Published by
NIGERIAN SOCIETY OF PHYSICAL SCIENCES
Available online @ https://asr.nsps.org.ng/index.php/asr

African Scientific Reports 2 (2023) 101

African Scientific Reports

Assessment of Radionuclide Concentrations in Catfish and Tilapia fish from Asa-Dam Ilorin, North-central Nigeria

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Abstract

High concentration of naturally occurring radionuclides in food can have adverse effect on human health. Radioactivity measurement of radionuclides in Catfish and Tilapia fish samples from Asa-Dam Ilorin, Nigeria was carried out using gamma ray spectrometer technique. The results of the gamma ray spectrometry were utilized in the estimation of some radiological parameters in the bid to effectively determine the extent of the health implications as regards to radiation from the consumption of fishes in that area. The mean activity concentrations of ^{40}K, ^{238}U and ^{232}Th for Catfish are 37.90±2.83, 8.08±2.71 and 11.73±2.51 $Bqkg^{-1}$, respectively. Similarly, the mean activity concentrations of ^{40}K, ^{238}U and ^{232}Th for Tilapia are 26.31±3.67, 6.16±2.47 and 8.89±2.19 $Bqkg^{-1}$, respectively. The mean values of ^{40}K, ^{232}Th and ^{238}U in Catfish were observed to be high when compared to Tilapia. The average absorbed dose rate for both Catfish and Tilapia samples were 12.40 and 9.31 $nGyh^{-1}$. The mean annual effective doses were 29.65, 276.81, 52.04, 41.10 and 35.00 μSvy^{-1}; 22.41, 209.10, 38.99, 30.93 and 26.43 μSvy^{-1} for adult, fishermen, 5 years, 10 years and 15 years, respectively for cat and Tilapia fish. The estimated excess lifetime cancer risk for adult, fishermen, 5 years, 10 years and 15 years were 0.10, 0.97, 0.18, 0.14, and 0.12 and 0.09, 0.85, 0.16, 0.13 and 0.11 for both Catfish and Tilapia, respectively. The results of all the radiological parameters estimated showed trends that are generally low, hence, poses no significant radiological health burden.

DOI:10.46481/asr.2023.2.1.101

Keywords: Gamma ray spectrometry, Absorbed dose, Effective dose, Radiation hazard indices, Excess lifetime cancer risk

Article History :
Received: 16 March 2022
Received in revised form: 10 April 2023
Accepted for publication: 18 April 2023
Published: 29 April 2023

Communicated by: Wasiu Yahya

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1. Introduction

The radionuclides are atoms having a nucleus which is unstable and contains excessive energy ready for utilisation. At the course of this process, the radionuclide is believed to undergo radioactive decay, ensuing the discharge of gamma rays together with some subatomic particles such as alpha or beta particles [1 -3]. Radiation is everywhere in the environment and are found in outer space (Cosmic Radiation), the ground (Terrestrial Radiation) and even from inside human bodies. It can also be found in the air, the foods and water. In other words, humans are naturally exposed to radiation from the moment they are conceived to the moment they die [4 - 7].

Nuclei with an unfavourable proton/neutron ratio will undergo nuclear disintegration to acquire a more stable configuration, whereas nuclei with an unfavourable proton/neutron ratio will undergo nuclear disintegration to achieve a more stable configuration [4, 8]. Radionuclides can be dangerous to active cells after they are inside a living organism, a place radiation on the rampage know how to be straight away absorbed. Radionuclides progress through the environment and into the human body through several numerous pathways in which the consumed fishes is part of it. Many authors have measured and reported radioactivity in soil and the environment [9 - 14]. For heart disease prevention, fish is highly suggested because it has a minimal amount of drenched fats, great composition of protein and important trace minerals, and comprises a long-chain of omega-3 fatty acids [15 - 17]. Catfish and Tilapia are prominent examples of fish that have a lower fat content and provide more of these heart-healthy elements than hamburger, steak, chicken, hog, or turkey, etc. (William, 2008). Tilapia and Catfish are ranked as two of the most common and most eaten fish in Nigeria [17, 18], thanks essentially to their mouthy sensation and their cheap source protein and vitamins.

Asa-River is surrounded by villagers that use various chemicals and applying fertilizers on their farmland in order to increase their farm produce. These chemicals and fertilizer containing some amount of radionuclides [12], which are washed down into the dam eventually. This can contaminate the dam and in turns affect the fishes inhabiting this dam. This paper is therefore targeted at measuring the extent of radioactivity in the fish samples in this dam and to further estimate the radiological risks posed by consuming fishes in this study area through some radiological parameters. This is necessary because previous works only focuses on sediments [12], soils and water samples.

2. The study area

Asa River Dam is located in Ilorin, Kwara State capital city within latitude 8.5276 °N and longitude 4.5533 °E. Julius Berger Nigeria PLC constructed the dam in order to augment the supply of water by about 50,000 m^3day^{-1}, to the settlements within the state. It is made up of three basic aspects: a 150 m long concrete gravity dam, a 400 m long earth fill dam and a lateral earth dam with a length of 160 m. The earth fill dam is 26 m in height above the ground, with a span of 150 m at the dam's foot and 5 m at the apex. The embankment dams dam, on the other hand, stands 20 m tall and measures 12 m wide at the foot and 3 m wide at the crest/ridge. The foundation of the side earth dam is 6 m high and 23 m in width. Average pH of the River Asa ranged from circumneutral to slightly alkaline (7.25 - 8.66) [12].

The visual representation of the study area is displayed in Figure 1. Ilorin capital is one of the highest on the increase settlements or towns in Nigeria with a hot wet and arid climate with mean annual rain of 1,200 mm. Its annual mean temperature is about 26.2°C; it heightens at about 30°C in March, which represents the month with the highest temperature. Rainy season is slated from April to October and the dry season span from November to March [12].

3. Materials and Methods

3.1. Sample collection and preparation

In collecting samples, some certain procedures have to be taken. This entails instituting a collection technique, acquiring right storage cans, and employing the correct process of safeguarding so as to ease or minimize the effect of adsorption. To guarantee that a good representative, sample collection method at the dam, the dam was divided into three spots. 3 fish sample of Catfish and Tilapia were gotten from each spot. A total of 18 fish samples were analyzed. This comprises 9 Tilapia fish samples (*Oreochromisniloticus*) and 9 Catfish samples (*Clariasheterobranchus*). The

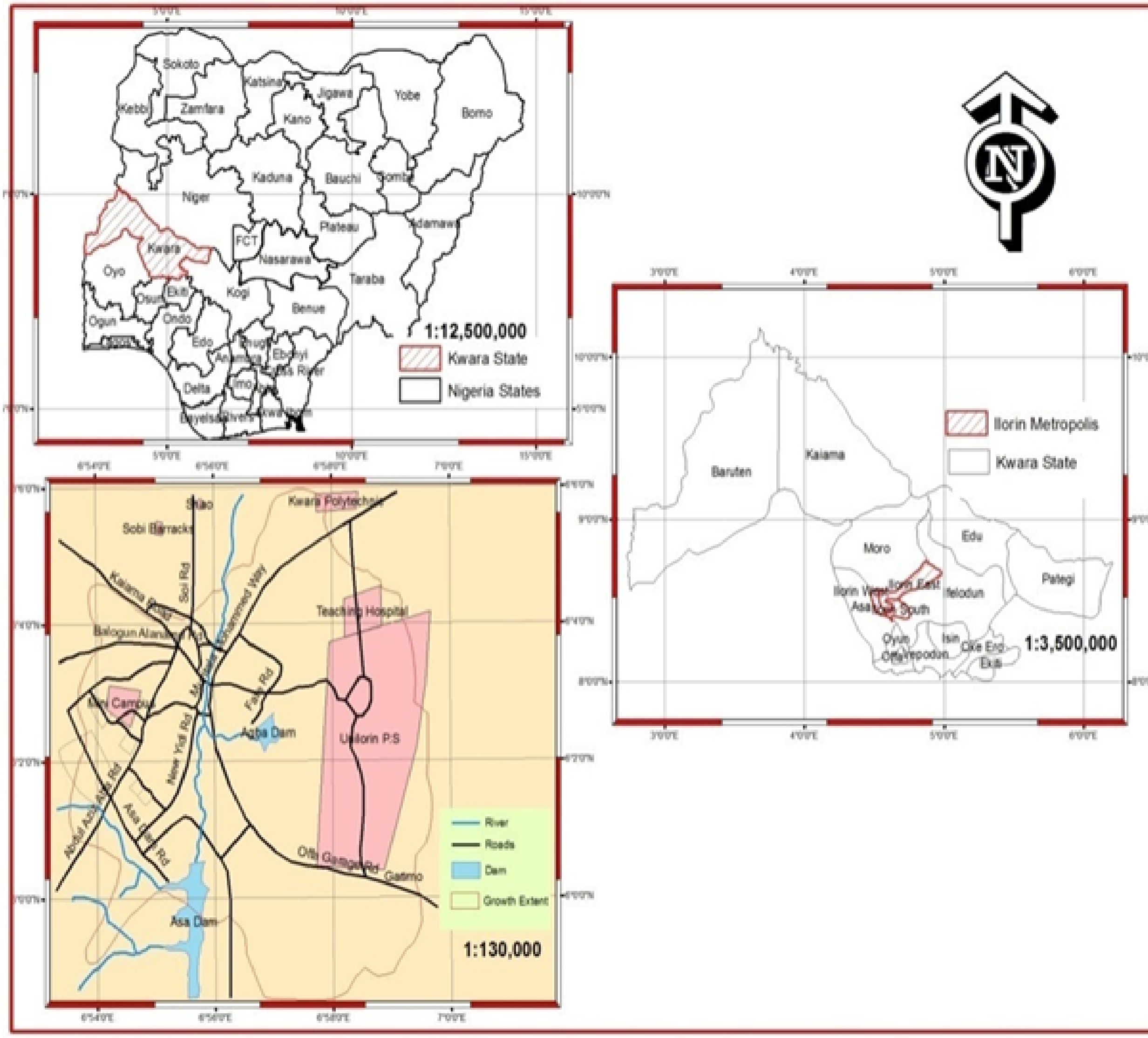

Figure 1. Map of Nigeria indicating the study area

fish samples were collected from the dam downstream (spot 1), middle/centre (spot 2) and upstream (spot 3) using fish hook and were kept in separate spick and span polythene bags to elude cross-contamination [18, 18]. The collected samples were then euthanized and demoisturised by keeping them in an oven at a temperature of about 100^{o}C to remove the water content until a constant weight was obtained. This was done in order to prevent biodegradation and to allow easy pulverization of the fish samples. For further preservation and easy gamma counting, the samples were pulverized and kept in a clean plastic containers with the same dimension and geometry as the IAEA reference sample used (IAEA-414). The container walls were also acidified using 11 M HCl, at a rate of 10 ml per liter to minimize the precipitation of the radionuclide present in the water samples and growth of micro-organisms.

3.2. Measurement Procedure

A lead-shielded of 76 mm × 76 mm Sodium Iodide Thallium-doped [NaI(TI)] detector (Model Number 802 series, Canberra Inc.) is linked to a Canberra Series ten (10) plus Multichannel Analyzer (Model Number 1104) through a preamplifier for radioactivity measurements.. A full-width-at-half-maximum (FWHM) resolution of around

8% at 0.662 MeV (^{137}Cs) energy that is carefully satisfactory to characterize the gamma rays energies which is of keen concern and of intellectual curiosity in this study. In order to quantify radionuclides, in a sample, it is necessary to ascertain the efficiency of the system by using a sample counting configuration (geometry) containers whose dimensions suit well to the dimensions of the detector and lead housing was used. The calibration method involved several theoretical methods but accuracy of the results based on these values will not be much better than 10 – 20 % and standard radionuclides with standardized activity A (Bq) with photon emission intensities of gamma sources well known (^{22}Na, ^{137}Cs and ^{60}Co) were used as the calibration sources. The calibration of energy was done by measuring mixed standard source of identified radioactive nuclides with definite energies within the range of our interested numeric values, usually 200 to 3000 keV. The detection efficiency calibration was done with the use of a standard reference material (IAEA-414), consisting of known activities of ^{40}K (481 Bq/kg), ^{238}U (1.11 Bq/kg) and ^{232}Th (0.028 Bq/kg). Detailed descrption of gamma counting had been described by several authors [3, 19, 20].

The pulverized fish samples were first weighed before being transferred to the plastic containers and sealed for at least 30 days in order for secular equilibrium to be attained. [5]. At secular equilibrium, the specific activity concentration of each radioactive nuclide present in a given series is equivalent to the specific radioactive activity of the nuclide that leads the series, i.e. the parent nuclide. Each concealed samples was positioned symmetrically on the protected NaI(Tl) detector and counted for 18,000s. The photons given off by the radionuclides would just be satisfactorily distinguished if the chances of discharge and their emitted energy were sufficiently enormous, and the periphery setting continuum appropriately low. By subtracting counts from the net part under the corresponding peaks in the energy spectrum, the net part was calculated as a result of Compton scattering of advanced peaks and other background sources from the aggregate sum of the peaks. From the net area, the activity concentrations in the samples were obtained via the next equation 1.

$$\mathrm{C_x} = \mathrm{C_s}\frac{\mathrm{M_s A_x}}{\mathrm{M_x A_s}} \tag{1}$$

where, C_x = concentration of specific radioactivity in the sample, C_s = specific activity concentration of the standard, M_s= mass of the standard, M_x = mass of the sample, A_s = area of the standard and A_x = area of the sample.

4. Results and Discussions

4.1. Activity Concentration

The result of the gamma ray spectrometry of the Catfish and Tilapia fish samples in Asa Dam is shown in Table 1 and explained in Figure 2. The radioactive nuclides detected are part of the decay series headed by ^{238}U and ^{232}Th including the non-series ^{40}K. The ^{40}K activity concentration ruled over that of ^{238}U and ^{232}Th as expected. The radioactive activity concentration of ^{40}K, ^{238}U and ^{232}Th for Catfish spanned from 33.28±2.13 to 42.16±4.20 Bqkg^{-1} with a mean of 37.90±2.83, 7.94±2.13 to 8.21±3.00 Bqkg^{-1}with an average 8.08±2.71 Bqkg^{-1} and 11.03±3.10 to 12.10±2.30 Bqkg^{-1}with an average of 11.73±2.51 Bqkg^{-1}, respectively. The activity concentration measured in Tilapia ranged from 25.60±4.60 to 27.18±3.22 Bqkg^{-1}with an average of 26.31±3.67 Bqkg^{-1}, 4.28±2.10 to 8.00±3.28 Bqkg^{-1}with an average of 6.16±2.47 Bqkg^{-1}and 6.31±2.01 to 10.34±2.13 Bqkg^{-1}with an average of 8.89±2.19 Bqkg^{-1}. The radioactivity concentration of ^{40}K, ^{232}Th and ^{238}U in Catfish were high when compared to Tilapia. This may be as a result of Catfish being found at lower depths closer to the sediment layer of the dam. Radionuclides concentrations in sediments/soil are relatively higher when compared to other environmental matrices [12] and Catfish being at lower depths may be prone to easy contamination compared to Tilapia. The radioactivity concentration may not be valid enough to know or infer the radiation hazard posed by these radionuclides, hence, the radiological parameters has to be estimated.

4.2. Annual Effective Dose (AED)

The Effective Dose scripts the stochastic health threats to the entire body by combining the tissue weight of equivalent dosages of known tissues and organs. Equation 2 was used to calculate the AEDE owing to the radioactive nuclides found in the fish samples [17, 21, 22].

$$AED = \sum_i I_i \times 365 \times D_i \tag{2}$$

Table 1. Radionuclide Concentrations(Bqkg^{-1}) estimated in Fish Samples

Samples Code	**K-40** (Bqkg^{-1})	**Th-232** (Bqkg^{-1})	**U-238** (Bqkg^{-1})
CATFISH			
Mean CAT 1	42.16±4.20	12.10±2.30	8.21±3.00
Mean CAT 2	38.27±2.16	11.03±3.10	7.94±2.13
Mean CAT 3	33.28±2.13	12.06±2.12	8.08±3.01
Over all Mean Cat	**37.90±2.83**	**11.73±2.51**	**8.08±2.71**
TILAPIA			
Mean TILAPIA 1	27.18±3.22	10.03±2.43	8.00±3.28
Mean TILAPIA 2	25.60±4.60	6.31±2.01	4.28±2.10
Mean TILAPIA 3	26.15±3.20	10.34±2.13	6.20±2.03
Over all Mean Tilapia	**26.31±3.67**	**8.89±2.19±2.35**	**6.16±2.47**
OVERALL MEAN	**32.11±3.25**	**10.31±2.35**	**7.12±2.59**

Table 2. Dose conversion factors of radioactive nuclides for the public of different age groups via ingestion

Radio Nuclides	**$T_{1/2}$ (years)**	**Infants**		**DCF (SvBq^{-1}) Other ages**					
		f_i	**DCF (SvBq^{-1})**	f_i **1yr**	**1yr**	**5yrs**	**10yrs**	**15yrs**	**Adults**
^{40}**K**	**1.2x10^9**	**1.0**	**5.2x10^{-8}**	**1.0**	**4.2x10^{-8}**	**2.2x10^{-8}**	**1.3x10^{-8}**	**7.6x10^{-9}**	**6.2x10^{-9}**
^{232}**Th**	**1.405x10^1**	**0.005**	**1.6x10^{-6}**	**0.0005**	**4.5x10^{-7}**	**3.5x10^{-7}**	**2.9x10^{-7}**	**2.5x10^{-7}**	**2.3x10^{-7}**
^{238}**U**	**4.468x10^9**	**0.04**	**1.4x10^{-7}**	**0.02**	**1.2x10^{-7}**	**8.0x10^{-8}**	**6.8x10^{-8}**	**6.7x10^{-8}**	**4.5x10^{-8}**

Table 3. The annual effective doses (µSvy^{-1}) and excess lifetime cancerous risks (× 10^{-3}) of the Fish samples

Samples Code	**AEDE** *(Adults)*	**AEDE** *(Fishermen)*	**AEDE** *5YRS*	**AEDE** *10YRS*	**AEDE** *15YRS*	**ELCR** *ADULT*	**ELCR** *(Fishermen)*	**ELCR** *5YRS*	**ELCR** *10YRS*	**ELCR** *15YRS*
CAT	30.48	284.70	53.96	42.45	36.02	0.11	1.00	0.19	0.15	0.13
CAT	28.96	270.40	50.96	40.17	34.11	0.10	0.95	0.18	0.14	0.12
CAT	29.50	275.35	51.20	40.69	34.86	0.10	0.96	0.18	0.14	0.12
CAT MEAN	**29.65**	**276.81**	**52.04**	**41.10**	**35.00**	**0.10**	**0.97**	**0.18**	**0.14**	**0.12**
TIL	27.83	259.50	47.53	37.97	32.57	0.10	0.91	0.17	0.13	0.11
TIL	16.15	150.89	29.03	22.66	19.09	0.06	0.53	0.10	0.08	0.07
TIL	23.23	216.93	40.42	32.15	27.63	0.08	0.76	0.14	0.11	0.10
TIL MEAN	**22.41**	**209.10**	**38.99**	**30.93**	**26.43**	**0.08**	**0.73**	**0.14**	**0.11**	**0.09**

$$ELCR = AED \times 70 \times 0.05 \tag{3}$$

Where I_i is the consumption of radionuclide on a daily basis (Bqd^{-1}) = (concentration of radioactive nuclide in sample fish in Bqkg^{-1}) × (consumption rate of fish in kgd^{-1}) and Di is the ingestion dose coefficient (dose conversion factor) ^{238}U, ^{232}Th and ^{40}K as displayed in Table 2 [22 - 26]. The globally estimated average annual consumption of fish is 18.7 kg per person, Nigerian per capita consumption is only 11.2 kg for the general masses and 109.5 kg for the fishermen [17]. This therefore means that the daily consumption of fish in Nigeria per individual is 0.031 kgd^{-1} for general populace and 0.3 kgd^{-1} for fishermen. The calculated results of the annual effective dose is shown in Table 3 and Figure 2. When the results obtained were compared with recommended limit (RL), it was observed that more doses are ingested from the consumption of Catfish compared to Tilapia and the values of the effective doses

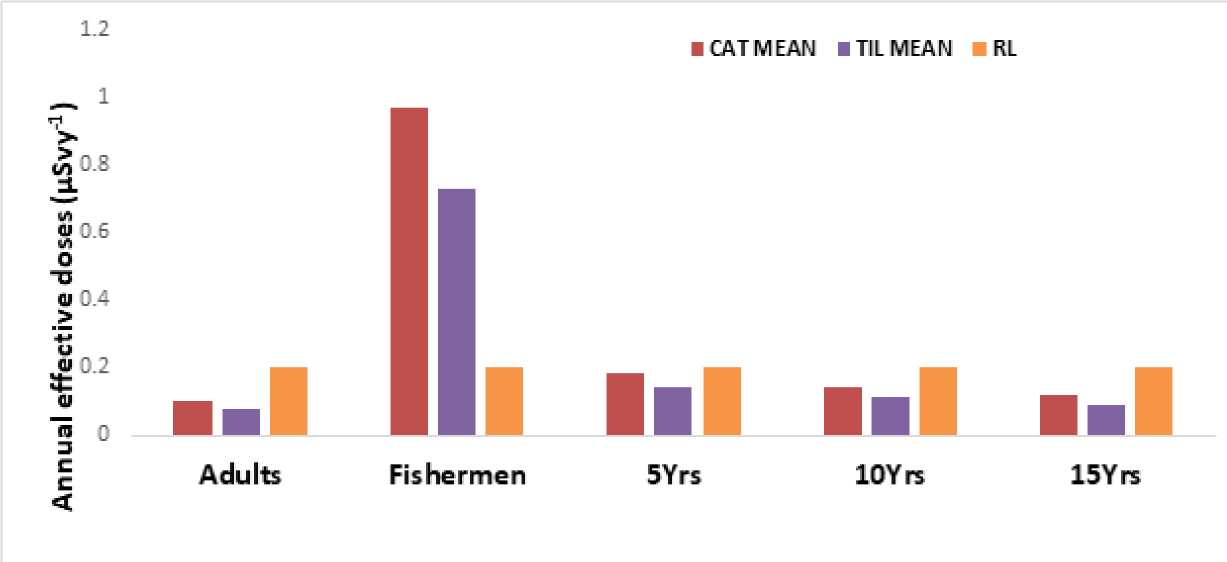

Figure 2. Mean AED of the fish sample

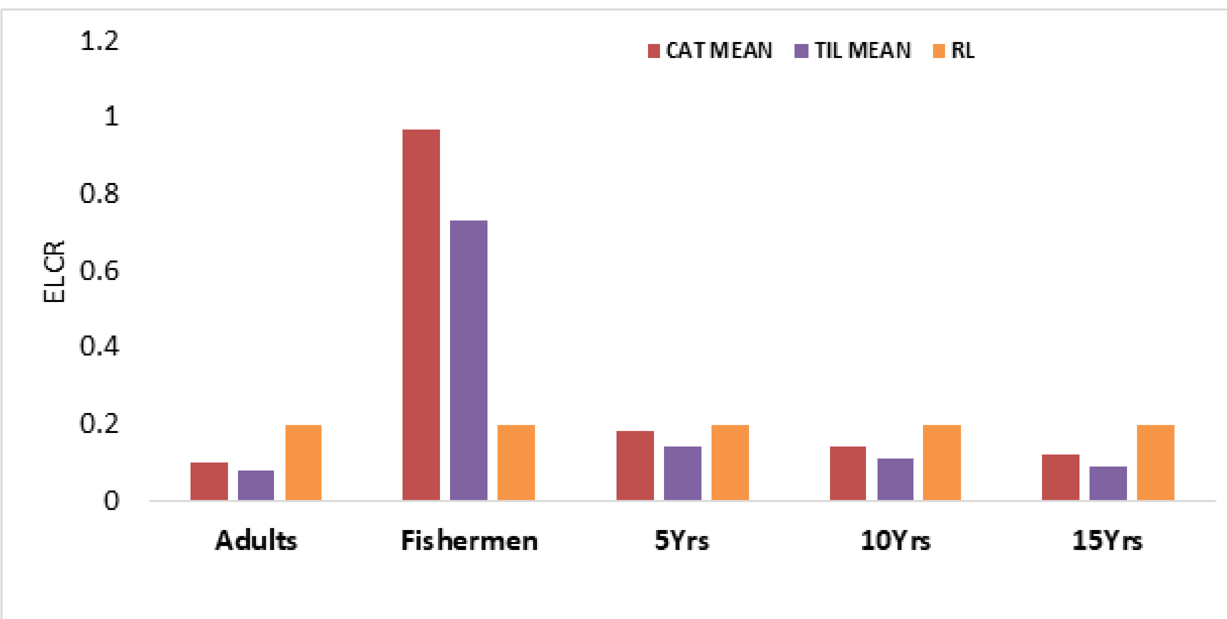

Figure 3. Mean ELCR of the fish sample

increase in the order of adult < 15 years < 10 years < 5 years < fishermen. Nevertheless, each and every one of these values were quite low compared to the mean world value of 1000 µSvy^{-1} and hence pose no serious radiation hazard [22, 27-31], but it is recommended that Tilapia should be consumed instead of Catfish in cases of long-term radiation injury.

5. Conclusion and Recommendation

The study assessed the radioactivity level in Catfish and Tilapia fish from Asa-dam Ilorin, Nigeria using gamma ray spectrometer. The gamma results were used for the estimation of some radiological parameters in the bid to know the extent of the radiological health risk to human due to consumption of fishes in this area. The values of the activity concentration of ^{238}U, ^{232}Th and ^{40}K calculated for Catfish were noticed to be higher than that of Tilapia. The result of all the radiological parameters estimated showed trends that are in general minimal to the world average values and therefore pose no critical abrupt radiological effects to the common populace in this area. All the radiological health parameters estimated values for Catfish were higher than that of Tilapia. This makes Catfish to pose more radiological health effects after a long term consumption than Tilapia.

Acknowledgement

The authors appreciate the anonymous reviewers for their invaluable efforts and contribution.

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