Non-carcinogenic and Carcinogenic Health Risk Evaluation from Fish Contaminated with Heavy Metals

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Authors' contributions

This work was carried out in collaboration among all authors. Author AIY designed the study, wrote the protocol and wrote the first draft of the manuscript. Authors LS, JIB, AN, AU and AA performed the statistical analysis and manage the analysis of the study. Authors MMM, ASS, IAY and HKM managed the literature searches. All authors read and approved the final manuscript.

Original Research Article

ABSTRACT

The pollution of water bodies with heavy metals can result into the possible contamination of freshwater fish. The levels of the heavy metals Pb, Fe, Cu, Zn, Ni and Cd were investigated in fish samples (*Ameiurus nebulosus, Pylidictis olivaris, Tilapia zilli, Clarias gariepinus*) collected from Kwanar-Are dam located at Rimi local government area Katsina State, Nigeria and the health risks of the evaluated heavy metals were estimated. The mean concentration ranges of Pb, Fe, Cu, Zn and Cd were (0.0851-0.4919, 0.3095-0.5039, 0.0366-0.0589, 0.1066-0.3015, 0.1048-0.1417, 0.0128-0.0686 mg/kg) respectively. The risk assessment for non-carcinogenic exposure effect showed that there was no health risk associated with these elements through consumption of the fish samples to the consumer population. However the risk assessment for carcinogenic exposure

effect has revealed that the incremental lifetime cancer risk (ILCR) and the cumulative lifetime cancer risks (∑ILCR) were all above the safe limit for cancer in the children and the adults population for all the fish samples evaluated. The heavy metal Ni presented the greatest cancer risk and the fish sample *Clarias gariepinus* having the highest cancer risk. There is a degree of concern for consumption of the fish samples for their potentials to contribute to the population cancer risk load.

1. INTRODUCTION

Fish is one of the most important food and is valued for its nutritional qualities [1]. It is one of the important and a good source of high quality and easily digestible protein containing essential amino acids and other beneficial nutrients for humans and other animals in the tropics and the provision of minerals, vitamins and essential fatty acids like Omega 3 that are required for good health [2,3,1,4]. Apart from provision of food for immediate consumption, people rely on fishing for economic gains and jobs and processed fish products have a ready market in developed countries as such contributing to foreign exchange earnings [3,5].

"Fish are more frequently exposed to heavy metal pollution because it is believed that regardless of where the pollution occurs, it will eventually end up in the aquatic environment" [6]. "Fish contamination with toxic heavy metals, may be attributed to the entry of wastewater containing chemical fertilizers, agricultural toxins and chemicals from mechanic repair workshops into the rivers, which in turn, may impact a deleterious effect on freshwater ecosystems and water species habitats" [7,8]. "Potential of heavy metal to accumulate in fish living in waters polluted with heavy metals is rather high" [9]. "However, despite its nutritional value, consumption of fish contaminated with heavy metals brings many times a potential hazard concern for the human consumers. It has been reported that prolonged consumption of unsafe concentrations of heavy metals which especially accumulate in organs of fish, such as internal organs, kidneys, and spleen, may lead to the chronic accumulations of the metals in the kidney and liver of humans causing disruption of numerous biochemical processes, leading to cardiovascular, nervous, kidney and bone diseases" [10,11,12,9].

The Kwanar-Are dam has multiple potential heavy metals contribution sources [13]. Being the culture of the Hausa/Fulani to consume fish whole, the study simulate this habit by analyzing whole fish for the heavy metal evaluation instead of using selected fish organs.

The main objectives of this study were to analyze heavy metals in fresh water fish from Kwanar-Are dam and assess the health risks associated to consumption of the fish samples to the population. Findings from the study may shed light on the heavy metal burden of the samples and the inherent health risks if they exist and provision of possible basis for comparison to other fish containing sites.

2. MATERIALS AND METHODS

2.1 Study Area

The study was conducted at Kwanar-Are dam located in Rimi LGA of Katsina State, Nigeria. Rimi LGA is located on Latitude $12^{o}46'$N and Longitude $7^{o}41'$E, covering an area of 452 km² (175sq miles) with a total population of 212,819 inhabitants. The adjoining human settlements are Tudun-Kadir, Faduma, Ci-ka-Koshi, and Are villages. The inhabitants of these villages are engaged in fishing, rain-fed and dry season farming and use the water for drinking and other domestic uses.

2.2 Fish Sampling (*Ameiurus nebulosus, Pylidictis olivaris, Tilapia zilli, and Clarias gariepinus*)

Fish samples (eight [8] samples per species of carnivorous and bottom feeding fish collected from commercial fishermen) were collected from the study area. The fish samples were placed in sterile polythene bags and taken in an icebox to the laboratory where they were washed with running tap water to remove dirt. All the fish samples were then separately stored frozen in the deep freezer and were allowed to thaw; transferred into sterile sample bottles, labeled and kept for digestion and analysis of heavy metals.
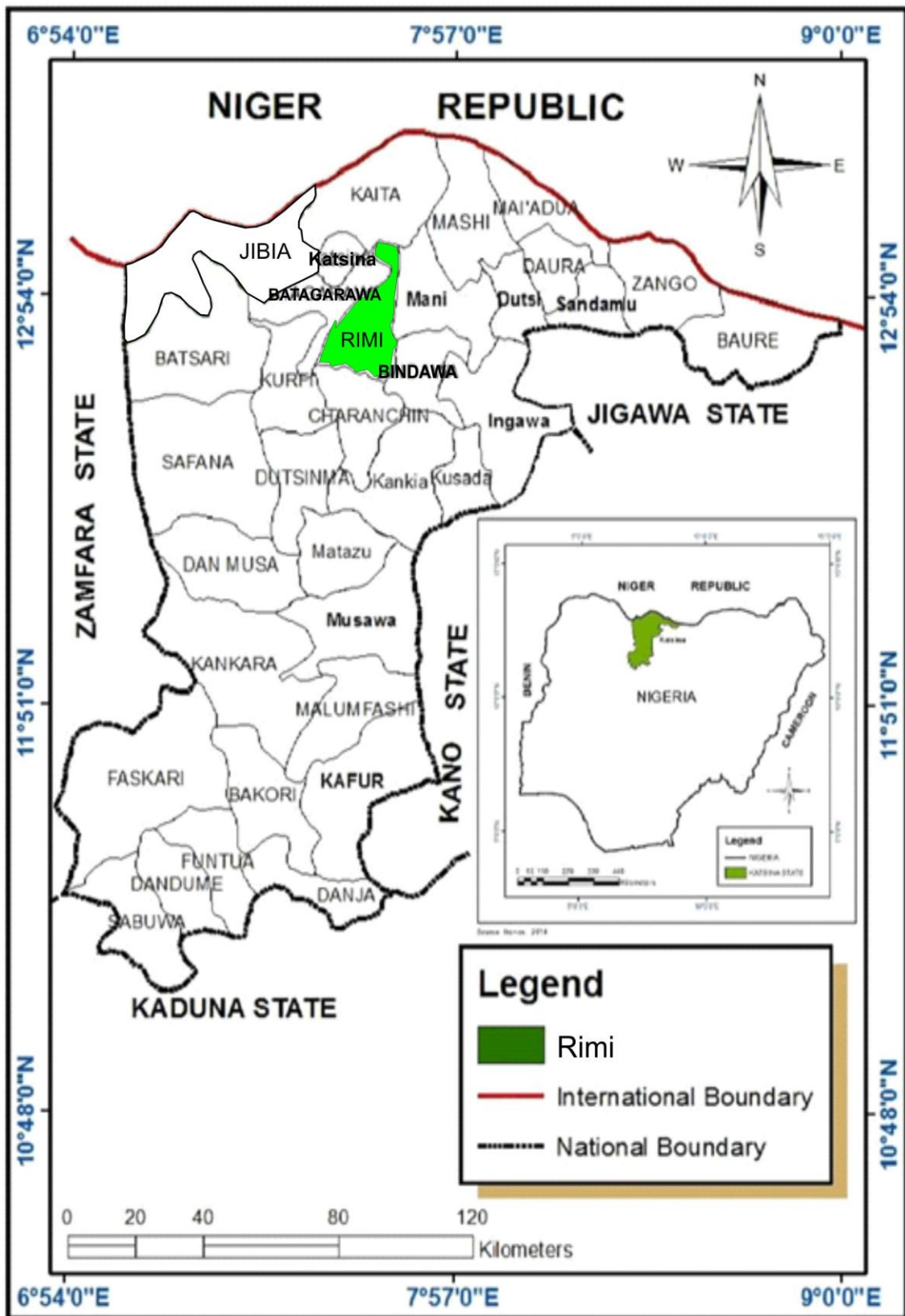
Fig. 1. Map of Katsina State Showing Rimi Local Government Area

2.3 Heavy Metals Determination

"Heavy metals in fish samples were determined using AA210RAP BUCK Atomic Absorption Spectrometer flame emission spectrometer filter GLA-4B Graphite furnace (East Norwalk USA), according to standard methods" [14] after ashing and digestion as described by Yar'adua et al. [8] and the results were given in mg/kg. Briefly a measure of 5 g of each composite fish species sample was dried at 80^0C for 2 hours in a Gallenkamp hotbox oven (CHF097XX2.5) and then blended in an electric blender. About 0.5 g of each sample was weighed and ashed at 550^0C for 24 hours in an electric muffle furnace (Thermolyne FB131DM Fisher Scientific). The ash was diluted with 4.5 ml concentrated hydrochloric acid (HCl) and concentrated nitric acid ($HN0_3$) mixed at a ratio of 3:1 the diluent was left for some minutes for proper digestion in a beaker. Exactly 50 ml of deionized water was added to the diluents to make up to 100 ml in a volumetric flask.

2.4 Daily Intake of Metals (DIM) From Consumption of Samples

The daily intake of metals from consumption of samples were calculated using the equation below (eqn. 1)

$$\frac{C\text{metal} \; x \; Cfactor \; x \; Daily intake}{Bweight} \quad \text{……..eqn. (1)}$$

"Where, C metal, C factor, D intake and B weight represent the heavy metal concentrations in the samples, the conversion factor, the daily intake of the sample and the average body weight, respectively. The conversion factor (CF) of 0.085 was used for the conversion of the samples to dry weights. The per capita consumption of fish and shellfish in Nigeria for human food is averaged 9.0 Kg" [15], "which is equivalent to 24.7 g per day was used for the estimation of daily intake of fish, and the average body-weight for the adult and children population were taken from literature to be 60 kg" [16] and 24 kg [17] respectively; these values were used for the calculation of HRI as well.

2.5 Evaluation of Non-Cancer Risks from Consumption of Samples

"Non-carcinogenic risks for individual heavy metal of the samples were evaluated by computing the target hazard quotient (THQ) using the following equation" [18].

$$THQ=CDI/RfD \quad \text{……………….eqn. (2)}$$

"CDI was the chronic daily heavy metal intake (mg/kg/day) obtained from the previous section and RfD is the oral reference dose (mg/kg/day) which represents an estimation of the maximum permissible risk on human population through daily exposure, taking into consideration a sensitive group during a lifetime" [19]. "The following reference doses were used (Pb = 0.6 mg/kg, Cd = 0.5 mg/kg, Zn = 0.3 mg/kg, Fe = 0.7mg/kg, Ni = 0.4 mg/kg, Cu=0.04 mg/kg)" [20,21]. "The evaluation of the potential risk to human health through more than one heavy metal depicted as chronic hazard index (HI) was obtained as the sum of all hazard quotients (THQ) calculated for individual heavy metals for a particular exposure pathway" [22]. It was calculated as follows:

$$HI=THQ_1+THQ_2+\cdots+THQ_n……… \quad \text{eqn. (3)}$$

Where $_{1, 2 …. n}$ are the individual heavy metals in samples.

"It is based on the assumption that the magnitude of the effect is proportional to the sum of the multiple metal exposures and that similar working mechanism linearly affects the target organ [23]. The population was assumed to be safe when HI < 1 and in a level of concern when 1 < HI < 5" [24].

2.6 Cancer Risks from Consumption of Samples

The possibility of cancer risks in the studied samples through intake of carcinogenic heavy metals were estimated using the Incremental Lifetime Cancer Risk (ILCR) [25].

$$ILCR= CDI \; x \; CSF \quad \text{……………….eqn. (4)}$$

Where, CDI is chronic daily intake of chemical carcinogen, mg/kg BW/day which represents the lifetime average daily dose of exposure to the chemical carcinogen.

The US EPA ILCR is obtained using the cancer slope factor (CSF), which is the risk produced by a lifetime average dose of 1 mg/kg BW/day and is contaminant specific [18]. The following cancer slope factor for specific heavy metals were used; Pb = 0.0085 mg/kg/day [26], Cd = 0.38 mg/kg/day [27], Ni = 1.7 mg/kg/day [28]. ILCR value in sample represents the probability of an individual's lifetime health risks from carcinogenic

heavy metals' exposure [29]. The level of acceptable cancer risk (ILCR) for regulatory purposes was considered within the range of 10^{-6} to 10^{-4} [19]. The CDI values were calculated on the basis of the following equation and CSF values for carcinogenic heavy metals were used according to the literature [25].

$$CDI = (EDI \times EFr \times ED_{tot})/AT \qquad \text{...eqn. (5)}$$

"Where EDI was the estimated daily intake of metal via consumption of the samples; EFr is representing the exposure frequency (365 days/year); EDtot is the exposure duration of 60 years, average lifetime for Nigerians; AT is the period of exposure for non-carcinogenic effects (EFr $\times$ ED_{tot}), and 60 years lifetime for carcinogenic effect" [18]. "The cumulative cancer risks in the samples as a result of exposure to multiple carcinogenic heavy metals due to consumption of a particular type of food were assumed to be the sum of the individual heavy metal increment risks and calculated by the following equation" [25].

$$\sum 1n = ILCR_1 + ILCR_2 + \cdots + ILCR_n \ldots \ldots \quad \text{eqn. (6)}$$

Where, n = 1, 2 ..., n are the individual carcinogenic heavy metal.

3. RESULTS AND DISCUSSION

"The results for the mean heavy metals in fish samples are presented in Table 1. From the results, the levels of the heavy metal Pb (range: 0.0851-0.4919 mg/kg) in the evaluated fish samples are higher than the maximum allowable concentration (MAC) 0.05 mg/kg. These values are higher than values reported for fish samples from some selected fresh water bodies in Katsina State" [8] and Jabi lake, Abuja [30] all in Nigeria. The range is also higher than values reported in samples from three coastal regions of Algeria [31] and the values reported for marine fish from Zhejiang, China [32]. A previous report have indicated an above MAC level for water sample from the study area which was attributed to the proximity of the area to a metal quarry site, vehicular exhaust contamination, agricultural activities and petroleum product conveying trucks that are frequently washed at the study site [13].

"In the present study, the mean Fe concentration in the fish samples was lower than the values reported in a study in eastern Nigeria" [33] and much lower than that recorded by Nyingi et al.

[34] who analyzed different fish species (tilapia, cat fish and lung fish) from Kenya and reported a higher Fe concentration and Seham et al. [35] "in fish sample from El-Rahamy drain Egypt. But the values are below the MAC of 425.5 mg/kg of Fe in fish" [36].

"The concentration of Cu recorded in this study was below the 1mg/kg limit set by the WHO/FAO. However, long term accumulation of Cu in fish may cause harmful hazards. The Cu concentration in fish samples from the Confluence of the River Benue-Niger in Nigeria" [37] was higher than the concentrations reported for fish samples in the current study.

"The range of Zn levels in the fish were low when compared to the Zn level reported by Mehouel et al. [31] in fish samples from Algeria and higher than the values reported in a previous study in Katsina State, Nigeria [8]. But the values were within the 100 mg/kg MAC for Zn in fish" [36].

The recorded range of the heavy metal Ni was below the MAC range of 0.5-1 mg/kg for Ni [36]. Although a previous study from Katsina State, Nigeria [8] has reported the heavy metal Ni to be below detection level (BDL) in fish samples, with similar studies conducted in the state in legumes, cereals and vegetables corroborating the same finding [38-43]. The present study is among the few of such studies [44,13] that reported a detection of Ni in evaluated food samples. A possible reason for the observation may relate to a waste sorting and recycling site situated near the study area that usually contain E-waste (used televisions, old computers and radios etc.) a contributor of Ni to the environment [45].

The mean concentration range of the heavy metal Cd in the present study was 0.0128-0.686 mg/kg, which falls within the MAC of 0.1 mg/kg [36] for Cd in fish. The values in this study were lower than the values reported for fish samples from Tigris River Baghdad [46], for fish samples from coastal regions of Algeria [31] and Rivers Ogun and Eleyele in Nigeria [47]. The lower value seen in the study as compared to the presented literature may be due to higher industrial activity in those areas as opposed to the study area.

The study DMI in children and adult population from consumption of the fish samples are presented in Tables 2 and 3. The results were higher than what has been previously reported in

fish samples from Katsina State, Nigeria [8]. From the tables the estimated daily intake of the heavy metals in adults and children were lower than the tolerable daily intake limit set by the USEPA [48] in all the samples.

"To assess non-cancer health risks associated with the consumption of the fish samples to the population the target hazard quotient (THQ) and hazard index (HI) were used. From Tables 4 and 5, the results of the THQs and HIs for both adults and children were all below 1, an indication that there was no potential health risk to the children and adult population. These results were in agreement with what was previously reported for fish samples from Katsina State" [8].

"The possibility of cancer risks to the population in the present study were estimated using the incremental lifetime cancer risk (ILCR)", [25]. The risk assessment for carcinogenic exposure effect has revealed that the incremental lifetime cancer risk (ILCR) and the cumulative lifetime cancer risks (∑ILCR) were all above the safe limit for cancer in the children population with the heavy metal Ni contributing the highest risk and the sample of the fish sample of *Clarias gariepinus* having the highest cancer risk (Tables 6).

Table 1. Heavy Metals Concentration (Mean ± Standard Deviation) (mg/kg) in Fish Samples from Are Dam, Rimi Local Government Katsina State, Nigeria

Sample	Heavy Metal					
	Pb	Fe	Cu	Zn	Ni	Cd
A. Nebulosus	0.0851± 0.0002	0.5039 ± 0.0127	0.0589 ± 0.0020	0.3015 ± 0.0549	0.1048 ± 0.0016	0.0420 ± 0.0010
P. Olivaris	0.4919 ± 0.0013	0.3524 ± 0.0089	0.0366 ± 0.0020	0.2259 ± 0.0411	0.1109 ± 0.0016	0.0686 ± 0.0017
T. Zilli	0.4006 ± 0.0011	0.3323 ± 0.0084	0.0507 ± 0.0018	0.1496 ± 0.0272	0.1220 ± 0.0018	0.0128 ± 0.0003
C. Gariepinus	0.2006 ± 0.0005	0.3095 ± 0.0078	0.0447 ± 0.0015	0.1066 ± 0.0194	0.1417 ± 0.0021	0.0277 ± 0.0007

Table 2. Daily Metal Intakes in Children from Consumption of the Fish Samples

Sample	Heavy Metal					
	Pb	Fe	Cu	Zn	Ni	Cd
A. Nebulosus	4.3E-02	1.2E-02	3.2E-03	1.9E-02	9.5E-03	6.0E-03
P. Olivaris	7.1E-03	4.4E-02	5.1E-03	2.6E-02	9.1E-03	3.6E-03
T. Zilli	3.5E-02	2.9E-02	4.4E-02	1.3E-03	1.1E-02	1.1E-03
C. Gariepinus	1.7E-02	2.7E-02	3.9E-02	9.3E-03	1.2E-02	2.4E-02

Table 3. Daily Metal Intakes in Adults from Consumption of the Fish Samples

Sample	Heavy Metal					
	Pb	Fe	Cu	Zn	Ni	Cd
A. Nebulosus	1.7E-02	1.2E-03	1.2E-03	7.9E-03	3.8E-03	2.4E-03
P. Olivaris	2.9E-03	1.7E-02	2.0E-03	1.0E-02	3.6E-03	1.4E-03
T. Zilli	1.4E-02	1.2E-02	1.8E-03	5.2E-03	4.2E-03	4.5E-04
C. Gariepinus	7.0E-03	1.1E-02	1.6E-03	3.7E-03	4.9E-03	9.7E-04

Table 4. Heavy Metal Target Hazard Quotients (THQ) and Health Risk Index (HRI) in Children from Consumption of Fish Samples from Are Dam Katsina State, Nigeria

Sample	THQ						HRI
	Pb	Fe	Cu	Zn	Ni	Cd	
A. Nebulosus	7.2E-02	1.7E-02	8.0E-02	6.3E-02	2.4E-02	1.2E-02	2.7E-01
P. Olivaris	1.2E-02	6.3E-02	1.3E-01	8.7E-02	2.3E-02	7.2E-03	3.2E-01
T. Zilli	5.8E-02	4.1E-02	1.1E-01	4.3E--03	2.8E-02	2.2E-03	2.4E-01
C. Gariepinus	2.9E-02	3.8E-02	1.0E-01	3.1E-02	3.1E-02	4.8E-03	2.3E-01

Table 5. Heavy Metal Target Hazard Quotients (THQ) and Health Risk Index (HRI) in Adults from Consumption of Fish Samples from Are Dam Katsina State, Nigeria

Sample	THQ						HRI
	Pb	Fe	Cu	Zn	Ni	Cd	
A. Nebulosus	2.8E-02	1.7E-03	3.0E-02	2.6E-02	9.5E-03	4.8E-03	9.6E-02
P. Olivaris	4.8E-03	2.4E-02	5.0E-02	3.3E-02	9.0E-03	2.8E-03	1.2E-01
T. Zilli	2.3E-02	1.7E-02	4.5E-02	1.7E-02	1.1E-02	9.0E-04	1.1E-01
C. Gariepinus	1.2E-02	1.6E-02	4.0E-02	1.2E-02	1.2E-02	1.9E-03	9.4E-02

Table 6. Incremental Lifetime Cancer Risk (ILCR) and Cumulative Life Time Cancer Risk (∑ILCR) in Children from Consumption of Fish Samples from Are Dam Katsina State, Nigeria

Sample	ILCR			∑ILCR
	Pb	Cd	Ni	
A. Nebulosus	0.1334	0.8322	5.8948	6.8604
P. Olivaris	0.0220	0.4993	5.6466	6.1679
T. Zilli	0.1086	0.1526	6.8255	7.0867
C. Gariepinus	0.0527	0.3328	7.4460	7.8315

Table 7. Incremental Lifetime Cancer Risk (ILCR) and Cumulative Life Time Cancer Risk (∑ILCR) in Adults from Consumption of Fish Samples from Are Dam Katsina State, Nigeria

Sample	ILCR			∑ILCR
	Pb	Cd	Ni	
A. Nebulosus	0.0527	0.3329	2.2579	2.6435
P. Olivaris	8.9973E-03	0.1942	2.2338	2.4370
T. Zilli	0.0435	0.0624	2.6061	2.7120
C. Gariepinus	0.0217	0.1345	3.0405	3.1967

Similar observations were recorded in the adult population (Table 7), but the values in the adult population were lower as compared to the cancer risks values in the children population. These observations were in agreement with what has been previously reported in studies that evaluate heavy metals cancer risks in various food samples from Katsina State, Nigeria [38- 43].

"The range of ILCR and ∑ILCR from consumption of all the evaluated samples as highlighted above, which raises the level of health concern for the consumer population as they may contribute to the population cancer burden was similar to what was reported from consumption of meat and sea food samples from Xiamen, China" [49].

"The THQ and ILCR are not specific estimates of expected chronic diseases and cancers. Rather, they are apparently an upper limit of the probability that the individuals may have a chronic disease or cancer sometime in his/her

lifetime following exposure to the heavy metal under the study" [50].

4. CONCLUSION

Heavy metals were investigated in fish samples obtained from Kwanar-Are dam located at Rimi local government area Katsina State, Nigeria and the health risks of the evaluated heavy metals were estimated. Assessment for non-carcinogenic exposure effect showed that there was no health risk associated with these elements through consumption of the fish samples to the consumer population. The risk assessment for carcinogenic exposure effect has revealed that the incremental lifetime cancer risk (ILCR) and the cumulative lifetime cancer risks (∑ILCR) were all above the safe limit for cancer in the children and the adults population for all the fish samples evaluated, raising the degree of concern for consumption of the fish samples to contribute to the population cancer risk load.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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