine water, the mean activity concentration varied from 688 ± 230 to 791 ± 39 Bq/kg, 23.0 ± 4.6 to 49.7 ± 33.1 Bq/kg and 32.1 ± 5.3 to 96.7 ± 19.9 Bq/kg for ^{40}K, ^{226}Ra & ^{232}Th respectively. The values for the activity concentration obtained by Ademola & Ehiedu (2010) were way higher than the present study and this could be because the oil exploration within that area. Also, Fasae and Isinkaye (2018) determined the mean activity concentration of feed samples in selected fish-farms within Ado-Ekiti, Nigeria whose activity concentration is high, compared to the values obtained from this present study. The mean values of ^{40}K, ^{238}U & ^{232}Th are 859.5±12.9 Bq/kg, 12.4±0.5 Bq/kg and 6.1±0.2 Bq/kg respectively. The mean activity concentration obtained by Fasae & Isinkaye (2018) is seen to be quite higher than the values as compared to this study. This could be as a result of the production process, ration and raw material origin that makes up the locally produced feed for the consumption of the fish.

Table 1: Activity concentrations (Bq/kg) for Catfish samples with the estimate of the committed effective dose and the excess lifetime cancer risk.

	Activity Concentration for Catfish samples				
No of samples	^{226}Ra	^{232}Th	^{40}K	Comitted Effective Dose (µSv/year)	Excess Lifetime Cancer Risk (x10^{-6})
FSH 01	29.36	0.32	0.66	0.0290	0.1015
FSH 02	34.75	0.54	3.28	0.0768	0.2687
FSH 03	23.32	BDL	0.67	0.0205	0.0716
FSH 04	53.32	0.93	4.83	0.1166	0.4080
FSH 05	67.29	0.41	0.71	0.0476	0.1667
MEAN	41.61	0.55	2.03	0.0682	0.2387

bdl = below detectable limit

Table 2: Activity concentrations (Bq/kg) for the feed samples.

No of samples	Activity concentrations (Bq/kg)		
	^{40}K	^{226}Ra	^{232}Th
FD 01	19.21	BDL	BDL
FD 02	53.85	0.98	5.48
FD 03	18.56	BDL	BDL
FD 04	38.01	0.63	3.4
FD 05	21.09	0.18	4.92
MEAN	30.14	0.60	4.6

bdl = below detectable limit

Committed Effective Dose

In order to estimate the internal radiation dose as a result of fish consumption, the data in this study was used to evaluate the committed effective dose. This information can be useful in determining the health risk due to ionizing radiation through the ingestion of fish resources. The total dose via ingestion of fish can be calculated by summing the doses derived for each radionuclide (^{40}K, ^{226}Ra and ^{232}Th). The effective committed dose due to dietary intake is provided by the following equation adapted from an ICRP Reports (ICRP, 2007):

$$C_{ed} = \sum\sum(C \times A_{fi} \times DC_{ing}) \qquad (2)$$

where C_{ed} is the Committed effective dose (μSv year^{-1}), C is the specific radionuclide activity of ^{226}Ra, ^{232}Th and ^{40}K (Bq/Kg) respectively, A_{fi} is the average fish intake with an average of 25 Kg year^{-1} and DC_{ing} is the ingestion dose coefficient of the ^{226}Ra, ^{232}Th and ^{40}K which is 0.2 μSv Bq^{-1}, 0.23 μSv Bq^{-1} and 6.2 nSv Bq^{-1}, respectively (Aswood *et al.*, 2017; Fasae and Isinkaye, 2018). The average consumption rate of fish per year for the general populace is 25 Kg year^{-1} (Fasae and Isinkaye, 2018).

The mean committed effective dose as seen in Table 1 is 0.0682 μSv/year. The mean total committed dose obtained in this study lower than values obtained by other researchers for different locations around the world. Fasae and Isinkaye (2018) which had the total committed effective dose due to intake of the catfish in a selected fish farm in Ado-Ekiti, (Nigeria) as 0.396 μSv/y. Khandaker *et al.* (2015) in Malasia (Malacca), estimated the average annual effective dose of the marine fish (*Rastrelliger kanagurta*) to be 226.7 μSv/y while Adamu *et al.* (2012) in Kainji lake, (Nigeria) determined the average annual effective dose of 68.31 μSv/y. The estimated average committed effective dose by Adamu *et al.* (2012) was higher than the value obtained in this study even though both researches were carried out within the same State. The difference in the committed effective dose between Adamu *et al.* (2012) and this study could be due to the bio-diversities attached to lakes which have more depth and could accommodate more aquatic animals than ponds. Ademola and Ehiedu, (2010) estimated the annual effective ingestion dose which varied between 23.3±10.2 μSv/y and 34.8±1.7 μSv/y for samples of fish in fresh water and 6.4±0.7 μSv/y and 14.2±1.6 μSv/y for marine water fish samples. These values indicate that the annual effective ingestion of marine water fish samples is lower than freshwater fish samples. The mean committed effective dose was lower than the recommended total annual effective dose of 1.0 mSv/y set by ICRP (2007) as the maximum acceptable level for the members of the public. The results obtained showed that the radiation dose incurred from the ingestion of the fresh fish samples pose no significant health effect to the population from a radiological point of view.

Excess Lifetime Cancer Risk

Excess lifetime cancer risk (ELCR) is defined as the probability that an individual will develop radiation cancer over his lifetime as a result of exposure to radiation (UNSCEAR, 2000). Natural radionuclide is present in fishes, however their presence in fishes beyond certain limits when consumed by humans, could cause serious cancer risk in the future. The Excess lifetime cancer risk (ELCR) is determined by the following equation:

$$ELCR = C_{ed} \times DL \times RF \quad (3)$$

where C_{ed} is defined in equation 3.2, DL is the average life duration/span of life (70 y) and RF is risk factor given to be 0.05 Sv^{-1} for stochastic effects in any given population (Kolo *et al.*, 2017).

From table 1, the mean excess lifetime cancer risk was obtained according to equation (3) to be 0.2387 $\times 10^{-6}$. Michael *et al.*, (2018) conducted a similar research at the Dadin kowa dam in Gombe State Nigeria, showing the excess lifetime Cancer risk with a mean of 0.14 $\times 10^{-3}$; 1.29 $\times 10^{-3}$; 0.23 $\times 10^{-3}$; 0.19 $\times 10^{-3}$ and 0.16 $\times 10^{-3}$ for both Adults, fishermen, 5 years, 10 years, 15 years respectively.

CONCLUSION

The mean activity concentrations of ^{40}K, ^{226}Ra and ^{232}Th were determined in fish feeds and harvested catfish samples from Lapai Gwari in Niger State, Nigeria using gamma spectroscopic technique. The mean activity concentrations in fish feeds of primordial radionuclides ^{40}K, ^{226}Ra and ^{232}Th were 30.14, 0.60 and 4.6 Bq/kg respectively. These may contribute majorly to the mean activity concentrations of ^{40}K (41.61 Bq/kg), ^{226}Ra (0.55 Bq/kg) and ^{232}Th (2.03 Bq/kg) in catfish samples. The calculated mean committed effective dose was 0.0682 mSv/y and lower than the maximum acceptable limit of 1.0 mSv/y set by ICRP (2007) The estimated mean excess lifetime cancer risk obtained was 0.2387 x 10^{-6} which was lower than the world average values of 0.29 x 10^{-3} (UNSCEAR, 2000). The results obtained from this indicates that the radiation dose incurred from the ingestion of fresh catfish in the area pose no significant radiological health effect to the population.

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